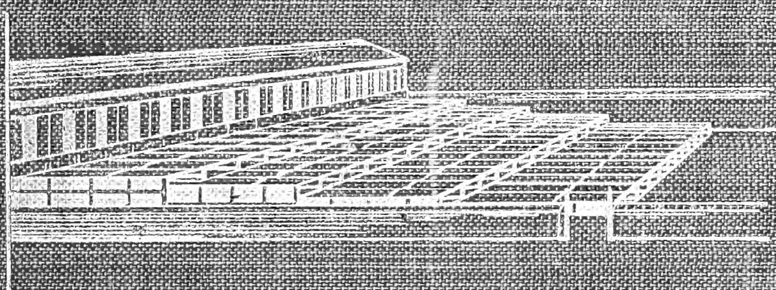
THE FERMENTATION OF CACAO



EDITED BY

HAROLD HAMEL SMITH

(EDITOR "TROPICAL LIFE")


Oceanica Classis

THE FERMENTATION OF CACAO.

A PROLIFIC CACAO TREE IN PARÁ, BRAZIL.

[Give us Agricultural Colleges in the Tropics at which to train our future planters and experts, and such trees will then be the rule, not the exception.]

THE

FERMENTATION OF CACAO

WITH WHICH IS COMPARED THE RESULTS OF EXPERIMENTAL INVESTIGATIONS INTO THE FERMENTATION, OXIDATION, AND DRYING OF COFFEE, TEA, TOBACCO, INDIGO, &c., FOR SHIPMENT

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DR. SCHULTE IM HOFE, BERLIN
DR. OSCAR LOEW, MUNICH
DR. J. SACK, HOLLAND
DR. FICKENDEY, CAMEROONS
MR. GEO. S. HUDSON, ST. LUCIA, B.W.I.
DR. LUCIUS NICHOLLS, OF CAMBRIDGE (ENG.) AND ST. LUCIA

EDITED BY

HAROLD HAMEL SMITH

Editor of "Tropical Life"; Author of "Soil and Plant Sanitation on Cacao and Rubber Estates"; "The Future of Cacao-Planting"; "Cacao-Planting in the West Indies," &c., &c.

WITH A FOREWORD BY

SIR GEORGE WATT, C.I.E., M.B., C.M., LL.D., F.L.S.,

Formerly Reporter on Economic Products to the Government of India; Author of "The Dictionary of Economic Products of India"; "The Pests and Blights of the Tea Plant"; "The Commercial Products of India"; "The Wild and Cultivated Cotton Plants of the World"; "Indian Art at Delhi in 1903," &c., &c.

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FOREWORD.

THE FERMENTATION OF CACAO.

By Sir GEORGE WATT, C.I.E., LL.D., F.L.S., &c.

I HAVE read every word of your work on the Fermentation of Cacao with absorbing interest, and must congratulate you on being able to bring out a book that will become a classic on the subject it deals with so very ably. You have brought together the opinions of several experts of scientific eminence and practical experience, and these must be drawn upon by all subsequent investigators until finally there is evolved something definite and of universal acceptance.

Here and there there are differences of opinion among your authors, as you yourself have pointed out, but in many cases these will be resolved into the effects of variations in climate, soil, water, variety of plant, or such like simple causes. In other words, the differences are more in the theories formed than in the observations made. I believe the entire industry of growing and curing cacao is very largely groping in the dark. There are a hundred and one directions of future improvements, many of these hardly less important than the so-called fermentation of the seed, as a stage in its curing (plantation manufacture).

Over thirty years ago, when I first took up the study of the cultivation and manufacture of tea, that industry was then in the very position of cacao to-day. We have reduced the area of cultivation but increased the outturn; we have improved the quality but reduced the cost. These are great triumphs of scientific precision as also of inventive ingenuity brought to bear on tea, but the same thing can be and will be accomplished with cacao. It seems to me possible that far too much merit is attributed to fermentation. That fermentation is necessary with the presently accepted method of curing goes without saying, but I would not be surprised were a new process introduced where fermentation could be entirely discontinued. The parallel with tea is worthy of the most careful study. But it is perhaps useless to speculate; the opinions your authors advance are certain to be tested at the plantations, and out of the new experience thus gained must evolve the future system of manufacture.

PREFACE.

I HAVE placed the essays in the order in which they will be found in accordance with the dates when they were first published. As I wish to acknowledge to whom I am indebted for the permission to reproduce them, and also wish to refer my readers to the originals in case they should wish to consult them, I cannot do better than to thank the journals, and to give the necessary list at the same time, as follows:—

(1) Dr. Axel Preyer's article will be found in *Der Tropenpflanzer*, No. 4, of April, 1901, pp. 157-173. The translation, made by my brother Victor and M. Ulrich Hugentobler, originally appeared in *Tropical Life*.

(2) Dr. Oscar Loew's essay is taken from Bulletin No. 1093 of the United States Department of Agriculture (Office of Experiment Stations), and first appeared in the Annual Report of the Porto Rico Agricultural Experiment Station for 1907.

(3) Dr. Fickendey's (Director of the Experiment Station, Victoria, Cameroons, German West Africa) was taken from *Der Tropenpflanzer*, No. 2, of February, 1909, pp. 87-90; and I am indebted to

Dr. Ronald Krohn, of Hampstead, for the translation.

(4) Dr. A. Schulte im Hofe's essay was included on the recommendation of Dr. Matthiesen, of the Kolonial-Wirtschaftlichen Komitee, of Berlin, to whom, as to Professor Dr. Otto Warburg, my thanks are due for this and other help given. The essay was published in 1908 by Herr Dietrich Reimer (Ernst Vohsen), of Berlin, as a separate pamphlet. Dr. Ronald Krohn also translated this essay.

(5) Dr. J. Sack's article was included on the recommendation of Dr. Dekker, of the Colonial Museum, Haarlem, to whom thanks are due for this and other forms of help. The translation was done under his supervision in Holland.

(6) The essays contributed by Mr. Geo. S. Hudson, of Errard Estate, St. Lucia, British West Indies, and Dr. Lucius Nicholls, until recently in Government employ in the same island, was brought into being through the help and generosity of a number of readers of *Tropical Life*, who, like myself, were interested in the question of the fermentation of cacao, and anxious to see whether the output, especially from those centres where the bulk of the producers were small peasant proprietors, could not be improved and equalized, so as to be shipped and purchased "to type," instead of being made up of a number of small,

and very small, parcels, often down to 1 lb. or 2 lb. each, no two beans of which, when picked up at random, had any points in common, and, therefore, extremely unsatisfactory to roast up and use, compared to the large parcels produced in, and purchasable from, such centres as San Thomé and Bahia.

What we particularly want to avoid, and what I hope the experiments described in this book will help us to do away with to a large extent, are the uneven and unsightly rows of cacao samples to be seen on the counter of any broker or dealer when offering such produce for sale. Anyone with a month's experience of the cacao trade will know the sort of lots I refer to; beans bright, dull, or grey mouldy and reddish; dark beans, black, mouldy, and fiery red lying side by side, and far too often mixed in the same tray or heap. Here is a lot with a thin, light, almost straw-coloured shell nearly as pale as cardamoms, there are some Haitians or San Domingo, with a coating of mould over them that would be a credit to a bottle of fine old crusty port. In any case no two bags or trays are alike, and the samples themselves show a most regrettable mixture of colours and qualities that should not be, since such a defect could be so easily avoided, and will be, I trust, after the results of the suggestions offered in the following pages have been tested and carried on to a final conclusion.

Great strides have been made of late years in the quality of the beans exported from the Gold Coast, but, in face of the improvements introduced in Grenada cacao since that island came to the front as a leading exporting centre, one can still see that there is much room for improvement in the African beans at times, and I anticipate seeing a steady and continuous levelling-up in its quality as regards evenness, colour, and general appearance until it can compete in external appearance with San Thomé and leave it behind for flavour, aroma, and freedom from hamminess. But there is much to be done before this is achieved, as was forcibly driven home to my notice the other day when valuing some lots from the Gold Coast, the beans of which were most miserable. Mouldy, greyish, lean, small, ill-kempt and ill-cured, they reminded me, in comparison to a lot of Costa Ricas close by, of a heaped-up pile of natives who had died of starvation in India and were awaiting cremation, contrasted with the soldiers of one of the Rajput regiments that came down into Udaipur to welcome the King and Queen when as Prince and Princess of Wales they visited India.

The following, therefore, subscribed to our fund, and so enabled us first to offer a prize of £50 for the best essay on the "Fermentation of Cacao," and then to engage such able men as Mr. William Fawcett, B.Sc., F.L.S., formerly in charge of the Agricultural Department, Jamaica, and Dr. J. Dekker, of the Colonial Museum, Haarlem,[1] Holland, to read through the essays and award the prize. This they did, and agreed that it had been won by the joint essay sent in by Mr. Hudson and Dr. Nicholls (see pp. 153 *et seq.* in this book).

The subscription list, quite international in character, includes the following names, and I would like to state "right here" (to use an Americanism) that it was Messrs. de Bussy's enthusiastic support on the continent that brought in many of the firms. The Kolonial Wirtschaftlichen Komitee also induced several to subscribe. Here is the complete list:—

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Messrs. van Houten and Zoon, Holland.
De Indische Mercuur, Holland.
Der Tropenpflanzer, Germany.
Deutsche Kautschuck Ges., Germany.

[1] Now amalgamated with the Vereeniging Kolonial Institute at Amsterdam.

Kako Einkaufs Ges., Germany.

The Sarotti Cocoa Manufacturing Co., Ltd., Germany.

Messrs. Suchard, S. A., Switzerland.

Agricultural Society of Dominica, B.W.I.

Arnold Gay, Esq., of "The Brothers" Cacao Estate, Grenada, B.W.I.

Tropical Life, London.

Having secured such generous support, I asked Mr. Fawcett if he would kindly translate my crudely worded phrases, setting forth the requirements and conditions of the competition, in a neatly worded paragraph, which he did thus :—

"The essay should record precisely and in full detail the changes resulting from the processes of fermentation and drying that take place in the bean from maturity in the pod to the time of putting the cured beans into bags for market. Biological as well as chemical changes should be noted. The action of maximum, minimum and optimum temperatures, and of checks producing differences of times in the fermentation and drying processes should be noted for every stage. The differences due to such variations on the resultant cured bean should be clearly traced. The possibility should be discussed of producing at will by such variations, and independently of the natural character of the bean, varieties of taste and of colour, both internal and external, so as to simulate the different kinds of cacao known on the market. Alterations that might be made in ordinary methods so as to improve the quality of the cacao should be explained. Waste products should be considered, and their potential value indicated."

Of the essays sent in for competition, only the joint one by Mr. Geo. Hudson, of "Errard Estate," St. Lucia (W.I.), and Dr. Lucius Nicholls, attached, at the time, to the Government service in that island, satisfactorily fulfilled the terms of the competition so as to render its publication of use and interest. This essay, as will be noticed, is divided into two chapters, say Chapter VI, by Mr. Hudson (see p. 153), dealing with practical estate work, and Chapter VII (p. 221), contributed by Dr. Lucius Nicholls, containing the biological and chemical part of the work.

In order to reach the subject intimately in all its aspects, the authors felt that some such collaboration between a scientist and a planter was essential, and therefore sent in a joint essay. Being awarded the £50 prize proves their judgment to have been correct.

In declaring Mr. Hudson and Dr. Nicholls to be deserving of receiving the £50, Mr. Fawcett wrote as follows :—

"London,
"*March* 13, 1912.

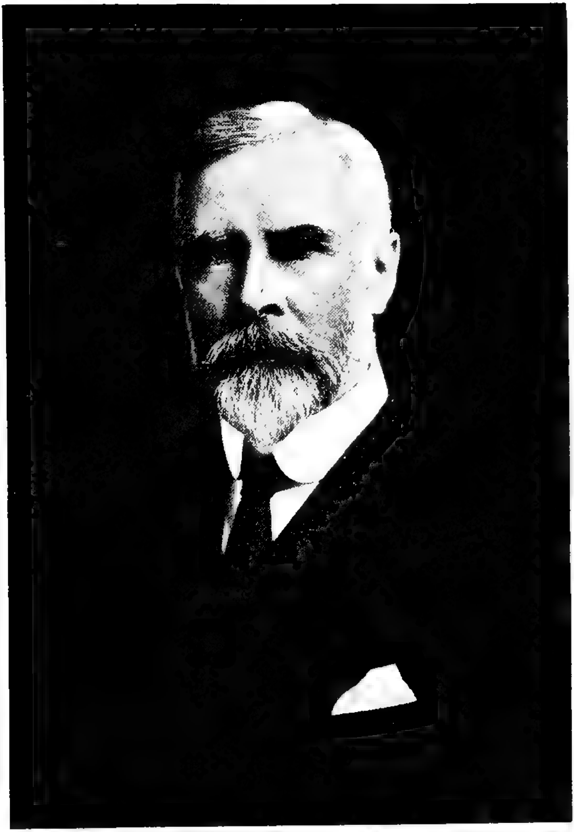
"Dear Sir,—I have now gone through the Essays on the Fermentation and Curing of

Cacao, and although I wish to consider them in more detail before giving my final opinion, I think I may fairly congratulate you on having obtained information that will be valuable to the cacao planter, and still more so, perhaps, to the local merchants, to whom the unfermented cacao is brought by the peasants. The investigations should also have the effect of inducing such of the peasant growers, who have not hitherto attempted curing, to carry it out on scientific lines, which can be easily explained to them by the agricultural instructors."

On March 29, 1912, Mr. Fawcett finally wrote :—

"The Essay 'A' (Mr. Hudson's and Dr. Nicholls') is in two parts, one being written from the point of view of the planter dealing with the details of the curing in a practical manner. The second part is a successful attempt to ascertain the causes which induce the changes in the character of the cacao bean during fermentation, and to put curing on a scientific basis that has been tested and proved to be satisfactory, instead of trusting to empirical methods.

"A marked improvement of low-grade cacao would be noticed in the markets, if due regard were paid to the principles laid down. This would apply especially to the peasant proprietors' cacao cured by merchants, and also to the cacaos cured by small settlers themselves.



Mr. Wm. Fawcett, B.Sc., F.L.S.

Estates will benefit, too, in that the process can be carried out with more certainty, and therefore with less anxiety.

"The essay shows that the fermentation of cacao is due to a definite organism, and that the organism can be cultivated and used in a pure state, excluding harmful organisms, and capable of starting fermentation in cases of difficulty.

"Proof is offered of the change that takes place in the 'skin of the bean,' so that it becomes a good diffusion membrane, allowing the ferment to pass through, but keeping organisms out.

"The manner in which fresh cacao beans become subject to fermentation is clearly shown, also the scientific method of inoculation which should be used. It is also demonstrated that there are three stages in the fermentation process: (1) the fermentation proper; (2) the stage when bacteria are most abundant and acetic acid is formed, and (3) the putrefaction stage. The author gives illustrations of how these changes can be ascertained from day to day, with directions for carrying on the first stage as long as may be necessary. He explains the effects of different temperatures on the various organisms and on the constituents of the beans.

"There are also directions for making the drainage from the fermenting vats or boxes into a valuable by-product, viz., a good, pure vinegar.

"Altogether excellent work has been done, and the publication of the whole essay, including the practical details by the planter (Mr. Geo. S. Hudson) would be most useful to all who are interested in the curing of cacao.

"(Signed) W. FAWCETT.

"*March 29th*, 1912."

The report of Dr. Dekker (translated from the Dutch—see *De Indische Mercuur* of May 7th, 1912, p. 406) read thus:—

"Messrs. J. H. de Bussy, who represent the Netherlands contributors towards the fund, have asked me to report upon the various essays received. In my opinion Essay 'A' deserves the prize. It consists of two parts written by different authors. The first portion is apparently by a man of practical experience, who has looked closely into the matter. He describes in detail the various methods used in the preparation of cacao, on which his information offers several hints. His remarks on the claying and washing of cacao are very interesting; he has, further, accurately examined the correct fermentation process, and noted the temperatures produced by it; and also traced the influence that a culture of yeast produces, according to Nicholls, during the process of fermentation. This, he points out, may bring about important improvements, which, if carried into general use, would, in his opinion, have great influence on the price of cacao fermented by this method. With respect to the drying, it was stated that besides 25 per cent. loss in weight by fermenting, a further 39 per cent. was lost in drying, so that the cacao as shipped represents but 36 per cent. of the 'green' article as it comes from the pod. It is in this portion of the essay that the author (Mr. Hudson) shows how experienced and thoroughly at home he is with his subject.

"The information given on the by-products, vinegar and alcohol, is somewhat limited, but at the same time a good deal of information is included that hitherto has not been made known. No mention is made of putting the pulp or pods to commercial use, possibly because the terms of the competition do not ask for this.

"The second portion of the essay (that of Dr. Nicholls)[1] discusses the question of fermentation from a scientific point of view. Here, after certain preliminary information on the chemistry of the subject, the author treats of the rôle played by different species of yeast in the preparation of cacao.

"From his remarks it appears that certain kinds or cultures of yeasts are produced which live upon the sugar-containing portions of the pulp of the fruit, and it is their presence that

[1] The names in each case were unknown either to Dr. Dekker or Mr. Fawcett. I only now include them to simplify matters.—[H. H. S.]

causes the increase in the temperature during the process of fermentation. The author obtained cultures of these, and discovered

MR. J. DEKKER, PH.D.

or isolated one in particular, which he has called *Saccharomyces theobromæ*,[1] which micro-

[1] It will be remembered, as Dr. Dekker points out, that Dr. Axel Preyer, in 1901, discovered *Saccharomyces*

organism is met regularly on the cacao in the sweating-boxes. In his description the author avoids deciding (*lit.*, is too sober in order to decide) whether these organisms are a yeast mixture or a single species. The discovery that the yeast mixture cultivated from cacao which has been fermented in the right way, when transferred to new sweating-boxes or to cacao that has been indifferently (*lit.*, irregularly) fermented, improves the cacao it is transferred to, is of great importance, for the resultant cacao, cured with this ferment or yeast, is decidedly of a higher market value. This fact alone is of such importance that I am quite willing to overlook weaker portions of the essay, such as including the results of a chemical examination without giving the analyses from which these conclusions are

theobromæ, Preyer—in fermenting Ceylon cacao. The name, therefore, had already been given to it. From Dr. Preyer's article in *Der Tropenpflanzer*, of Berlin (1901), or the translation of this important treatise published in *Tropical Life* in 1909-1910, and now forming the first essay or chapter in this book, it will be seen that the influence of yeast in the fermenting of cacao was discovered and noted over twelve years ago. It was, in fact, through reading Dr. Preyer's article that the idea occurred to me of utilizing his invention for trying to secure a more even class of cacao from all or any centre through the use of the culture that he mentions. If uniformity is possible with rubber, why should it not be with cacao? Dr. Preyer's and Dr. Nicholls' information shows that it is possible. Having started the ball of research rolling, we must now hope that others will take up the matter and carry it on to practical and general use.

deduced, and on account of the very interesting general information given, to declare that it is worthy of the prize."

Having thus explained in detail the causes which brought the prize essay into being, and through that, caused this book to be published, I would like to add a few comments of my own.

Both Dr. Dekker and Dr. Loew suggested that the notes on the fermentation of coffee should not be included, much less, therefore, the notes on the fermentation of tobacco, which I have published at the end of the book. Whilst thanking them for the suggestion, however, I have asked to be excused from following it, on the plea that I am most anxious to call into being (for with many, if not with most planters, the desire, as yet, does not exist) the desire to seriously consider this question of standardizing the system of fermenting, curing, and generally preparing cacao and other produce for market; and having brought the desire into being, to stimulate and spread it to all planters irrespective of what they produce, so long as the crop needs fermenting and oxidizing to make it suitable for trade purposes. It may be some little time before such a book is again published, and therefore, as the preparation of coffee, tea, tobacco, &c., is as important as that of cacao, if not more so, as the output and the capital required are larger, I hope I may be excused when I try to kill these several birds with one stone. Having done so, I can only express the sincere hope that scientific and other experts will take up the tale where my essayists have left off, and carry it on until there is nothing more to be said or learnt on the subject.

Meanwhile I would ask the readers of these essays to note where the authors agree and where they differ, where at times, as they themselves explain in the Last Word, their views seem almost directly opposed to one another. This, however, I do not think is altogether the case, for whether, as some claim, the loosening and removal of the pulp are the chief objects of the various processes, or if, as others claim, the advent of the air and the oxygen it contains, to the produce, is what should be mainly sought for, and whether you oxidize or dry your cacao in the final process (the air certainly cannot get in the cells if the produce is wet and the cells are full of moisture), the fact or facts remain, that the pulp has to be loosened and got rid of if you want to ship an attractive cacao, and the oxidation has to be encouraged and regulated if you want to export cacao of good commercial quality. I would therefore ask the readers to carefully note where and why opinions agree and differ, as it is of interest and importance for all to know the various authors' past and present views on the subject, and to note where they are of the same opinion and when they find it necessary to criticize each other. "When doctors disagree the patient gets well." I am, as just stated, not at all certain that the doctors have disagreed in this case, but if they have then all the better, if the old saying goes for anything, for then we shall know for certain that the future health and prosperity of the plantation cacao industry are assured.

In these days of rush and hustle, when nature and civilization alike are supposed to move to time and obey man's wishes and orders whether they are reasonable and possible or not, I would like to call attention to Dr. Sack's remarks on p. 151 regarding the disadvantage of rapid drying. Dr. Sack tells us: "This experiment at the same time made it quite clear why the old method, by which the drying was done slowly, yielded a product which far surpassed in quality the cacao, that was rapidly dried, for with a slow process of drying the reactions will continue for some considerable time. With rapid drying they will speedily cease."

I have always maintained that produce can be, and often is, dried far too quickly, but was unable to explain why. Dr. Sack's essay, however, and the book generally, will, I think, show that the mere evaporation of surplus moisture is not the chief object sought after, and that if you want to bring out and generally develop the aroma and flavour of your beans, you must give them a reasonable time to ferment and undergo the various changes without which they can never become a desirable article of commerce.

Mr. Hudson, it will be noted on pp. 153 *et seq.*, briefly touches on the question of by-products. To his remarks I would add that since a spirit could also be produced, it might pay in some cases to substitute this industry for that of vinegar making. I do not say either would pay, but since there is an excellent demand everywhere now for good vinegar, and petrol or else denatured spirit, it is just as well to discuss fully, once and for all, what we can do with these present waste products of the cacao estate, especially as in the aggregate they tend to be a nuisance. There are several kinds of spirits or oils used as fuel for internal combustion engines, and the demand tends, judging by complaints of high prices, to exceed the supply. In theory, therefore, there is no reason why a well-organized cacao estate should not produce its own spirit, if not its own vegetable oil, as fuel for any power required in the sweating or drying-houses, or for tractors transporting the produce.

In face of such a theoretical possibility it is well to note the following :—

If any further stimulus were needed to the solution of the problem of bringing the production and consumption of motor engine fuel oil within more commensurate limits, the *New*

York Oil and Paint Reporter told us a little time back, it has undoubtedly been furnished in the sharply advancing trend of crude petroleum prices within the last few weeks. The restriction upon the supply of gasoline for the constantly growing requirements, while keenly recognized during the last year or two, has recently assumed a more serious aspect as constituting a menace to the progress of the industry. Almost every day brings some new suggestion for relief, and the movement to secure a more economical fuel for automobiles has reached a national and international scope through the initiative of the New York Garage Association, the International Association of Automobile Clubs and the Society of Automobile Engineers. The reported offer of a substantial financial reward by the second-named organization for a substitute for gasoline is calculated to lend a quickening influence to the mastery of the question. So far the most practicable efforts in this direction have been conceived in supplying a fuel in which gasoline is used on a much reduced scale. Kerosene was naturally bound to attract attention as the most adaptable agent, for production of the latter was outstripping consumption at a rate to make its outlet as an illuminant an occasion for increasing concern, but what may have appeared as the economical advantages of this medium were offset to a material extent by the bothersome questions of starting the engine on such a comparatively heavy fuel and of overcoming the effects of the excess of carbon. After several years of steady application a practical kerosene carburettor is said to have been evolved, in which 70 per cent. kerosene to 30 per cent. gasolene is used, the fuels being mixed in the same tank and readily vaporising upon entering the combustion chamber of the motor. Another method which is said to have found approval is the use of a vaporizer to heat kerosene to a point where it volatilizes and then mixing the vapour with air.

At the same time the advocates of denatured alcohol are exploiting its advantages as a motor fuel with new zeal, as the market is believed to be nearing a level to bring it into more practical competition with the petroleum product. While alcohol meets the general fuel requirements, it cannot be adapted to the prevailing type of motors, but with motors designed especially for its use, greater efficiency and almost 30 per cent. increased power are claimed for alcohol over gasoline. On a sufficiently extensive scale, fuel alcohol may be produced about one-third cheaper than gasoline on its present basis, but this realization presupposes its adaptability to the automobile engine. Its service in this field has already been established as an inexpensive carbon remover; the larger use of lower grade gasoline has magnified engine troubles by increased carbon deposits, and a gill of denatured alcohol poured into each cylinder has proved effective in loosening the carbon so that it may be readily blown out through the exhaust.

So speaks the New York trade paper; going East I noticed *The Indian Trade Journal* told us in an article last January, in which it also discussed the question of liquid fuel, that "Alcohol, although in many cases an excellent fuel, is not commercially practicable in those countries which impose a high excise duty upon it, as in Great Britain, whereby its price is rendered prohibitive. It is a vegetable product, obtained by the fermentation and distillation of grain, &c. It has a specific gravity of ·820, is moderately volatile, and has a greater explosive range for variable proportions of gas and air than petrol and air, and can stand a much higher compression without self-ignition taking place. Methylated alcohol, or wood spirit, is the commercial article mostly used in preparation of varnishes, &c. French alcohol is purer and cheaper. Wood naphtha is also sold as distinct from mineral naphtha."[1]

On June 12 the same paper (*Indian Trade Journal*) tells us India, as one of the largest producers of vegetable substances suitable for the manufacture of industrial alcohol, is keenly

[1] Coco-nut planters, instead of losing the milk, as well as those having manila and sisal fibre refuse, could also make alcohol, so should note these particulars.

interested in the continuous rise in the price of petroleum spirits and in every fact that points to the alternate substitution of alcohol as a source of power. We therefore quote in full an article from the *Manchester Guardian* which furnishes a number of useful data:—

"There are many practical difficulties in the way of producing a sufficient supply of benzol under conditions which would allow any attempt at price cutting on the part of the suppliers of other motor fuels to be disregarded. Alcohol is the only fuel which can be obtained in virtually unlimited amount without encroaching on capital, so to speak, as we have to do with other fuels. It is obtainable from virtually everything in the vegetable world; not only from roots, as beets and potatoes, and from grains, but from such things as peat and even sawdusts. There should be no difficulty, therefore, in securing an adequate supply at a low price. The sources from which it can be obtained are so numerous and their interests so competitive, that there would be no possibility of an alcohol ring being formed to force up the price of the fuel.

"As regards denaturizing, when alcohol is mixed with 25 per cent. its bulk of benzol, the alcohol being of a specific gravity of 0·833, an engine can be started up from cold and run with an ordinary carburettor. Benzol is often employed as a denaturizing substance, especially in Germany. It is stated that it is impossible to separate benzol or benzine from the alcohol to obtain pure or dutiable spirit. In just the same way it is quite impossible to separate wood spirit or methyl alcohol from the pure spirit by redistilling, as, although the wood spirit boils at a lower temperature, they both distil over together. In England it is the custom to add one-third of 1 per cent. of mineral naphtha to the alcohol as a further precaution. It would seem, therefore, that a use could be found for as much benzol as could be produced in denaturing alcohol and rendering it more suitable for fuel. The supply of benzol would be at least sufficient to cope with the demand for the mixed fuel, and it could not be affected in a price war, because the cheapness of alcohol would be the determining factor, and not the price of the comparatively small percentage of benzol. A mixture of pure 100 per cent. alcohol with 9·12 per cent. of 90 per cent. benzol gives the best results in practice.

"The calorific value of alcohol is little more than half the calorific value of petrol by weight, but taking volumes into consideration the difference is not so marked, because alcohol is the heavier fuel. As will be mentioned later, experiments have been made which have shown that the thermal efficiency of a petrol engine is not so high as that of one specially designed for using alcohol, and that the net value per unit of volume is not far from the same with both fuels. Alcohol, in fact, compares much more favourably with petrol than is popularly supposed. The fuel consumption of internal combustion engines using alcohol is from 370 to 380 grm., or about 13 oz. to 13·5 oz. per effective horse-power hour; and when using alcohol of a calorific value of 6,000 calories there is obtained a thermal efficiency of some 22 per cent. At one time alcohol was in commercial use in Berlin for automobile work, but by reason of its high price, compared with that of petrol, its use was discontinued; and in Paris it has been used successfully with an equal proportion of benzol for motor-buses.

"In internal combustion engines using alcohol the explosive mixture can be compressed to a much higher degree than can a mixture of petrol vapour and air before self-ignition takes place. When the alcohol is hydrated, the compression can be carried still further, so that, although the fuel is poorer, a larger percentage of it can be converted into useful work. In practice the compression is carried to 10 or 14 atmospheres, this high figure being made possible by the water which is present in the alcohol used. It is a fact that alcohol when slightly adulterated with water is a better fuel than when pure.

"As to the properties of alcohol, from experiments the heat value of alcohol appears to lie between 13,310 and 11,664 B.t.u. per lb., the latter value being the one most generally accepted. One gallon of pure alcohol (specific gravity 0·79 at 59° F.) has a corresponding heat value of 77,274 B.t.u. One pound of 100 per cent. alcohol requires theoretically 9 lb. of air, or 111·5 cubic feet, at 62° F., for complete combustion. Care must be taken to see that the right quantity of air is given, because if the engine is run on an over-rich mixture acetic acid is produced and causes corrosion of the engine parts.

"A series of tests have been carried out in the United States with a view to determining whether the petrol engines now in use could be run on alcohol, and what improvements could be effected in the design to render them more suitable. In the trials eight engines ranging from 2 to 40 h.p. were used, three of them being high-speed motor-car engines of which two were of 40 h.p., the other engines being of the internal combustion types such as are used in commercial and agricultural operations. Each of the eight engines was run on alcohol as well as on paraffin and petrol, as many as thirty distinct and separate tests being taken on some of the engines. The alcohol used was virtually the same as that obtainable in this country under the name of methylated spirit, and consisted of 90 per cent. of ethyl alcohol and 10 per cent. of methyl alcohols with about 0·5 per cent. benzine added, the percentages being in volume. Its specific gravity was about 0·83. The petrol used had a specific gravity of 0·71, which is to say that it was practically similar to the motor spirit that can be bought to day in any garage in England. The conclusions that were arrived at from the tests were that any petrol engine of modern type can be run on alcohol without any material change in its construction, and that the only difficulty would be that of starting up from cold. For air-cooled automobile engines alcohol was found to be specially suitable, as the temperature of the cylinder can rise much higher before pre-ignition takes place than is the case when petrol is used. No tests were made to determine the maximum possible change in fuel consumption that could be effected by causing the spark to occur at different positions, but it was found that an early ignition was most suitable, and that the fuel consumption was better at low than at high speeds. When the initial compression was increased from 75 lb. to 125 lb. per square inch there was a slight but appreciable reduction in the amount of fuel used. With any good stationary engine it was found that a consumption of 1·16 lb. of alcohol produced the same power as a consumption of 0·70 lb. of petrol."

In spite of the excise trouble elsewhere, no doubt in the Tropics, although everyone there is not always a strict teetotaler, the spirit could be rendered so unpalatable that it would be impossible even for the owner of the most hardened palate to drink it, while its use, if purchasable at a cheap rate, would by supplying cheaper fuel certainly go a long way to help overcome the clamour one hears on all sides for a cheap and reliable fuel, in order to obtain better transport facilities. In face of all this, when the reader comes to page 216 in Mr. Hudson's essay, and sees that for every bag of cacao produced we can look for two gallons of vinegar and a corresponding supply of alcohol, it is pleasant to think of the large supples of alcohol that might be forthcoming from cacao estates, since, according to the Hamburg *Gordian*, the world's output of raw cacao is as follows:—

THE WORLD'S CACAO CROPS, AS PUBLISHED BY THE *Gordian*, OF HAMBURG, IN ITS ISSUE NO. 429, FOR MARCH 6, 1913, P. 6040.

Tons of 1,000 kilos.	1910	1911
Gold Coast	23,112	40,357
Ecuador	36,305	38,804
San Thomé	36,665	35,000
Brazil	29,158	34,994
Trinidad	26,231	21,220
San Domingo	16,623	19,828
Venezuela	17,251	17,381
Grenada	5,846	5,948
Lagos	2,978	4,471
Cameroons and German Colonies ...	4,073	4,404
Ceylon	4,069	3,064
Fernando Po	2,349	3,000
Jamaica	1,743	2,783
Dutch Colonies	2,579	2,460
Surinam	2,043	1,595
Haiti	1,851	1,485
Carried forward	212,876	236,794

Tons of 1,000 kilos.	1910	1911
Brought forward	212,876	236,794
French Colonies ...	1,575	1,364
Cuba	1,412	1,251
St. Lucia	743	940
Belgian Congo	902	681
Dominica	573	576
Colombia	297	400
Costa Rica	184	343
Other centres	1,000	1,500
Total ...	219,562	243,849

For last year, taking those centres of which the actual figures have come to hand—and this includes all the chief ones—and adding to that the average of the others, the *Gordian* gives us a total for 1912 of 230,000 tons, so we can work out the following table:—

Total output, 1910	...	219,562 tons.
,, ,, 1911	...	243,849 ,,
,, ,, 1912	...	230,000 ,,
		693,411 ,,

This gives an annual average output for the three years, 1910-12, of 231,137 tons (each 1,000 kilos) or 227,500 English tons. Taking therefore Mr. Hudson's figures of 2 gallons of vinegar per bag of 200 lb. (see p. 216), we have (227,500 tons = 509,600,000 lb.) 5,096,000 gallons, valued at 2s. to 2s. 6d. per gallon wholesale. Even at 2s., we thus have over half a million sterling at present being allowed to run to waste, and causing a nuisance in most cases by doing so. If instead of vinegar it is found better to make alcohol, then, following Mr. Hudson still, we are to get 4 gallons of juice per bag of 200 lb., or twice the quantity discussed above, viz., 10,192,000 gallons, at 3d. per gallon, giving the planter *£127,400* a year without any trouble and expense to obtain; whilst it will probably save him both in getting rid of the fluid in that way instead of his present one.

All this, I know, is on paper, but that is the proper place for every calculation to begin with; having thereby started the ball rolling along the right channel, I leave it to the readers of this book to see how far their practice agrees with Mr. Hudson's figures and my theory.

I must not forget to thank M. Leplae, of the Belgian Colonial Department at Brussels, for the loan of the blocks out of their agricultural bulletin, showing work in progress on cacao estates in San Thomé. These will be found on pp. 36, 86, 94, 96, 108, and elsewhere, and their inclusion has added considerable interest to the explanations of the various processes and apparatuses described throughout the book.

Since I started these notes, Mr. Fawcett called my attention to a paragraph in the *Pharmaceutical Journal*, of London, for June 7, 1913 (p. 801), in which we are told that—

"E. Perrot (in *Comptes rend.*, 1913, 156,

1395) states that the method of getting rid of the pulp from cacao beans by means of alcoholic fermentation is detrimental to the quality of the beans, and furthermore, that the changes that take place in the seed itself, due to diastasic action, further reduces its value. He suggests that the beans should be treated with very dilute alkali, which renders the pulp easily separable from the seeds. Mechanical means, he urges, should be used to separate the pulp from the seeds, and the seeds should be at once sterilized by steam, thus arresting the diastasic action. After drying, the beans would be unalterable and of a definite character."

On coming to p. 73 in this book the reader will notice that Dr. Fickendey also discusses the use of an alkali, in this case potash, for treating the beans, since "experiments led to the discovery that the oxidation of tannic substances increases very quickly in weak alkaline and neutral reaction." Further, Dr. Fickendey reminds us: "In some manufactories the cacao, after roasting, is treated with potash." On pp. 182-183 it will be seen that Mr. Hudson discusses spraying the beans with a cheap alkaline solution in the shape of a lime wash.

More than one of the essayists strongly urge, as I have always done, the necessity of the Government—either the Imperial Government at home, or the local authorities at the various producing centres—coming to the help of the planters by carrying out experiments, of testing new machines, supplying cultures, &c., that will, if successful, benefit all, and which—until proved to be satisfactory or not—it is hardly fair to an individual planter or maker to force him, as at present, to risk losing his capital so that all may benefit at the one man's expense. It certainly is not fair to any planter to do so, and even with engineers the risk of placing the right machines on the market before putting them to the test in the Tropics is so great that the introduction of labour-saving appliances is being seriously discouraged thereby—discouraged, too, when they are badly needed. Personally, I consider all such matters, once a number of reliable and practical men speak well of any new system or machine, as well as the establishment and financing of an institution to scientifically train planters, experts, plant-doctors, &c., must be undertaken by the Home Government, since it is mainly, if not entirely, for the benefit of the folks at home, by insuring the output of the raw material, food supplies, &c., that they require not only being maintained, but increased, so as to keep pace with the rapidly increasing requirements of the tax-collector and the wage-earner, to say nothing of the mouths to be fed on all sides. We are to-day at an epoch of gigantic concerns and huge figures, as exemplified by our 1913 Budget, in a time of peace, standing at the enormous total of *£195,000,000.* All this discourages individual action by causing those wishing to help to ask, "What can I do against this or that concern?" And unless the Government that dominates, or should dominate, all trade concerns points the way, individual members of the rising generation will become still more and more timid and averse to setting out on those voyages of adventure that their forebears undertook, and to which this country owes its greatness, and without which our prosperity, in comparison to that of other countries, will not continue.

It is well to remember in connection with this that an aggregate of individual efforts, whether large or small, is far more advantageous to any country or colony, as it brings in its train greater anxiety for a settled state of affairs, more local responsibility, and general contentment, than is, as a rule, forthcoming, when large labour-employing concerns are the order of the day. In saying this I do not by any means wish to decry the latter; they are bound to be a most important factor in opening up new lands; but at the same time, when we can secure the development of the Tropics by the help of peasant proprietors, and big privately-owned estates, I would urge that we encourage and help them in every way possible. This book offers one means of assisting such folks, for it shows how the cacao or other crops, produced by these innumerable large and small landholders in varying degrees of quality, can perhaps be standardized, and offered for sale "to type," to the advantage of everyone, and the small proprietor, perhaps, most of all. If the authorities, therefore, wish to attract and keep such people to the land as owners, they must see to it that they do not allow them to "lose their market" through shipping an inferior and mixed, hence defective, article. I would claim that the action of the Governments in some of the tropical colonies support me in this contention, since they have, I understand, discouraged, if not actually forbidden, company-promoting syndicates from buying up small coco-nut estates belonging to many independent owners and forming them into one big company-controlled concern. Apart from having a crowd of unemployed, listless natives hanging about—for they soon lose their purchase-money—I have no doubt that the authorities feel that, both for the natives themselves as well as for the general trade and prosperity of the colony, a thousand small garden settlements are preferable to ten big company-controlled areas; and if this is true with owners of a few acres, who have but a few dollars at stake, it is trebly true if we wish to draw capitalists from the United Kingdom and the self-governing colonies to take up their own lands and invest capital in planting them up, that is, either money of their own or that which has been entrusted to them personally, in the belief that it will be utilized as carefully as if it were their own.

Organized systems and follow-the-man-from-Cook's routes must, owing to this, become the order of the day, and the same as this noted tourist agency so ably caters for our pleasures and education, so must the Government of this country recognize that, if they wish our young men to go out to the Tropics to plant and trade, they must not only train men to show them the way, but also interpreters and guides to direct and show them how to proceed from the time they arrive. Arrangements, in fact, must be made whereby the boy whilst still at school (or his father who wishes to train him for his future career) can see his way quite clear ahead, to first study agriculture and agricultural chemistry, &c., on this side, and then go to an agricultural college in the Tropics (to be, I hope, soon established) for one, two, or three years, to specialize in tropical agriculture, plant diseases, and the preparation of the crops. Given these encouragements and facilities, a large number of young men would, I am sure, go to the Tropics to extend our trade in many ways, and increase our supplies of raw material and foodstuffs at home. They would, in a word, go where they were wanted, and not remain here to increase the struggle for existence and for profitable investments in these Islands. No local centre can do this; it would not be fair to ask them to do so, since the training is but part of the huge co-operative scheme in force at home whereby the wealthy educate and insure the poor, and keep them from want when out of work; only in this case it is the sons of the capitalist class that we want to catch—not for their own benefit, but to train them to supply the masses here with raw materials for the factories and food for the home. Under such circumstances, therefore, who but the Imperial Government at home—that is, the representatives of those for whose benefit the scheme is being formulated—should finance such institutions?

Coming to where reference is made in this book as to the necessity of the Government, either at home or in the Tropics, helping those who are trying to solve the difficulties of agriculture in the Tropics, and the production of crops thereby, I would like my readers to notice the footnote on p. 47, where we are told by no less an authority than *The Indian Planters' Gazette*, of Calcutta, that "much uncertainty is attached to practically every branch of tea manufacture. It is surprising that a scientific department was not created many years ago. If such had been the case we should probably now be 'groping in the dark' to a much less extent than we are." This refers to the cultivation of tea, but it could equally well be applied to cacao, coffee, tobacco,

&c., and even to rubber, although with that product a mass of information has been issued of late years. But, with rubber also, the output of such data has been a spasmodic, haphazard and uncertain, often unexpected one, not an organized campaign carried out as part of a systematic series of researches at the instigation of the Home Government, whose revenues through the increased prosperity of its subjects, shareholders, engineers, rubber-manufacturers, workpeople, and allied trades have benefited enormously, owing to those concerned being able to pay such heavy contributions at home and abroad into the Imperial exchequer.

"Such trades as those in which the material used has to be fermented," Dr. Schulte tells us on p. 115, "require special scientific institutes to which the manufacturer can turn at any time for advice when unexpected results or irregularities occur in their work. Unfortunately, as regards the treatment of cacao such an establishment is, at present, practically non-existent. . . . What should be done is to introduce the process (likely to be of use) on one plantation in each colony, a scientific expert specially trained to the work being engaged to assist, and only when these two, the scientist and the planter, together have thoroughly mastered the process, to then introduce it generally to the other estates. In order that advice might be at hand when required, an expert, as described above, should be permanently appointed to, and reside in the colony, with a suitably equipped scientific institute placed at his disposal, in which further investigations and experiments could be carried out and checked."

Dr. Schulte is quite right, and perhaps up to a certain point it can be claimed that such work can be carried out in some of our colonies, but not sufficiently to give confidence to those who wish to see an assured success in view before they send out their sons to take up planting, or entrust their capital to ventures run by other people's sons. Such investigations once started and discussed as those reported in the forthcoming pages must satisfy no one, they are only intended to point the way to further research, but that way is, I fear, too intricate and costly for individual action to carry out all such investigations to their uttermost point of finality. To do that we need a centre or centres of learning which will stand in relation to the plant world on the same lofty plane that hospitals do with human beings, that is to say we need agricultural colleges in the Tropics to train plant-doctors and experts overseas, as we have long had to train physicians and doctors over here.

As things now are, whilst the public get the benefit of cheaper tea, &c., and the Exchequer scoops in its millions of revenue therefrom, the planter is left alone to discover how he can still turn out the tea as cheap, or still more cheaply, in the future, in spite of the higher wages, increased freights, and heavier expenses that are menacing him on all sides. Truly the British public is neither grateful nor wise; because a few men stake their all to feed them cheaply, and will go to the wall if adverse circumstances cause luck to go against them and stop the work, is it right, either morally or economically, to take no interest in such people? Would it not be a wiser policy to encourage them to further action by training them scientifically to the highest standard to fight our commercial battles as we do the officers of H.M. Services to fight for us internationally; and in this training should we not show them how to handle the machines they will be called upon to use, and train them to learn which to reject as unpractical and unprofitable, and which to adopt as being likely to save them time, labour and money? I feel sure that we should, and so do many others. Thank goodness there is no longer lacking that first glint of light that makes one believe the sunrise of realization is about to dawn upon the public, and so enable them also to share our opinion! I devoutly hope they will. And now to get back to our subject, viz., "The Fermentation of Cacao."

H. Hamel Smith.

London, August 1, 1913.

SYNOPSIS.

fermentation in the Cameroons — the chemical changes in cacao are similar to those in black tea—tea fermentation described—the oxidation of tea—the main object of rolling tea—the processes with cacao compared—how to secure uniform fermentation—the change in colour in the beans—what constitutes cacao fermentation—the process, as generally understood, not absolutely essential—oxidation of cacao and tea compared—beware of over-acidification—drawbacks of over-rapid drying — why sun-drying was considered to be best—self-heating more favourable to oxidation—why mechanical dryers are necessary — slow-drying favours oxidation — higher temperatures helps oxidation both in tea and cacao — oxidation experiments at Victoria, Cameroons — oxidation an essential point in cacao fermentation—fermentation experiments carried out in Germany—ferments discovered on imported beans—higher temperatures accelerate oxidation—the moisture content—small water content means slow oxidation—is 15 per cent. the optimum amount of water?—factory experiments *v.* laboratory work—20 per cent. moisture caused moulds to form—what Dr. Schulte proved by his experiments—the question of optimum temperatures for oxidation—fermentation experiments in San Thomé—a description of the oxidation chambers erected—how the fermentation was carried out—changing the beans assists the process—trolleys of trays and chamber drying made use of—shall the beans have 15 or 20 per cent. of moisture?—how to detect excess of moisture—the change of colour and how long it takes—testing for flavour—how it is done with tea—when to check oxidation—oxidation depends on temperature—the optimum temperature—period of fermentation on Boa Entrada—the essential processes of fermentation, viz., the sugar converted into alcohol, and the alcohol into acetic acid—why oxidation is necessary—cacao oxidized at high temperatures turns out best—gathering the cacao—fermenting—"unripe" beans an incorrect term — methods in the Cameroons — in San Thomé—when to stop fermentation—the simplest, cheapest, and most certain method—fermenting saccharine juice can start the process on non-

prove matters—chemists to sell the medium—the Government should co-operate—£300 extra profit per 1,000 bags to result—Is unfermented cacao asked for?—care needed to inoculate successfully—"weathered" cacao—sweating boxes—vacuum dryers to revolutionize drying—the small producer—picking unripe pods—"unripeness" a misnomer—remove the placenta and refuse—separate the qualities—capacity measurements of wet cacao—how to calculate same and check loss in weight—four baskets equal one barrel weighing 300 lb.—ratio of uncured to cured cacao—full details as to weights and loss in curing—Is fermentation profitable?—fermenting receptacles or sweating-boxes discussed—7 barrels or 2,100 lb. wet cacao in a box—the need to make them strong—materials for making boxes discussed—what to avoid and what to choose—plan of an ideal curing house (illustrated)—slate sweating-boxes—fermenting cacao, temperature, ferments, changing, &c., &c. discussed—a week's work detailed—beware of 100° F.—keep your boxes clean—maintain perfect drainage—how to secure this—arrange your leaf-cover carefully—what happens when you do otherwise—most suitable leaves to use—how to assist stubborn fermentation—give "cacao-flies" free access—the importance of "changing"—immediate result of slackness in this—use a wooden spade—some negative experiments—a table of fermentation temperatures—again regarding the distribution of inoculating cultures—drying by natural and artificial means—sun-drying—boucans—covered-in areas—trays, trolleys, and floors—areas, say 5 sq. feet per cwt. of dry cacao—might be reduced to 3 sq. feet—the palette—sun-drying discussed in detail—artificial dryers—Whitfield-Smith's design (illustrated) and Mr. Hudson's improvements (illustrated)—rotary dryers—Messrs. John Gordon's make—the Hamel Smith dryer—the difficulty of interesting planters—vacuum dryers—Messrs. George Scott's described—the Passburg vacuum dryer—if more expensive still worth the money—the Government stations should test machines for the information of the planters—washing cacao—the loss in weight and gain in price—washing *v.* claying or polishing—"airing" washed cacao—clayed cacao—

ILLUSTRATIONS.

ERRATA.

P. 25, line 12, *for* "p. 29" *read* "p. 27."
P. 53, line 23, *for* "p. 36" *read* "p. 35."
P. 233, under illustration, *for* "convolution" *read* "convolutions."
P. 249, line 11, *for* "600 gallons" *read* "400 gallons."

THE FERMENTATION OF CACAO.

CHAPTER I.

BY DR. AXEL PREYER.

Is it absolutely necessary to ferment freshly gathered cacao seeds or beans? This query has already been repeatedly raised and discussed. However, the answer from the planter's point of view is given in the difference in the price between the fermented and unfermented cacao. With Ceylon cacao this difference is so great that, as far as I know, no European out there sends unfermented cacao to market. The unimportant quantities produced by natives are for the most part consumed at home.

The bitter substances in cacao seeds give them an unpleasant taste, and this can only be removed by fermentation. Furthermore, the fermentation influences the aroma of the product to a large extent, as well as the colour of the bean, shell and inside contents (cotyledons), each and all of which are important in determining the price.

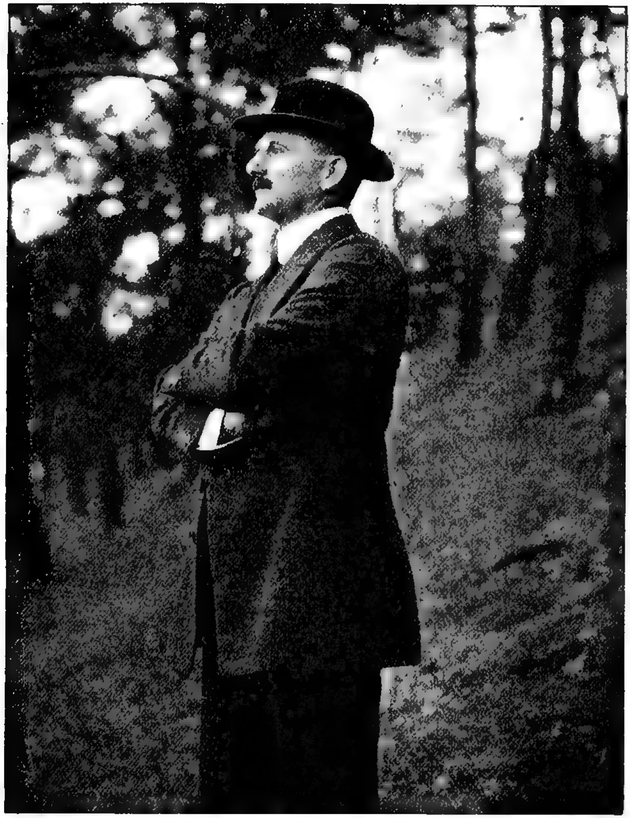
Finally, the pulp surrounding each seed is loosened to such an extent that in the washing process which follows it is removed. Washing the beans enables them to be dried quickly and uniformly, consequently there is no doubt that it is necessary to ferment cacao; but wide differences of opinion still prevail as to which are the best methods to be employed to do so.

The excellent quality of Ceylon cacao seemed to justify an examination of the fermentation process as carried on there, and after a series of practical tests on both a large and small scale, I have hit upon practical results. For the detailed statements of these results I wish here to express my hearty thanks to Dr. J. C. Willis, Director of the Royal Botanic Gardens in Ceylon, for his very kind help.[1]

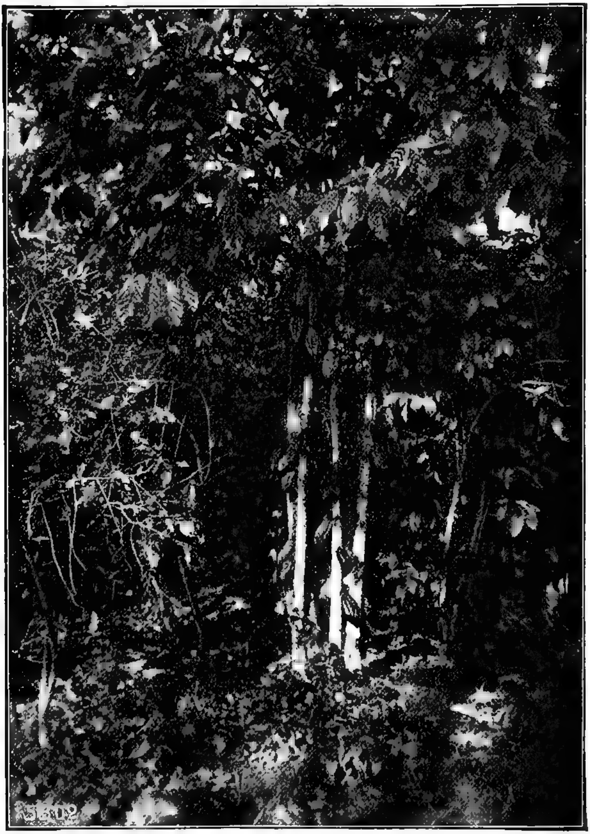
For practical purposes it is customary to employ many ways to ferment cacao; these, however, are similar in several points. Some of the methods of preparation in use in the West Indies are mentioned in Hinchley Hart's "Cacao," published in 1892.

Aublet said in his work, "Plants of Guiana" (1775), concerning the fermentation of *Theobroma guianensis*: "The beans taken from the broken fruit were put with the pulp in a vessel; this substance after about twenty-four hours' fermentation became liquid and wine-

[1] Since the above was written, Dr. Willis has left Ceylon and taken charge of the important Botanical Gardens at Rio, Brazil.—H. H. S.



Dr. Axel Preyer.



Cacao Shading Coffee, Guadeloupe.

like; the beans were left in until the shell became brown, and one was certain that the germ had been killed. The quality of the cacao depends on the degree of ripeness of the fruit and the length of time that the beans are fermented; beans, when ripe and fermented, separate themselves easily from the surrounding substance and soon dry; the wine-like liquid is slightly sour and drinkable; distilled it becomes a sharp spirit, which is inflammable and of pleasant taste."

Sir William Robinson reports on a method tried in Venezuela. The Conuquero dries his beans by exposing them in the sun for some five or six hours, after which they are fermented until the following day, and again exposed for five or six hours in the sun, and so on. Another method, used by the small planters, is to ferment the cacao beans during the evening whilst still warm from the sunning.

Mr. Strickland[1] recommends the following process: Three stone tanks to be built and cemented, each 11 ft. (3·35 m.) long, 7 ft. (2·13 m.) broad, and 5 ft. (1·53 m.) deep; high above these a corrugated iron roof is placed, and below a drain made for the liquid. The broken cacao (*i.e.*, the contents as taken from the pod) remains in the first tank five

[1] Of Trinidad. The originator of the well-known Strickland process of fermentation.—H. H. S.

days, and is only covered with banana leaves,[1] the air being supplied through five perpendicular[2] bamboos (made into tubes by breaking through the joints), with numerous holes in their sides; these bamboos can be closed at the ends as desired, either partly or altogether, by clay stoppers. Closing them soon produces a pleasant vinous odour, and the fermentation takes place.

The cacao is then removed to the second tank, when an acid reaction at a lower temperature takes place; after remaining for five days the cacao is transferred to the third tank, in which it is left for the same length of time. The pleasant smell then disappears, and, if attention is lacking, decomposition of the beans easily sets in, whilst injurious gases are formed and beans become discoloured. After the fermentation is ended the beans are washed and dried.

In Semler's "Tropical Agriculture" the actual fermentation is briefly touched on, and the following is a report of the different methods described:—

"The crudest method of fermentation is this: A hole is dug in the earth, and the beans are thrown in and covered with banana leaves

[1] See illustration on p. 36 showing sweating boxes in San Thomé with the cacao covered with banana leaves.

[2] I believe they should be placed horizontally.—H. H. S.

and a thin layer of earth. The drawbacks of this process, especially in rainy weather, are too obvious to need discussing. Instead of using these earth holes, others erect cemented pits inside the warehouses, which, after being filled, are likewise covered with banana leaves and form a great improvement over the holes in the ground. Other planters use casks or wooden cases for fermentation; others, again, pile the beans in large heaps on the floors of the warehouses, covering the heaps first with banana leaves and then with bags or thick cloths over the leaves.[1] The spreading out of the beans on tables or trays, or in regular layers 10 to 20 cm. high, is a process very much to be recommended. These layers are covered with banana leaves and cloths, after which boards are laid on them. The advantage of this method consists in a moderate and very uniform heating of the whole mass."

The preparation of cacao on the Bimbia Plantation in the Cameroons is described in an earlier issue of this Journal (*Der Tropenflanzer*, second year, 1898, p. 9).

E. Friederici says "that if the three tank method is used, the whole fermentation takes about sixty hours, and the cacao heaps are turned about at least twice a day—at noon and

[1] See Dr. Preyer's illustration of a cacao-sweating tank, p. 30.

Cacao Tree in Bearing, Trinidad.

evening. The contents of the third tank are washed in the morning, and those of the other two tanks are each brought into the succeeding tanks. The fermenting mass can easily become over-heated during the second day, and great care must be taken to avoid this."

The fermentation of cacao in Surinam, of which the following is a short extract, is fully described by Dr. Preuss in his earlier account of his journey out there: "Eight wooden boxes, 1·5 m. broad, 2·25 m. deep and 1·7 m. high, with inclined bottoms, are placed close together in the small fermentation house, and well shut in on all sides. These are filled with the freshly-gathered cacao to at least 1 m. high, and one of the boxes must always be empty. Banana leaves serve as a covering, and the wooden lid is closed. On the second day the contents of each box are shovelled into the succeeding receptacle, one again remaining empty, and so on with daily changes for five to eight days. In damp weather the fermentation goes on better than in dry. Air coming in spoils the fermenting cacao. Only on the fourth day are the boxes opened so as to encourage the fermentation. In Surinam, the cacao, after being fermented, is immediately dried, and therefore not washed."

Finally, let us glance at the methods in general use in Ceylon. In this island the system of the three tanks is seldom met with. Most of the planters ferment their cacao in covered heaps, and, thanks to this and the care they take in drying, the cacao is of excellent quality. Let me describe in detail the entire process of preparing the cacao as practised on the Gangaroowa plantation near Peradeniya :—

The ripe cacao pods are opened by the Tamil women as they are brought in. This is done by first cutting the pods crossways by means of small knives fixed in a clumsy wooden handle, after which they are broken by light blows, and the contents collected in baskets. The empty pods are then taken to the compost or manure heaps. The various qualities met with (Forastero, Criollo, and wild varieties) are not separated, but the fruits attacked by canker, or otherwise diseased, are carefully picked out and fermented apart. As soon as about 100,000 pods are opened, their contents are placed together in a heap on a covered-in cement floor, which has a slight gradient and outlet. The latter is like a truncated cone, and is formed and polished by beating with short wooden spades. Then the heap is at once covered with double layers of banana leaves; over these damp jute mats are spread, and the whole is then covered with a layer of moist earth, 3 cm. to 5 cm. thick. The mats and the earth are used again and again until it is necessary to renew them. Thus heaped up, the cacao is left from five to seven days to ferment, but every other day the covering is taken off, the heaps stirred round, and again covered over as before. The vinegar or liquid percolates through the bottom. The fermentation goes on slower in damp weather than in dry; on the other hand, a certain amount of moisture is necessary for fermentation. If the air gets in owing to the faulty covering of the heaps, decomposition and discolouration of the shells of the beans take place. The fermentation is ended when the outer pulp of the cacao bean is so far loosened that it can be removed in the succeeding washing. The pulp of well-fermented beans comes away in the washing in small particles, not in long, slimy threads. The washing itself is done in small baskets which are smooth inside; made from perforated palm leaves, these are filled with the beans, which are washed where there is a large volume of water but not too strong a current; immersed in this the baskets are subjected to a steady, constant shaking, after which the contents are transferred to a large receptacle. All this takes place very quickly, and a thorough cleaning of the bean is obtained without any damage. In wet weather the washed cacao is dried in layers in a drying-house by artificial heat; on sunny days they are carefully spread out in the open on coco-nut-matting, so that no two beans lie one on the other. At night the whole is placed under shelter. After three or four days the cacao is ready for sale, and sold as soon as possible: this refers to the preparation of first-class Ceylon produce. Colouring the beans is never resorted to.

On other plantations in the island modifications of the methods described are in use; thus the heaps are made larger and higher, and, owing to a higher temperature, are fermented in two or three days less. One planter prefers to make the heaps pointed, and not round; others prefer round-shaped heaps.

In cacao fermentation there are many widely divergent reports as to the development of heat, as well as the smell of the fermented mass and the dispersion of the liquid. A short enumeration of the reports of the various authors is shown in the table on the opposite page.

Continuous trials in cacao fermentation are only met with in isolated cases, and in Chittenden's prize essay is found probably the only attempt at an explanation of the fermentation processes. The author says as follows: "Unfermented cacao yields the same analytical results as fermented, although it has been said that a slow oxidation and formation of new matters take place. If the fermentation is properly carried out, the cotyledons are separated from each other, and the wine-like fluid of the pulp which forces itself through the membrane husks fills the hollow space as well as the intermediate space between the solid particles. This is what shows such a physio-

Author	Method of fermentation	Temperature	Smell
Aublet ...	Cask without outlet (Guiana)	...	Wine-like, fluid wine-like, slightly acid
Chittenden	Several samples fermented well at	80° F. = 26-7° C.	Like beer-wort
	With the usual Trinidad methods	115-120° F. = 46-49° C.	...
Morris ...	With the usual West India methods	About 140° F. = 60° C.	...
Strickland ...	West India three-tank system	...	...
	In tank 1	Not over 115-120° F. = 46-49° C.	Pleasant vinous smell. Wine fermentation
	,, 2	Not under 95° F. = 35° C.	Acid milk fermentation
	,, 3	Ditto	Butyric acid
Semler ...	General rules ...	Never over 60° C. Best at 50° C.	...
Friederici ...	Three-tank system, Cameroons	...	...
	In tank 1	30-33° C.	...
	,, 2	35-38° C.	...
	,, 3	Not over 43-45° C.	...
Preuss ...	Three-tank system, Surinam	Never over 45° C.	...
Preyer ...	Heap method (Ceylon)	...	On second day like inferior wine must
	In the upper half ...	30-40° C.	On fourth day strong alcoholic, like inferior wine
	,, lower half ...	Outside temperature up to 30° C.	The separated liquid like fermented and sour milk

logical influence, and on which depends the aroma, whilst the beans to a certain degree are stewed in their own juice. Further, the osmose (the tendency of two different fluids, when separated by a membrane, to pass through the pores and mingle) through the seed shell in the fermentation is easy to demonstrate by the insertion of the fermented beans in fuchsin solution. Then also, after the drying of the resulting hollow spaces, an elastic pressing together of the shells becomes possible, and the ability to obtain this 'spring' is a sign of a properly finished fermented bean. The different claims of the various cacaos are dependent on the percentage of their fats. Concerning Strickland's tank methods, it may be further said that in tank No. 1 there is wine fermentation owing to *Saccharomyces cerevisiæ*, and probably at the same time milk fermentation (*Penicillium glaucum*). Brought into tank No. 2, the cacao shows an acid reaction; further lactic acid fermentation takes place in a lower temperature. The lactic acid will later (in tank No. 3) change into butyric acid, after the formula—$2C_3H_6O_3 = C_4H_8O_2 + 2CO_2 + 2H_2$. The pleasant smell disappears and butyric acid is also traceable. Decomposition easily sets in, with formation of nitrous acid and nitric acid, as well as injurious gases." Further, Chittenden recommends in cases of defective fermentation that a repeated fermentation with the addition of some invert sugar and yeast be carried out.

In order to obtain the nearest or most exact explanation of the nature of the fermentation of cacao, I carried out, when in Ceylon, a series of microscopical examinations of the fresh beans as well as of the fermented mass, to which numerous practical tests were added. The complete report is as follows:—

The fresh cacao bean as it comes from the ripe fruit is a longish, egg-shaped body varying in size, chiefly 2 cm. to 2·5 cm. long, and 1 cm. to 1·5 cm. thick; it is white, pale pink, or pale yellowish. With a cross cut one can distinguish two coverings, which surround an inside hollow space, outside the pulp, but inside the shell proper. In the outside of the hollow space the little germ is found, surrounded by two large bud leaves (cotyledons) which are covered with a very thin skin over all their surface.

The pulp (Schleimschicht), which covers the seeds as well as the sides of the inner hollow space of the cacao bean to a thickness of 0·5 mm. to 1 mm., usually consists of large cells of irregular shape, originally parenchymatous cells; between these large intermediary cell spaces are found. The pulp cells swell very much in warm water. Small to larger agglomerations of a granular substance form the contents of the cells; these consist chiefly of gum, whilst the cell walls consist of cellulose. Besides this, sugar is found in the fresh pulp; on the other hand, albumen could not be found in distinguishable quantities. The colour of the pulp is pure white, only by fermentation does it become a reddish to brownish colour; the taste of the pulp is sweet and gum-like.

The shell of fresh cacao beans is of a leathery nature. It is firmly surrounded with the pulp, but free on the inner side, so that a removal of the leathery skin from the cotyledons can easily be effected. The leathery skin is 0·5 mm. to 0·6 mm. thick, and consists of three layers of different cells: (1) A single (and here and there a double) layer of thick-walled stony cells, which are packed closely together, and connected with the compressed cells of the pulp on the inside. (2) A thick middle layer of fibrous tissue which surrounds chlorophyll-bearing cells, and contains spindle-shaped hollow spaces. (3) A single and occasionally double layer of parenchymatous cells which form from within the epidermis of the shells of the beans; the cells are mostly empty. The colour of the leathery skin at first is a pale brownish; but after the fermentation it becomes yellow, and then turns red to dark brown.

The thin and shiny transparent skin which entirely envelops the whole surface of the cotyledons consists of a single layer of very regularly formed empty parenchymatous cells, which do not grow firmly together with the germ leaves, but can be removed.

Lastly, the cotyledons form together a longish egg-shaped body with a smooth surface; inside they lie in numerous deep folds on each other, and round the germ; they are of soft nature, white, yellow, or violet in colour, and possess a strongly bitter taste. The cotyledons come from the parenchymatous tissues. In the cells are deposited reserve substances in the shape of thickly compressed globules, such as fat, starch, and albumen.[1]

If several samples are taken from a heap of cacao beans on the second day after fermentation has been started, and the outer pulpish substance be examined under a strong microscope, countless organisms of various natures show themselves in and about the pulp cells. In Ceylon were found yeasts of ellipsoidal or rounded spindle-shaped form, besides bacilli, which occurred singly or in pairs, and spores of various sizes on the cacao beans lying on the surface, also moulds (*Penicillium* among others). On the other hand, in Java several other kinds of wild yeasts were noticed, including pointed, spindle-shaped and cylindrical forms; also spores, bacilli, and spirals.

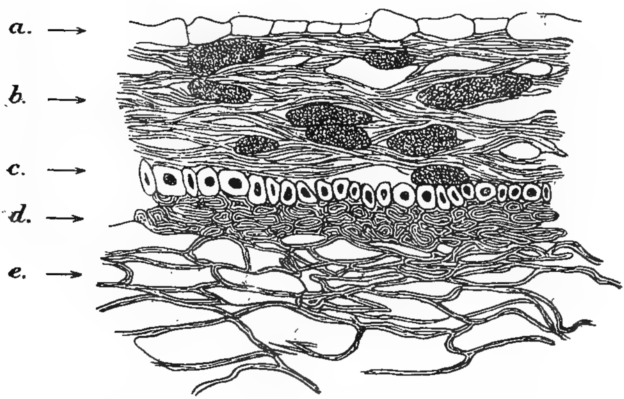
The question then arose whether the changes were produced during the fermentation by enzymes, generated by the living plasma of the cacao seeds, or the assimilation of the existing bacteria, or by the vitality of the yeast cells. The production of enzymes in the living cacao seeds or beans can take place by the germs;

[1] See illustrations in Dr. Nicholl's Essay.—H. H. S.

this, however, never appears to be the case in fermentation, the germ soon being killed owing to the fermenting process, and therefore fermented seeds are not germ bearing (this Hart has already mentioned). On the other

PULP OF FRESH FORASTERO CACAO BEANS FROM CEYLON. Mag. × 330.

hand, it would be possible that the other plasma-containing cells generate the enzyme. Against this, as well as against the second question, whether the bacteria are the inciters of the fermentation, there is the fact that neither in the total exclusion of living organisms in general, nor in the absence of yeast cells, do the known phenomena of fermentation take place; at the most it is only with the presence of bacteria that the formation of acidity or decomposition follows. Of



THE SHELL OF A RIPE CACAO BEAN—FORASTERO VARIETY—FROM CEYLON. Mag. × 70.

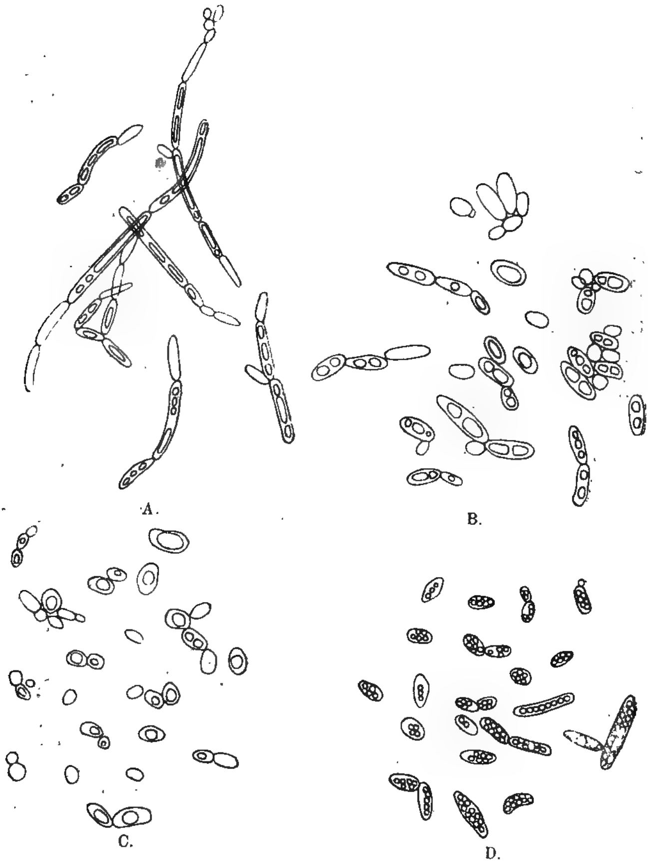
a, Epidermis; *b*, fibrous tissue with chlorophyll-bearing cells; *c*, stone cells; *d*, compressed chlorophyll cells containing pulp; *e*, cells containing pulp.

course, in the case of fresh cacao beans which are exposed by the exclusion of air organisms, a darker brown colouring soon takes place, but that is all; further changes do not take place either in the colour of the cotyledons or in the bitter taste; the pulp also is not so easily washed away as in well-fermented beans.

The living yeast cells in the pulp are apparently the inciters of fermentation; according to Buchner, the chemical changes they produce with the help of the existing enzyme always deserve consideration when studying cacao fermentation. After several attempts at yeast cultivation in Ceylon, I was able to isolate one variety, and grow it separately. This one is always found in Ceylon plantations on fermenting cacao, and in the fermentation trials it gave by far the best results. It appears, without doubt, that other kinds of yeast, perhaps even European beer and wine yeasts, can create a fermentation of cacao. However, the ideal yeast will probably only be discovered by the careful cultivation of those which at present seem to be most satisfactory. As a starting point the kind of yeast found in Ceylon seems to be very suitable. This is distinguished from all the *Saccharomyces* described hitherto, or at the most it slightly resembles *S. ellipsoideus* (I. Hansen), and *S. membranæfaciens*. I would describe the new variety as follows:—

The sprouting fungus of cacao fermentation —*S. theobromæ* (Preyer)—is of longish, ellipsoidal shape, in the midst of almost cylindrical cells, which, though separate, lie together in short chains or in heaps. The length of a cell measures on the average ·00615 mm., with a cross diameter ·0031 mm.; such cells are found in the middle of a pure bacilli culture in nourishing liquid. The cells of the sediment have a short, compact formation, and those of the mycoderm skin are of very long cylindrical form, generally with rounded ends, the latter variety being up to ·032 mm. long. The contents of the cells consist of plasma and vacuols (vakuolen = hollow spaces in the protoplasm of a cell), and these are, in most cases, easily discernible. In the long mycoderm skin-cells three or four vacuols are also to be found. With the withdrawal of nourishment, Askospores form in eighteen to twenty hours (in 25° C.). The spores are very small, and fill the cells in large quantities. *S. theobromæ* are found in Ceylon on fermented cacao. A pure bacilli culture can be made in a decoction of fermented cacao beans. In raw sugar solution yeast is not found, and no fermentation takes place, but degenerate dwarf-shapes form, and finally die off. In the cacao decoction the fungus begins to form after one and a half to two days (at 25° C.), at first a white, later a grey, mycoderm skin, which becomes light red on its upper edge (on the walls of the test tubes). The yeast germinates in cacao pulp of alcoholic fermentation.

Thus are explained a few facts about the nature of cacao fermentation; but it still appears doubtful how the contents of the seeds, *i.e.*, the cotyledons, can become affected through the outer fermentation of the pulp.



Cacao Yeast. *S. theobromæ*, Preyer.
A, C, D, × 800; B, × 1,000.

A, Long mycoderm skin cells; B, pure culture from pulp liquor; C, yeast sediment; D, askospores, formed after eighteen hours.

Chittenden at first expressed the opinion that the soluble or liquid matters penetrate through the leathery skin in the seeds, and produce the change in taste and colour. He proves the possibility of this theory by a trial, in which the cotyledons of a cacao bean were coloured red after being immersed in a fuchsin solution for a few hours. The leathery skin is also permeable, at least by some substance. I repeated this trial in the following manner. On the one side I used fresh seeds, on the other, seeds fully intact but fermented for several days; both were put into an alcoholic fuchsin solution, and after twenty-four hours cross-sections were examined. The fresh beans showed (even after forty-eight hours) no trace of a red colouring of the germ leaves; the fuchsin solution had only percolated through the pulp, and no further. On the other hand, the fermented seeds had intensely red-brownish coloured cotyledons after one still (more after two) day's immersion, whilst other fermented seeds not treated with fuchsin were of a pale brownish colour inside; therefore the fuchsin colouring matter had penetrated through the hitherto impermeable leathery skin. During the microscopical examination of the coloured beans it was found that through the fermentation a loosening of the hard cells takes place, so that the hitherto impenetrable layer is now loosened, exposing the middle fibrous layer and, more especially, allowing the inner cells to be acted upon. Whether the loosening is brought about through dissolving agents which are produced in the fermentation or through pressure from inside remains uncertain.

As to what chemical combinations arise in the fermentation, to exert an influence upon the quality of the cacao, chemical investigation must determine. Here I am only able to note that in the fermented pulp are found ethyl alcohol, and in the places covered with mildew fungi, bad-smelling alcohol (probably methyl among other stronger alcohols), lactic acid, and similar substances, and, finally, aromatic substances.

The principal result of the activity of the bacteria is the formation of organic acids, and in those experiments in which bacteria were absent no free acid could be detected. The organic acids formed are chiefly produced by the action of bacteria. Since, as is shown later on, acid fermentation of the pulp affects the taste of the cacao unfavourably, such bacteria are to be considered as harmful to the fermentation process.

After it was proved by comparative tests that the *S. theobromæ*, as a rule, was the best ferment, further tests were made to find out under which conditions this yeast thrives best and produces the most superior quality of cacao. For this purpose it is necessary to characterize shortly the attributes of a superior cacao. Morris says: "If well prepared the outside shell should be hard, crisp, and easily detached from the kernel; the latter must be hard, light coloured, and easily broken under pressure. A light chocolate or cinnamon colour, combined with even break, are signs of the highest quality. It can also be added that a cinnamon-coloured shell is also much to be desired, and an aromatic, not bitter, taste for the kernel."

The results of the fermentation trials which were undertaken with equal quantities of fresh cacao beans in large glass cylinders are recapitulated on pp. 26 and 29 in the form of a small table.

Whatever, in the first place, may be the cause of the inoculation of the unfermented mass with bacilli, it can be seen that the uninoculated lots, Nos. 1 and 4, developed a sourish smell during the fermentation, a rapid growth of bacteria, and, after drying the beans, a sour and bitter taste as well as an irregular or uneven inner colour or break. Referring to the temperature, I wished to ascertain the highest point up to which the cacao beans can be heated and still give a good article. In this experiment the peculiar circumstance manifested itself, that on the third day the outer colour was spoilt—"scorched"—whilst the pulp all through was not properly loosened, and could only be washed very badly. In the lower temperature, 23° to 26° C. (air temperature), excellent results were achieved. A slight heating at all events seems to be desirable,

Trial number	Inoculated with a pure culture of *Saccharomyces theobromæ*.	Temperature ° C.	Air	Water	During Fermentation		
					After three to six days		Odour after ten days
					Smell	Microscopical result	
1	Not inoculated	23 to 26	Access	Remains standing	Very sour and alcoholic	Numberless bacteria, a few yeast cells	Suffocating, sour
2	Inoculated	,,	,,	,,	Aromatic, pleasant, wine-like	Numerous yeast cells, later no bacteria	Sourish, aromatic
3	,,	,,	Exclusion	Runs off	Pleasant, wine-like	Many yeast cells and bacteria	Sourish, alcoholic
4	Not inoculated	,,	Access	Remains standing	Sourish, alcoholic	,,	—
5	Inoculated	,,	,,	,,	Aromatic, alcoholic	Numerous yeast cells, also bacteria	—
6	,,	,,	Exclusion	,,	Sourish, alcoholic	Few yeast cells, many bacteria	—
7	,,	,,	Access	Runs off	Aromatic, alcoholic	Numerous yeast cells and bacteria	—
8	,,	38 to 42	,,	Remains standing	,,	Many yeast cells and bacteria	—
9	,,	48 to 52	,,	,,	,,	,,	—
10	,,	52 to 55	,,	,,	Decomposing	Mildew, fungi and few yeast cells	—

Remarks.—All the glass cylinders were covered over with glass plates, which, in the trials arranged "with air access," were raised by a layer of wadding. The temperature in trials 8, 9 and 10 was not regular, owing to the lamps not burning properly. The trials under "water remains standing" were placed in upright cylinders, those with "water running

Washing on sixth day	Quality of Dried Beans after Five to Six Days' Fermentation.				After ten days' fermentation
	Outer colour	Inner colour	Break	Taste	
Moderately good	Very light, good	Uneven, moderate	Moderate	Somewhat sour, bitter and aromatic	Too dark, black spots, bitter, aromatic
Superior	Cinnamon red, superior	Very good	Very good	Mealy, aromatic, slightly bitter	Too dark, taste good
Bad	Light, good	,,	,,	,,	,,
Good	Moderate, spotty	Bad, irregular	Good	Bitter, somewhat aromatic	—
Superior	Cinnamon red, superior	Superior	Good	Slightly bitter, very aromatic, mealy	—
Fairly good	Moderate	Grey, moderate	Bad, too hard	Bitter, not aromatic, bad	—
Moderate	Light, very good	Good	,,	Slightly bitter, very aromatic, mealy	—
		After three days' fermentation			
On third day bad	Very bad, black spots	Good	Good	Somewhat bitter, aromatic	—
,,	Very bad, black, spotty	Good, somewhat dark	,,	,,	—
,,	,,	Good	,,	,,	—

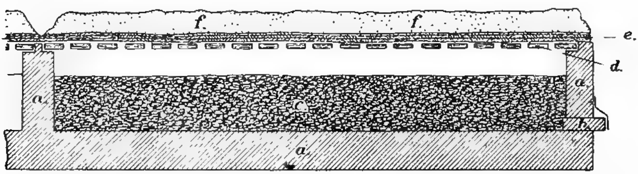
off" in inverted cylinders. The washing is classified respectively as "superior" or "good" if the pulp separates easily and in small shreds, or "bad" when it is difficult or impossible to separate. All the trials were made with yellow and red fruits of the Forastero variety.

in order to reduce the period of fermentation, nevertheless it is as well to keep as much as possible within the limits of 28° to 35° C., as occasionally at 38° to 42° C. an inferior colouring is obtained. That an even temperature should exist as far as possible through the whole mass to ensure the production of a uniform quality goes without saying. It does not seem difficult to determine whether access of air or its total exclusion is more favourable for the process of fermentation (supposing that the penetration of organisms from the air is stopped), as neither in trial 3 nor 6 were the best qualities throughout obtained.

On the other hand, it is less easy to say whether it is more advisable to let the existing fluid drain away as it forms, or let it remain about the fermented beans. If the trials 3 and 7, and 2 and 5, are compared, the latter, which were fermented "wet," turned out considerably better. On the other hand, trial 6 shows that the non-removal of the liquid, together with the exclusion of air, yields very lean cacao. Finally, as regards the duration of the entire fermentation, special trials were made. Samples of trials 1, 2, and 3, which were fermented ten days, all showed too dark an inner and outer colour, but with a five to six days' fermentation at the low temperature stated, the cacao was found to be normal. General rules for the duration of the processes cannot be given, as the time is governed, even more than the other factors, by the temperature, the kind of cacao, and the degree of ripeness of the fruit.

If we recapitulate, the method of fermentation used in the two parallel tests 2 and 5 proved best, especially as the colour of the seed shells and the taste of these were identical with those of the most superior plantation products. If we compare this treatment with the various methods of the cacao planters described at the beginning of this treatise, we find the oldest record of a "wet" fermentation in casks, *viz.*, that reported by Aublet in 1775, is, strange to say, the one that comes nearest to it, whilst the good smell and taste of the wine-like fluid also point to an excellent fermentation. Of course, one is not forced to use small receptacles, large tanks can be used just as well. If I have described a method which is likely to yield good results in most cases, I do not wish in doing so to offer such instructions or suggestions as general guiding rules, much less do I profess that they are infallible, for, as already stated, the entire fermentation process is dependent on numerous circumstances which may cause it to be necessary to introduce a modification in the manner of procedure and preparation.

Analogous to the tank system, divisions of cemented brickwork are constructed some 2 m. broad, 3 m. to 4 m. long, and only 30 cm. deep, with a drain, which, however, is only opened for cleaning, being otherwise firmly closed with a stone stopper. Corresponding with the directions given in Semler's "Tropical Agriculture," the fresh gathered cacao beans are poured in uniformly in layers 20 cm. high, so that the whole bottom surface is covered, up to the side walls; then a small quantity of good cacao yeast is spread over the mass, and the beans can, as desired, either be covered with banana leaves or left uncovered. The division is closed with a wooden lid, provided



SECTION OF A TANK FOR THE REGULATION OF THE CACAO-SWEATING PROCESS.

a, Cement wall-work, each division 2 m. wide, 3 to 4 m. long, 30 cm. deep; *b*, stone stopper or bung; *c*, cacao beans; *d*, wood cover or lid with air-holes; *e*, coco-nut or jute matting; *f*, layer of sand, 5 to 8 cm. thick.

with many ventilation holes, but with a tightly fitting edge. Over this, clean (often washable) mats are laid, and on the latter is a layer, 5 cm. to 8 cm. in depth, of damp, clean sand. In this manner the air is not shut out, but the penetration of bacteria is stopped.

About every forty-eight hours the cacao is turned over as quickly as possible, and then spread out as before; too high a temperature need not be feared. On the other hand, the possibility of sourness must be carefully watched, and if this becomes too pronounced, the liquid must be drained off. After five to seven days, as a rule, the fermentation is finished, and the whole mass is washed. The progress of fermentation is checked by examining small samples obtained when turning over the layers of beans. On account of this, as well as for the drying process that follows it, both the methods of fermentation already described as being used on the Gangaroowa Plantation (Ceylon), and the drying process employed there, are to be recommended.

Although I have, in the above communication, provided some details regarding the causes of fermentation and the methods employed to induce fermentation in cacao, there still remains a difficult but important point to be solved, *viz.*, the recognition of the chemical changes that take place during the fermentation and drying, and of the intermediary and final substances formed during the process. It would still be too risky before even the composition of the fresh cacao bean in its various parts is fully known, to wish to advance chemical hypotheses about the processes and changes that take place during the process of fermentation; but it is very probable that, later on, the chemist will play an important part in the preparation of cacao on the estates.

CHAPTER II.

By Dr. OSCAR LOEW.

With some Comparative Notes on the Fermentation of Tea and Coffee.

Although much has been written about the fermentation of cacao, there stills exists a great difference of opinion in regard to the process, its purpose and necessity, and the kind of action involved in it.

Herbert Wright, in his exhaustive work on cacao,[1] mentions yeast cells[2] as the most important organisms causing the fermentation, while other authors attribute it to unorganized ferments, others again to bacteria, and even the changes due to germination were supposed to play a rôle in it.

According to Sir George Watt, in his Dictionary of the Economic Products of India[3] :—

[1] "Theobroma Cacao or Cocoa." Colombo, 1907, p. 108.

[2] According to Dr. Axel Preyer (*Tropenpflanzer*, 5 (1901), pp. 157-173), a special kind of yeast, which he named *Saccharomyces theobromæ*, effects the best fermentation in Ceylon. See Dr. Preyer's essay, p. 20 and elsewhere, also Dr. Nicholls's, p. 225, *et seq.*

[3] London, 1893, vol. vi, pt. 4, p. 44.

Dr. Oscar Loew.

"The coolie dexterously strips all the beans off the centre stalk (placenta). The empty pods are then thrown round the trees and act as manure, while the beans are removed to the fermenting cistern. It takes from five to nine days to properly ferment the cacao and it is then ready for working. It is trampled first, as in coffee, with the feet, and then removed in baskets and carefully hand-washed[1]. . . . I have no doubt that before long some means less expensive will be found for washing . . . The prices obtained for it will depend, to a more considerable degree, on the careful attention to the curing than in the case of coffee."

Safford, writing on cacao in Guam,[2] says :—

"Cacao beans are sometimes kept in jars and allowed to 'sweat' or undergo a sort of fermentation which improves their flavour, but this custom is not universal. Many families, after having dried the beans in the sun, keep them until required for use, when they roast them as we do coffee, grind them and make them into chocolate. Chocolate made from the newly ground bean is especially rich and aromatic."

Hinchley Hart[3] writes :

"The prime object of sweating or fermenta-

[1] Such methods are followed in Ceylon and the East, but not in America, as a rule.—H. H. S.

[2] "Useful Plants of Guam." U.S. Nat. Mus., Contrib. Nat. Herbarium, 9 (1905), p. 387.

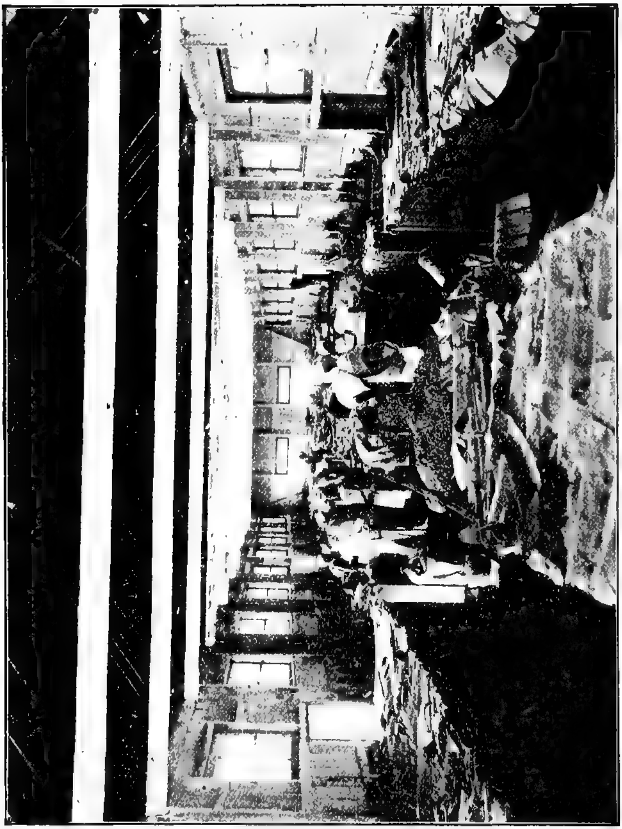
[3] "Cacao." Trinidad, 1900, 2nd ed., p. 38.

tion appears to be to change the inside portion of the bean by absorbing into it products obtained from the fermenting pulp, and where this is not fully accomplished by any of the methods the bean is classed as unfermented, and the product is generally of lower value."

The changes brought about by the fermentation have been minutely examined by Prof. Harrison, the well-known chemist and Director of Agriculture in British Guiana. Some of the changes observed, as, for example, the decrease of protein in the seed and the increase of amido compounds, are only incidental and not of any importance, since they do not affect the colour, which is simply due to the action of an oxidizing enzyme in the seed.

The principal conclusions reached by Harrison[1] are that the process of "fermentation or sweating in cacao consists in an alcoholic fermentation of the sugars in the pulp of the fruit accompanied by a loss of some of the albuminoid and indeterminate nitrogenous constituents of the beans, . . . and some parts of the carbohydrates other than sugars undergo hydrolysis and either escape in the runnings from the boxes in the form of glucose, or undergo in turn the alcoholic and acetic fermentations." Further he declares: "During this change some of the

[1] *Proc. Agr. Soc.* Trinidad, 2 (1896-97), p. 250; Hart, "Cacao." Trinidad, 1900, 2nd ed., pp. 106, 107.



CACAO IN THE FERMENTING OR SWEATING BOXES (SAN THOMÉ).

The banana leaves encourage fermentation by partially shutting out the air.

astringent matters, to which the somewhat acrid taste of the raw beans is due, are also hydrolyzed, and thus a marked improvement in flavour is gained." Finally he adds: "This work has necessarily only resulted in a partial and incomplete study of the results of the fermentation."

The so-called fermentation is carried out either by heaping the fresh seeds, after separating them from the shell, on the floor, or placing them in receptacles and covering them with banana leaves or with cloth. The floor or the receptacles slope so that the watery products can escape during the fermentation. A period of two to six days, according to circumstances, is usually allowed for fermentation. The height of the heaped seed measures 1 to 1·5 metres and over. In some countries the highest temperature allowed for fermentation is 45° C., in others 50° C. According to Hart[1] there is "danger in allowing [the temperature] to rise above 140° F. [60° C.],[2] as the character of the product is sure to suffer." An apparatus has been recently devised by M. Schulte in which a constant temperature of 60° C. is maintained.[3] In this case the yeast is fully excluded and bacteria with few exceptions

[1] "Cacao." Trinidad, 1900, 2nd. ed., p. 42.

[2] Note, p. 248, that Nicholls says 110° to 120° F. is the optimum temperature.

[3] See Dr. Schulte im Hofe's essay, p. 95, *et seq.*

also, and the necessary changes are brought on mainly by the heat, but this method has been considered too tedious and of little value to cacao planters, as is shown by

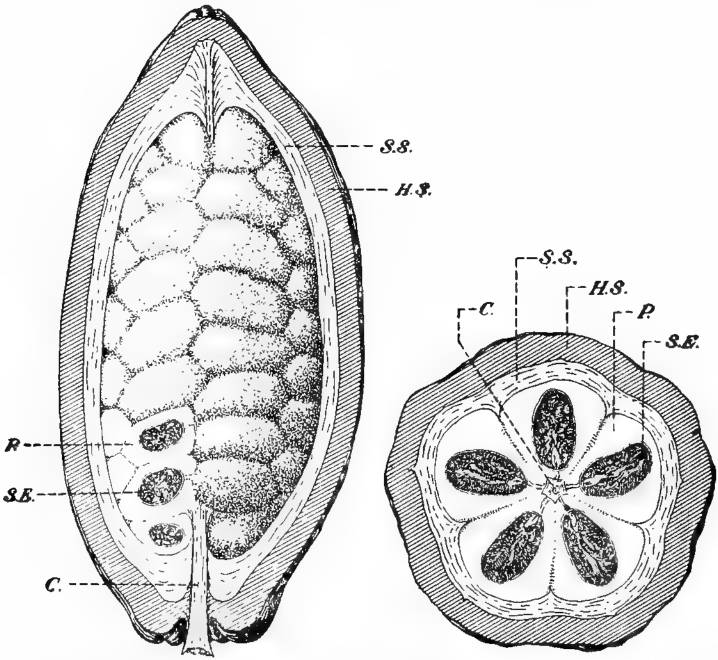


FIG. 1.—Structure of cacao fruit: *H. S.*, Hard outer shell of fruit; *S. S.*, soft inner layer of fruit shell; *P.*, pulp of seed or slime tissue; *S. E.*, seed with testa or envelope; *C.*, core or placenta.

Maurice Montet[1] in his criticism of the apparatus.

[1] *Journ. Agr. Trop.*, 5 (1905), No. 52, p. 297.

The rise of temperature amounts to about 5° C. in twenty-four hours, and after four days the fermenting beans show generally an elevation of 18° to 20° C. above the temperature of the surrounding atmosphere. The more or less rapid rise of temperature in the fermenting pile depends, of course, upon the height of the pile and upon the temperature of the surrounding air.

The cacao fruit resembles a cucumber in shape, but the form is subject to certain variations. The shell is of violet, red, or yellow colour, sometimes even nearly white, 15 to 25 cm. long and 6 to 10 cm. thick. The shape of the seed is more or less round, often laterally compressed or flattened, when it resembles the bean of Phaseolus; its length varies from 2 to 2·5 cm., the diameter from 0·8 to 1·8 cm. Between the fleshy and corrugated cotyledons, showing convolutions on the surface, lies the bitter, purple embryo with its white chalaza. The cotyledons of one variety are white in colour. As many as 50 seeds may exist in one fruit.[1] The loose parenchymatous slimy tissue (pulp) surrounding the testa of the seed appears to be of a similar nature to the tissue forming the soft inner layer of the hard fruit shell. The structure of the entire fruit is somewhat

[1] The average would be below 40, however, including the small and lean beans at the extremities.—H. H. S.

complicated, and nature has evidently taken much pains to protect the embryo by four different envelopes. Figure 1 will suffice to explain the structure.

The chief purposes of the fermentation process are:

(1) Removal or contraction of the pulp surrounding the seeds.

(2) Loosening of the connection between the seed and its testa.

(3) Development of colour and improvement of taste.

Some authors hold that the heat of the fermentation is required to harden the interior of the bean, and also pass it to a second fermentation; further, that another change consists in the hardening or toughening of the testa of the bean, whereby brittleness is avoided during drying, and thus the seeds are better protected against the entrance of mould fungi.[1] Various authors also ascribe to the fermentation a great influence upon the development of the aroma.

As regards the first of the above-named purposes, namely, the removal of the slime layer attached to the seed coat, a somewhat similar process occurs in the fermentation of coffee. (See p. 59.) The first step is the development of numerous yeast cells, which find ample nutrients in the sweet juice oozing

[1] Hart, "Cacao." Trinidad, 1900, 2nd ed., pp. 35, 49.

from the pulp. The yeasts are chiefly *Saccharomyces ellipsoideus* and a certain amount of *S. apiculatus* (see also p. 62, *re* "Coffee Ferments"), which develop rapidly. These organisms occur on fruits, as well as in the dust of the air and on the surface of the soil, together with numerous bacteria. The alcohol formed in the fermentation of the sugar from the pulp by these yeasts kills the cells of the superficial strata of the pulp or slime tissue, and as its juice passes freely to the outside, nourishment is given to innumerable bacteria, among them the widely distributed acetic bacillus. The respiration of these organisms and the fermentative activity generate heat, and gradually a considerable elevation of temperature is reached.

The juice on the surface now assumes a strong acid reaction, due to the oxidation of alcohol to acetic acid, and this suffices to destroy the remaining cells of the slime layer, causing thereby a considerable shrinkage of it, and also a further discharge of juice, as the cytoplasm of the dying cells becomes permeable to the interior juice. Thus a considerable amount of liquid gathers at the bottom of the receptacles and, since this liquor has an agreeable sour smell and taste, it is used in some factories as vinegar. By the bacterial action the attached pulp is further loosened from the testa to some extent and can be washed away, as is done in Ceylon.

In many parts of Central America, however, the shrunken pulp is dried with, *i.e.*, on, the beans, which are shipped in this condition to other countries.

Cacao beans, when fermented and well-washed, show a uniform yellowish or brownish colouration of their testa. The testa of unwashed fermented beans do not show a uniform colouration on account of the adhering films of fermented and shrunken pulp, which has turned from the original colourless condition to a violet brown colour, and which is reduced from the original thickness of 0·1 to 0·2 cm. to a mere film. An advantage of removing the remaining films by washing consists doubtless in the greater rapidity of drying, whereby the danger of attack by mould fungi is diminished. Eugene Lange[1] holds that the extra trouble is not compensated by the additional price obtained for washed cacao. Nevertheless, the washing of the cacao has been recently introduced in Trinidad.[2]

When pulped cacao is not fermented, but simply dried in the sun, the slimy layer around the testa shrinks considerably, but not to such insignificant thin films as after fermentation. When the entire juice of the slimy layer is simply dried up instead of being removed, a hygroscopic condition of the product results, which in moist weather becomes sticky and

[1] *Agr. Record.* Trinidad, 4 (1891), pp. 105-107.
[2] It is, however, very seldom used to-day.—H. H. S.

might support fungus growth. Hence, fermentation is preferable to a simple drying process, and after washing yields a much cleaner product.

In the fermentation of coffee the slimy layer to be removed from the testa (parchment envelope) is much thinner than that of the cacao seed. Hence, the fermentation of coffee is of much shorter duration that that of cacao.

In regard to the second purpose above mentioned, namely, loosening the connection between the seed and its testa, it must be mentioned that by the death of the seed, caused by the elevation of temperature during fermentation to 40° to 45° C., some contraction takes place and the seed recedes somewhat from its walls. Later on, in the manufacture of cacao from the fermented and dried beans, these are roasted and some further contraction of the seed is caused. The testa having lost its hygroscopic water by the heat, now can be easily separated, especially while still warm and brittle.

An important change, also due to the fermentation process, is the production of a fine brown colour. The effect of the fermentation in this direction is, however, not a direct, as supposed by many, but an indirect one, and may be secured by simply drying the bean. Sun-dried beans are uniformly deep brown. When the fresh seed is cut, the surface thus opened will turn from the original violet to a deep brown colour within a short time, while boiled seed thus treated will not show any change of colour, even after many hours' exposure to the air. This is in full analogy with similar phenomena observed very frequently with plants, and is due to the presence of oxidases or oxidizing enzymes. When cells are killed by being cut open or in any other way that will not injure the oxidases, these will, upon the death of the protoplasm in which they are stored up, be liberated and at once commence their activity, easily recognized by the early appearance of a brown, black, or red colour. These colours are often due to the oxidation of various kinds of tannins originally present in the juice or cell sap.[1] If, however, the death of the protoplasm is produced by strong acids or boiling temperature,[2] the oxidases will also be killed and no colour change will be noticed, as the tannins and other readily oxidizable matters in the juices cannot easily take up the atmospheric oxygen without the assistance of oxidases.

A further control experiment was made in which the pulped cacao (seed with testa and attached slime layer) was boiled for about twenty minutes with a 2 per cent. dilute sulphuric acid. The slimy tissue contracted, and

[1] Such a case is observed in the curing of tobacco, whereby a fine brown colour is produced.

[2] The killing temperature for oxidases is 20° to 30° C. higher than that for protoplasm or living matter.

together with the swollen testa was easily separated from the seed. These seeds showed a pure red colouration on the outside, while the interior was violet, and no trace of brown colour appeared even after many hours' exposure to the air, since the oxidizing enzyme (oxidase) had been killed, together with the living matter (the protoplasm of cells).

The seeds commence to die when the entire fruit is kept for several days at 40° to 45° C., and the browning can be observed progressing from the surface of the seed toward the interior. By becoming over-ripe, the soft interior strata of the fruit shell, as well as the slime tissue around the seeds, contract more or less, and a hollow space is formed between the fruit shell and the seeds with their adhering slime tissue. Air diffuses into this space, and the reason for the brown colour produced by oxidation within the fruit becomes apparent. During the fermentation process the browning does not often go farther than this, and the interior of the seed often continues to show the original violet colouration. It is then that the subsequent drying process, which admits air abundantly by diffusion through the testa, completely finishes the browning process. Some further darkening can take place during the roasting process when powdered cacao and chocolate are made from the fermented beans.

The colour change of the cacao seed is no doubt similar to the colour change in the preparation of black tea, in which it has been positively proved[1] that an oxidizing enzyme acting on a specific tannin is the real cause of the blackening of the leaves. When the oxidizing enzyme of the tea leaves is killed by steam, the leaves retain their green colour and never turn black, thus giving us the green tea of commerce.[2]

Tea leaves contain 7 per cent. tannin and over, and the production of a black colour from this tannin commences as soon as the leaves die, which takes place when they are kept in heaps after picking, and are deprived of sunlight (death by starvation). Indeed, black tea contains less tannin than green tea. In order to increase the black colouration, the leaves are rolled, which brings their juice to the surface,

[1] K. Aso. "Bul. Col. Agr." Tokyo, Imp. Univ., 4 (1900-1902), p. 255. It may be of interest to readers to remember that, from 1893 to 1897, Dr. Loew occupied the important position of Professor of Agricultural Chemistry at the College of Agriculture, Tokyo University. See *Tropical Life*, February, 1910, p. 32.—H. H. S.

[2] Even to-day we are told that whilst great strides have been made since the formation of the Scientific Department, it is doubtful, according to the Dooars correspondent of a contemporary of the *Indian Planters' Gazette*, if there is any agricultural pursuit about which less is known by the men occupied in it than tea. Especially is this the case in the tea house. We succeed in turning out quite passable tea, and are at times vain enough to think that we have made as good tea as it is possible to produce from the leaf at our disposal. But the present methods may be revolutionized at any time by new discoveries. Take one branch of manu-

and the access of air accelerates the blackening process.

A case in which tannin is changed by partial oxidation for the sake of removing the astringent taste is observed in the curing of the fruit of certain varieties of persimmon (kaki) in Japan. By the curing process, which consists in keeping the fruits in alcohol vapour or in subjecting them to slow desiccation in the sun, the tannin is changed, in contact with an oxidizing enzyme and oxygen, to a brown, tasteless substance.[1] The fruit thus acquires an agreeable taste.

Since a moderately brown colour is also produced in white "nibs," free of cacao red, it follows that the brown colouration is not due

facture by fermentation, and we find that we do not know what is the cause of this process. If we rule the pure oxidation theory as out of court there then remain the enzyme theory and the micro-organism theory. The former as propounded by Dr. Mann—that fermentation is caused by a soluble ferment or enzyme which exists in the cells of the leaf, and which on being set free during rolling causes the oxidation of the tannin. The latter was advocated about two years ago by Dr. C. L. Bernard, of Java, who claimed that fermentation is caused by soluble enzymes which do not exist in the cells of the leaf but in those of micro-organisms. Much the same uncertainty is attached to practically every branch of tea manufacture. It is surprising that a Scientific Department was not created many years ago. If such had been the case we should probably now be "groping in the dark" to a much less extent than we are.—H. H. S.

[1] S. Sawamura. *Ibid.*, 5 (1902-3), p. 237.

exclusively to a change of cacao red. If the production of the colour is due to an incomplete oxidation of the tannin, then there will be less tannin found in the cured cacao than in the fresh cacao. This agrees, indeed, with some analytical determinations of Prof. Harrison, published by Hart.[1] The fat content is assumed not to change during the curing process, and this is in all probability the case. The data compiled under this condition are as follows for Calabacillo cacao :—

ANALYSES OF CALABACILLO CACAO.

Constituents	Fresh. Per cent.	Cured. Per cent.
Fat	29·25 ...	29·25
Tannin...	5·00 ...	3·61
Cacao red	2·95 ...	1·39
Theobromin	1·35 ...	1·00
Caffein...	0·11 ...	0·03
Starch	3·76 ...	3·22
Glucose	0·99 ...	0·60
Hemicelluloses ...	5·11 ...	3·74
Woody fibre	3·03 ...	2·78
Protein	6·69 ...	4·42
Amido compounds ...	0·53 ...	2·06

A part of the changes brought about by curing is probably due to the action of the living cells in the seed, before they are killed by the rising temperature. This would account for the decrease of starch, glucose, and hemicelluloses, which may be consumed by the respiration process, but the other

[1] "Cacao." Trinidad, 1900, 2nd ed., p. 100.

changes are due to several enzymes. A proteolytic enzyme brings on the decrease of protein and the corresponding increase of amido-compounds, while oxidizing enzymes, generally liberated from the protoplasm upon its death, cause the decrease of tannin and cacao red and their change to other compounds. The most conspicuous changes are, therefore, only possible after the death of the protoplasm, which is a desirable factor. Hence, it is a mistaken idea of Zipperer that the changes are due to a germination process of the seeds. He has even attributed the rise in temperature of the fermenting pulp cacao to this process, considering it analogous to the behaviour of barley on the malting floor. This error can only be explained by the fact that he has never witnessed the fermentation of cacao or coffee; for germination changes are not in the least apparent.

Another result is the change of flavour. In the fresh state the seeds have a raw, bitter, and astringent flavour, while after fermentation and drying the bitter and disagreeable taste has entirely disappeared. This change is doubtless due in a certain measure to the decrease of tannin; that is, to its change by oxidation to a brown substance, as in the case of the persimmon fruits, mentioned on p. 47.[1]

[1] The opinion of Harrison already mentioned, that the decrease of the astringent taste is due to a hydrolysis, is erroneous and would be without analogy.

The flavour of the fermented beans is still far different from that of the prepared cacao product, which is produced by roasting the fermenting beans; hence a part of the taste must be due to changes caused by the heat of the roasting process.

The presence of oxidizing enzymes in the seeds of cacao can be proved by the usual reaction. Upon moistening a freshly cut section of cacao seed with tincture of guaiacum[1] resin, just after taking the seed from the ripe fruit, a blue colour is rapidly produced, first and most intensely in the chalaza of the embryo and gradually spreading over the entire seed tissue; the placenta, also, soon shows an intense blue colour. When a cross section through the whole fruit is moistened with guaiacum tincture, the chalaza of the embryo and the interior soft stratum of the fruit shell become rapidly and intensely blue, then follow in order the colouration of the convolutions of the cotyledons of the seed and the tissue of the hard outer shell. Finally the whole surface of the sections of the seed and the exposed tissue of the testa become blue; but the slime tissue or pulp around the testa remains perfectly colourless, presenting a most striking contrast.

If the tissue of the seed is crushed with some water in a mortar, the filtered liquid will show no blue colouration on addition of guaiacum tincture and shaking with air, while the un-

[1] *Lignum vitæ.*—H. H. S.

filtered liquid will become blue very soon. This shows an exceptional case, namely, that the oxidase (laccase) is present in an insoluble state and perhaps held in combination with an insoluble protein.[1] Upon standing, the blue colour, obtained with the unfiltered liquid, will gradually disappear, except on the surface, but on adding a few more drops of the reagent and shaking, the intense blue colour reappears. This phenomenon is due to the presence of a reducing compound in the juice.

In testing for a second oxidizing enzyme, the peroxidase, the tissue of the seed, crushed with a little water, was heated for five minutes to 75° C. and one portion of this liquid was filtered ; the other not. The test with guaiacum tincture yielded no blue reaction in either liquid, proving that the oxidase was killed, while on addition of a little peroxide of hydrogen the unfiltered juice gave an intense blue reaction and the filtered juice showed only a trace. This difference proves that the peroxidase, like the oxidase, was present, but retained as an insoluble compound—an exceptional case.

Reactions with guaiacol were also tried. This substance produced no colouration when applied by itself, but in conjunction with hydrogen peroxide a red colour turning to brown was soon produced in both the hard

[1] This recalls the existence of a soluble and insoluble form of catalase.

as well as the soft layer of the fruit shell. Later, in the testa and the seed generally, as well as in the slime tissue covering the testa, a reddish colouration was produced, but only a weak one. This peroxidase reaction agrees also with that just mentioned, in so far as the slime tissue gave only an exceptionally weak reaction compared with all other parts of the fruit. The slime tissue of the coffee fruit is also poorer in oxidase and peroxidase than the other tissues.

The further generation of the characteristic aroma of cacao is of great importance. Is this process due to the action of an oxidizing enzyme or to that of a hydrolizing enzyme, and does the fermentation influence the generation of aroma only indirectly by the development of heat or directly by furnishing some compound? Or, is the roasting of the fermented cacao beans alone responsible for the aroma? The investigations thus far made do not solve this problem satisfactorily. It may be mentioned, however, that Hart[1] agrees with Chittenden,[2] who declared that after a certain stage of the fermentation "the cotyledons are found separated and the vinous liquor of the pulp, which passes through the membranous covering, occupies this space as well as the cavities between the convolutions. . . . This it is which has so marked a physiological influence

[1] "Cacao." Trinidad, 1900, 2nd ed., p. 38.
[2] *Agr. Record.* Trinidad, 2nd ed. (1890), p. 110.

on the bean and affects its flavour, the bean being, as may be said, 'stewed in its own juice.'"

According to the laws of osmosis some acetic acid and some alcohol from the fermenting liquor will doubtless enter through the testa and come in contact with the cotyledons, which thereby may be killed, if the temperature of the fermenting mass has not already accomplished this. The reaction of the cotyledons after drying the fermented beans is acid, but whether this is wholly due to the entering acetic acid may be doubtful, since the reaction is weakly acid in the fresh state. A stronger acid reaction is shown by the slime tissue.

The expression "stewed in its own juice" used by Chittenden can hardly be admitted, since the juice of the pulp, after being entirely decomposed by yeast and bacteria, is certainly not the "own juice" of the cotyledons. Still, that author attributes to it the generation of the flavour.

The opinion of Prof. Harrison (see p. 36) that the decrease of tannin during the fermentation process stands in relation to the development of the aroma (see p. 37) is certainly far from the mark, as tannin cannot produce ethereal oils by any oxidation or fermenting process. Only colour and taste stand in this relation to the tannin content.

Several experiments were made by the writer with an aqueous solution of 1 to 4 per cent. acetic acid containing from 3 to 5 per cent. of alcohol in order to imitate the composition of the fermenting pulp juice. After twenty to thirty hours' digestion of pulped cacao at 40° to 44° C. it was observed that the pulp had died and shrunk to skinny masses, partly separating in small pieces, but mostly still firmly adhering to the testa. It appears that for bringing about an easy separation of the dead pulp from the testa a bacterial enzyme is necessary, as in the case of coffee fermentation. It was further observed that the amount of acetic acid, which entered by osmosis through the testa to the cotyledons, was not sufficient to kill the oxidizing enzyme, since the freshly cut surface of these seeds rapidly turned brown on exposure to the air. On the other hand, it was observed that when the freshly cut surface of the seeds so treated was moistened with 4 per cent. acetic acid no further change by oxidation took place. In this case the oxidizing enzyme was killed.

It is stated by Hart[1] that "of late years there has been a large amount of inquiry for cacao which is but slightly fermented or not fermented at all." This renders it very probable that the decomposed juice of the slime tissue is not required for the generation of the aroma, as was supposed. Indeed, the true aroma of cacao is faint before roasting the fermented beans. The case is, therefore,

[1] "Cacao." Trinidad, 1900, 2nd ed., p. 33.

similar to that of coffee, and is different from that of tea. With tea the aroma is the result of the action of a hydrolizing enzyme, yielding the volatile tea oil, as was shown by Katayama.

That the aroma of the cacao is chiefly produced during the gentle roasting process is the opinion of manufacturers of chocolate from the fermented beans. The fermentation seems, indeed, to have nothing at all to do with the production of aroma. Seeds simply dried in the sun and then gently roasted may yield an especially rich and aromatic chocolate, as Safford[1] has also indicated. Hart says :—

"No adulteration . . . is equal to the flavour of the virgin cacao, provided the essential oil has not been destroyed during the process of roasting, during which process it appears to be developed."[2]

The question now arises: which compound yields the aroma in the cautious roasting of the fermented cacao beans? It is certainly not a glucoside, for neither the testa nor the cotyledons of the beans develop anything like a cacao flavour upon being boiled for some time with dilute sulphuric acid (3 to 6 per cent.). The same negative result was obtained by

[1] Compare the quotation in the introductory remarks to this article on p. 34.

[2] "Cacao." Trinidad, 1900, 2nd ed., p. 111. These words, however, contradict his previous opinion already quoted in regard to the influence of fermentation on aroma.

boiling those materials with moderately concentrated solution of caustic potash. It seems probable that it is a certain concomitant of the fat which causes the production of the flavour, after being moderately oxidized during the drying of the beans. Only seeds in which the oxidizing enzymes have produced changes can yield the true aroma by roasting, not the fresh beans.[1]

In the manufacture of the cacao powder of commerce the fat of the beans is more or less removed, since a suitable powder cannot otherwise be obtained, but in the direct manufacture of chocolate this removal of the cacao fat cannot be justified. It is claimed that cacao fat or cacao butter is difficult of digestion, but in reality cacao butter is as easily digestible as cow's butter. Besides, the removal of fat also diminishes the aroma of the chocolate. In the manufacture of chocolate in Porto Rico, fermented cacao seeds are placed in a small baker's oven for about one hour, until the testa have become very brittle and can be easily removed. This roasting temperature is kept considerably lower than that required for

[1] Fresh beans were crushed, washed with alcohol, and the oil extracted with ether. Neither the extracted fat nor the seed powder developed on moderate heating any flavour resembling that of cacao; only the alcoholic extract yielded thus a very faint flavour of cacao. On evaporation of the alcoholic extract another aromatic odour is noticed.

baking bread. The cacao butter is not removed in Porto Rico, and therefore the chocolate manufactured there has an exquisitely fine aroma.[1]

SUMMARY.

The fermentation process itself is due in the first place to yeast cells, which multiply rapidly in the saccharine juice oozing from the pulped cacao, and produce alcohol and carbon dioxide. In the second place bacteria participate, which develop rapidly after a certain time, and change the alcohol formed by the yeast by oxidation, either wholly or partly, into acetic acid. These processes cause a rise of temperature, and the death of the cells of the seed and slime tissue, whereby the juice of the slime tissue can separate and, more or less altered, collect at the bottom of the receptacles, together with the acetic acid produced.

The chief object of the fermentation is to kill and shrink the slime tissue or pulp attached to the testa of the seed, allowing the remnants either to be washed away, as is done in Ceylon, or dried upon the seed, forming an irregular brown film upon the testa. The advantage of thus changing the voluminous slime tissue lies in the increased facility of quickly drying the

[1] I think it will be generally agreed that the English term "chocolate" denotes an article for eating rather than drinking, and in that case not only is *all* the natural fat or butter left in the beans, but even extra butter is added at times, I believe.—H. H. S.

seed. In this regard there exists a close analogy to the fermentation of coffee. The loosening of the adhesion between the seed and its envelope, and the hardening of this envelope (testa), are claimed as further effects of fermentation.

The fermentation has also an indirect influence on changes going on within the seed, inasmuch as by the temperature produced (40° to 50° C.) the cells of the seeds are killed, thus liberating the oxidizing enzymes, which cause the formation of the brown colour, by oxidation of the tannin of the seed. This brown colouration is increased during the drying process, and finally by the roasting.

The taste of the raw cacao bean is not only altered by the partial oxidation of tannin during the fermentation or sun drying of the seed, but also by products of roasting.

The action of oxidizing enzymes, as well as the final roasting process, plays a part in the development of the aroma.

The Fermentation of Coffee.

The so-called fermentation of coffee has thus far not been investigated, and has been defined sometimes as an "alcoholic fermentation necessary to remove the saccharine matter."[1] Such saccharine matter, however, should be easily removable by simply washing with water.

[1] *Cf.* Watt, "Dictionary of the Economic Products of India." Calcutta, 1889, vol. ii, p. 476.

Upon close examination the writer concluded that the aim of the "fermentation" is the removal of a slimy stratum firmly adhering to the parchment envelope of the seeds. The removal of this is necessary, because the drying of the seed envelope would otherwise be very much retarded, and because a bad flavour may finally be imparted to the seeds by the partial decay of the slimy stratum during the drying process. The process will be explained by

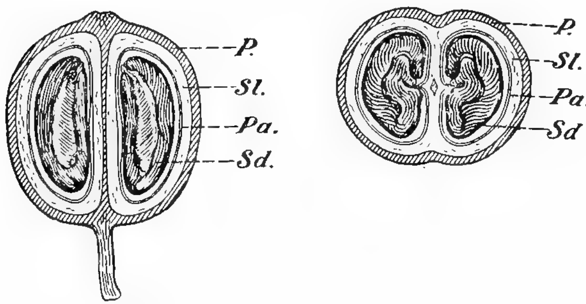


FIG. 2.—Structure of coffee fruit: *P*, pulp; *Sl.*, slimy layer; *Pa*, parchment envelope; *Sd.*, seed with silver skin.

examining the anatomical structure of the fruit (fig. 2).

Just below the skin of the fruit and extending between the enveloped seeds is a fibrous tissue containing a sweet juice. This pulp, together with the skin, is easily separated by mechanical means from the seeds, which are enveloped in a hard parchment. Adhering to this parchment is a stratum of very slimy cells, the slime layer.

The preparation of coffee for market requires the following manipulations:

(1) Pulping to secure removal of the skin with the adhering tissue.

(2) Fermentation to separate the slimy layer from the parchment envelope.

(3) Washing away the loosened slime.

(4) Drying the envelope around the seeds, to prepare for and obtain the brittleness necessary for the next operation.

(5) Hulling or milling, consisting in the removal of the parchment envelope, with subsequent subjection to a fan to blow away particles of parchment envelope and silver skin.

The entire fruit is often called "cherry" from the similarity of form and colour. The expression "pulped coffee" signifies seeds in the parchment envelope with slimy layer. "Coffee in parchment" means the product after pulping, fermenting, and drying. The "bean" means the seeds deprived of parchment and silver skin.

Fruits of red or yellow colour should be picked for pulping, as only such furnish seeds of the desired bluish-green colour. Green unripened fruit containing a hard pulp and little or no sugar should be excluded, but such fruit cannot be entirely avoided, since some unripened seeds will drop off in gathering the ripened ones.

The fruits are well moistened with water when passing through the pulper, which easily separates the skin and fibrous layer. Attached to the pulper is a conical sieve ("séparateur") placed in a horizontal position, which retains the fruits which have accidentally escaped pulping, and they are carried back to the pulper.[1]

In order to understand the fermentation process it must be remembered that on the surface of all sweet fruits are a great many yeast cells and bacteria. When, by pulping, the sweet juice is forced out and spread all over the separated skin, and over the pulped coffee, it is not surprising that these organisms develop rapidly. The sweet juice not only contains sugar, but also some nitrogenous and mineral matters required for the development of organisms.

An examination of the skin with a high magnifying power, several hours after pulping, shows numerous cells of Saccharomyces, which

[1] It has been proposed to dry the pulp and bring it into commerce as a cheap substitute for coffee. When well pressed to remove the caffein and then mixed with molasses, it might serve as a food for hogs. Greshoft holds that its best use would be as a manure and gives the following composition in the air-dry state:

	Per cent.
Caffein	1·1
Carbohydrates	23·3
Albumin	7·6
Cellulose	16·1
Water	14·9
Fat	3·3
Ash	6·9

in form resemble chiefly *Saccharomyces ellipsoideus* and sometimes also *S. apiculatus* (see p. 41, *re* "Cacao Ferments").

Numerous bacteria are also present. Alcoholic fermentation can soon be detected by the vinous odour, and the fact that the fermentation produces heat explains why the temperature of such a heap of pulp rises considerably after a time. A heap of nearly 30 cm. in height showed after sixteen hours a temperature of 41° C. at an air temperature of 26° C. Later, acetic acid is formed and the red colour of the skin is changed to a brownish one.

When the pulped coffee, on the other hand, is examined, few yeast cells and bacteria are noticed on the slimy stratum after one hour, while after sixteen hours an immense increase has taken place and not only is considerable alcohol formed by the yeast cells, but also acetic acid by certain bacteria. Mycoderma and the mycelium of fungi are occasionally seen. Litmus is reddened intensely and the odour of acetic acid is readily discernible. At the same time another volatile product is formed in small quantity, which modifies somewhat the acid odour.

The alcoholic fermentation of the sugar adhering to the slimy stratum, as well as the further oxidation of the alcohol to acetic acid, and finally the respiration process carried on with considerable intensity by all these organisms, cause a rise of temperature depending upon the depth of the stratum and the temperature of the surrounding air. The heaps of pulped coffee are generally 1 to 2 ft. high. In such heaps the temperature was found after fifteen to sixteen hours to range from 34° to 42° C. at an air temperature of 25° to 29° C.

The alcoholic and acetic fermentations proceeding in the heaps of pulped coffee are, however, not the most essential phenomena; the most important point is that the slimy stratum is separated from the parchment envelope. It is by no means dissolved, but merely loses its firm adhesion and is left loosely spread upon the parchment coffee so that it can easily be washed away by a current of water and the parchment coffee dried.

Neither the acetic acid nor the enzyme already present in the slime causes the separation of the slime layer, as tests have shown.

Freshly pulped coffee was kept in dilute acetic acid (about 1 per cent.) at 35° to 40° C. and another portion in some water containing a few drops of ether to prevent bacterial growth. In both cases the slimy layer was found still firmly attached to the parchment after twenty-four hours. This leaves no other inference but that a peculiar enzyme dissolving the adhesive substance (a carbohydrate?) between the parchment and the slimy stratum was furnished by the bacterial growth, or, what is less probable, by the yeast cells.

The "fermentation" should not take longer in Porto Rico than fifteen to twenty hours, while in some sections of Central America, as Guatemala, it must be carried on for two days [1]

Undue prolongation of the fermentation must be avoided, as otherwise a brown colouration of the parchment and of the seeds is produced, and the seeds would further acquire a disagreeable odour—two circumstances which render the product unfit for market.

After the fermentation and washing, the parchment coffee is readily dried, either on cement floors exposed to sun and air, or better in rotating cylinders through which warm air passes. At a certain degree of dryness the parchment becomes brittle and breaks easily in the milling process, which thus removes the parchment envelope and silver skin from the seeds. In fact the milling must be done while the parchment is still warm.

This milling is in many cases done in London and not in the country where the coffee is produced. Better preservation of the shape and colour of the bean has been

[1] When carrying out these investigations Dr. Loew was Physiologist to the Porto Rico Agricultural Experiment Station, and this essay or report was first published in the Annual Report for 1907 of that station, and afterwards reprinted separately, as pamphlet 1093 by the U.S. Dept. of Agriculture.

observed when the latter is protected for a time by the parchment envelope. The cost of transportation is in this case a little higher, but it does not come into consideration, as from \$2 to \$3 more has been realized per hundredweight for coffee thus treated, than for that cleaned in Central America.

In reviewing the so-called fermentation of coffee the conclusion is inevitable that alcoholic and acetic fermentations are not of direct benefit, but only indirect, inasmuch as heat is thereby produced which supports the action of a body (enzyme) furnished by the bacteria, which dissolves the adhesive substance between the parchment envelope and slimy layer.

CHAPTER III.

BY DR. FICKENDEY.

IT was originally intended to follow up the question of cacao fermentation to its final conclusion before publishing any report on what had been done towards that end. As, however, the investigations and experiments carried out so far have yielded results likely to be of use to planters and others if tried on a commercial scale, I feel justified in publishing the following details, without waiting for the final conclusions to be arrived at.

When preparing green cacao (*i.e.*, the beans as taken from the pods), two different processes are necessary, and must be distinctly recognized by those having to carry out the operation of turning such beans into the cacao of commerce. On the one hand, there is the fermentation of the pulp which surrounds the beans—that slimy, sugary mass in which the beans are embedded in the pods; whilst, on the other hand, we have those processes which go on inside of and affect the bean itself, and which, on the whole, are only indirectly caused by agencies arising as one of the results of fermentation. In fermenting the beans, the chief aim is to kill the germ each one contains but to kill it in such a way that the enzymes[1] present are not destroyed at the same time.

This statement is confirmed by the fact that the most important changes—which manifest themselves after fermentation has taken place, both to the eye in the brown colouration of the cotyledons, and to the palate in the reduction of the bitter taste so well known in unfermented beans—can also be obtained without fermenting the cacao by killing the germs in the beans in such a way as not to render the enzymes less efficient. This can be done by the use

[1] These enzymes are organic catalyzers. By a catalyzer is understood a substance which is able, through its mere presence, and without the substance itself undergoing any alteration, to alter the rapidity of the chemical changes that the beans undergo, and in most cases to quicken them. These organic catalyzers, known as enzymes, differ from inorganic ones in that they are more individualized, that is to say, each enzyme is only able to influence one quite definite process, as, for instance, the diastase known in distilling, which brings about the conversion of starch into sugar. Inorganic catalyzers, on the other hand, as, for instance, finely-divided platinum, used in the self-ignition of gas lamps, are able to influence a whole series of widely different processes. These enzymes, in their behaviour, *i.e.*, in the effect they have on surrounding substances, are similar to albuminous bodies. They are soluble in water, and lose their efficiency if the watery solution is heated to a temperature approaching the coagulation temperature of albumen.

of 96 per cent. alcohol, in which the beans, after all the pulp surrounding them has been carefully removed, are laid for ten minutes, and then left for four or five days suspended over the alcohol. After this they must be laid for one minute in water, and then dried. The germs can also be killed by freezing if the beans, placed in a glass vessel filled with water, are exposed to the influence of a freezing apparatus. In both cases it is with the access of air that the cotyledons in the bean gradually turn brown and, at the same time, lose their bitter taste; but such beans differ from those that have been fermented in one point, viz., in the aroma. This is but natural, and could not be otherwise, as the fermenting process causes all sorts of substances to penetrate into the beans, and these affect the taste and aroma, beneficially or otherwise. Nevertheless the beans so treated (*i.e.*, placed in alcohol or under the influence of freezing water) still have the recognized chocolate flavour.

The browning of the cotyledons and the removal of the bitter taste are in the relation of cause and effect. The bitter taste is to be attributed to the presence of substances containing tannin, and the brown colouring is due to the changes that the beans undergo on account of the oxidation of these tannic substances. If a bean is cut through, the exposed surface turns brown, which peculiarity is generally to be met with in fruits containing tannic substances, as, for instance, in apples, in which the colour or discolouration that results

DR. FICKENDEY, AGRICULTURAL DEPARTMENT. CAMEROONS, GERMAN WEST AFRICA.

from being cut is caused by the oxidation of the tannic substances in the fruit. The query as to whether a kind of leathery formation results at the same time, has still to be decided, but that is outside the present discussion.

The cotyledons also turn brown, and the bitter taste is removed if the green cacao, freed from the surrounding pulp, is ground into a pulp or jelly. This treatment also kills the germs, but leaves the enzymes intact. At this point it will not be out of the way to compare the behaviour of the sloe (*Prunus spinosa*), which has a strong resemblance to cacao in certain points. Left to itself the sloe has such a bitter taste that it is unfit to eat, but after a frost the pulp cells die off and the enzymes make their action felt, with the result that the acidity disappears, and the fruit becomes palatable. Here, again, the reduction and final disappearance of the acidity is also accompanied by the appearance of a brown colouration which is likewise caused by the oxidation of the tannic contents (perhaps after a previous separation of the glucoside). The supposition that an oxydase plays a part in bringing about the fermentation of cacao beans (by an oxydase is meant an enzyme which hastens oxidation) has been stated more than once, and that it is so can be easily proved. The oxidation of the tannic substances in other fruits containing tannin is attributed to the assistance of oxydases. If cacao beans are heated in water at 75° C. and then ground, no change of colour and no reduction in the bitter taste of the mass takes place, whilst the bluish-red colour remains. This, after an hour's heating at 70° C., changes to brown. The beans themselves can be made to turn brown if warmed to 75° C. and a small quantity of watery extract from some fresh beans is mixed in the pulp. As a comparative experiment to this, take another lot of beans and mix them with some of the extract which has been previously warmed from 80° to 100° C.; it will then be seen that no brown colouring results. This watery extract, which also contains the enzyme, is obtained by grinding fresh beans with cold water, afterwards filtering off the liquor. The resultant extract is coloured brown. Again, if the cacao pulp from heated beans is kept with the extract from fresh beans in glass vessels with only a small surface exposed, it will be noticed that the browning first sets in on the surface and penetrates downwards in proportion to the ability of the air to likewise enter the mass. Even if the beans be boiled in water the tannins enter into solution. This solution also turns brown, owing to oxidation, if a small quantity of the above-mentioned extract is mixed with it. Even a purified solution of tannin (obtained by precipitation by acetate of lead, filtering off the liquor, and separating the lead compounds by means of sulphuretted hydrogen), to which some of the extract has been added, also causes the brown colouration to set in again from the surface downwards. All these results will probably lead to the acknowledgment that an oxydase assists in producing the brown colouration of the beans, and that this is brought about by the oxidation of the tannic substances. Whether a decomposition of the glucosides takes place prior to oxidation has still to be investigated and ascertained. The behaviour of beans with a whitish break, *i.e.*, Criollo beans, differs from the beans having purple cotyledons, *i.e.*, of the Forastero variety, inasmuch as the devitalizing temperature is 5° to 10° higher (for Criollo beans), but in other respects the conditions are the same. Here, again, we have the same tannic substances formed in the white cells, as can be proved if sections of the beans are examined. Under the microscope the cells containing the tannic substances can be distinguished in the purple (Forastero) beans, on account of the purple-coloured matter they contain, which matter also is of a tannic character.

Comparing the results of all these experiments led to the discovery that the oxidation of tannic substances increases very quickly in weak alkaline and neutral reaction, and that, on the other hand, with an increased proportion of acid, the influence of the oxydase diminishes to a corresponding degree. The concentration of the acid which is noticeable in the pulp (some $\frac{1}{10}$ to $\frac{1}{5}$ normal) causes, already, a considerable reduction in the oxidation process. As in the case when fermenting the pulp, acid is again formed but of a more concentrated nature, the percentage of acid, when the work is carried out on a commercial basis, being increased. From the above facts, when carrying out these operations on a commercial scale, one has to note first of all that the temperature must not be raised above 65° to 70° when drying the beans, and I am nearly certain that the cacao can be dried without exceeding that temperature. As the beans continue to attract moisture after being dried, the enzymes can still develop their activities and further improve the quality of the cacao whilst in warehouse or being transported; but otherwise (*i.e.*, if the temperature is raised) the enzymes run the risk of being killed. Further experiments resulted in the proposal to pass the beans through a potash solution after being fully fermented, but previous to being dried. Doing so, whilst offering no practical difficulties, promises to offer the following advantages:—

(1) The addition of potash reduces the acidity in the cacao.

(2) This reduced acidity increases the activities of the enzymes, enabling them to act more freely, and the beans to be freer from bitterness.

(3) Cacao cured in this manner should, when manufactured, become more soluble, and

show greater capabilities of suspension in the cup. On this point I may remind my readers that in some manufactories the cacao, after roasting, is treated with potash.

Experimental trials have shown that the advantages claimed from experiments Nos. 1 and 2 have been realized; but whether there is also a greater solubility and capability of suspension in the manufactured article must be left for the maker to find out.

In conclusion, I would add that it is highly desirable that some of the estates should arrange to carry out the experiments described on a large scale and so prove their advantages, or otherwise, on a commercial basis; and this can be done in the following manner:—

After being fermented, place the beans in bags or baskets,[1] and steep them in a potash solution, containing between 5 and 10 per cent. potash, for ten minutes, taking care that the liquor comes into contact with all the beans to an equal extent[2]; now run off the liquor, and dry the beans in the usual way. The cost of such a treatment is not heavy, and experimental shipments will soon show whether the increased prices obtained pay for the extra trouble and cost incurred; otherwise to form

[1] I would suggest baskets, as used in Ceylon and elsewhere, when the beans are washed by dipping and holding the baskets in running water. See Dr. Axel Preyer's essay, p. 11—H. H. S.

[2] This can be assured by gently shaking, or otherwise agitating, the baskets of beans.—H. H. S.

an opinion without making a series of shipments sufficiently long to thoroughly test the market, and to enable the makers to decide whether or not the beans prepared in the manner described are preferable, is most difficult, for the cacao market depends almost entirely on the whim of the public, and the style of cacao and chocolate called for at the time being.

CHAPTER IV.

BY DR. A. SCHULTE IM HOFE.

In which is included some Comparative Notes on the Fermentation of Indigo, Tea, Coffee, and Tobacco.

[NOTE BY DR. RONALD KROHN, THE TRANSLATOR.—There are some German technical terms used in this section that I cannot find the exact equivalent for. In one or two instances there are errors, possibly overlooked during proof-reading, which I have corrected as far as possible.

Page 77, line 16: From "that the process . . . indigo." As the German original stands the passage cannot be understood, but I am certain from the context that I have given the author's meaning.

Page 81, line 25: "Kernel." The German is "Kern" and may be rendered kernel, cotyledons or nucleus.

Page 95, line 12 (and elsewhere): "Tray." The German is "Horde," literally "hurdle," but I have used the technical term "tray."

Page 105, line 26 (and elsewhere): "Fermentation floors." The German is "*Tennen Fermentation.*" "Tenne" is a floor and is used in malting as well. The technical term in the case of cacao may be different.

Page 113: "Tunnel drying," German "Kanal trocknen," from the description I should have thought the German word "Gang" would be better, *i.e.*, "Passage," but here again there probably is some technical term, and I believe "tunnel" is best.]

WHEN I was in British India some seventeen years ago, I turned my attention to the study of indigo fermentation, believing that the experience I had gained in the sphere of industrially applied fermentation would prove of particular value to me. From all that I had read and heard about the manufacture of indigo, I had come to the conclusion that micro-organisms played an important rôle in the production of indigo from *Indigofera tinctoria*, but I was very soon able to prove, however, that the process known as "fermentation" in the manufacture of indigo has nothing to do with the formation of commercial indigo, and that, in fact, the latter can be obtained from the plants even when the fermentation process is entirely omitted, because, as a matter of fact, the formation of indigo depends on a process of oxidation.[1]

When, some years later, I took up the study

[1] Dr. A. Schulte im Hofe: "Indigokultur und Fabrikation in Britisch Indien," *Der Tropenpflanzer*, 1902, pp. 70 to 128. "Studien über den Gehalt der *Indigofera tinctoria* au Indican, sowie über die Gewinnung des Indigo." "Berichte der Deutschen Pharmazeutischen Gesellschaft," 1902, p. 19.

of the cultivation and manufacture of tea, I found that here again an oxidation process constituted the essential factor in the conversion of the freshly gathered green leaves into black tea.[1]

Studies in Cacao Fermentation in the Cameroons.

It was, therefore, only natural that when, towards the end of 1899, an opportunity of studying cacao fermentation was afforded me in the Botanical Gardens at Victoria in the Cameroons, I began my researches by seeking to determine whether an oxidation process does not also occur in this case.[2] Even the first experiments confirmed my assumption, and I found that the chemical changes that take place in the cacao beans are precisely similar to those that bring about the conversion of green tea-leaves into black tea. Before entering more fully into the results of my investiga-

[1] Dr. A. Schulte im Hofe: "Die Kultur und Fabrication von Tee in Britisch Indien und Ceylon mit Rücksicht auf den wirtschaftlichen Wert der Teekultur für die deutschen Kolonien." *Der Tropenpflanzer*, 1901, vol. ii.

[2] In all these experiments I have not attempted to determine whether the oxidation is due to the action of enzymes or not. For, in the first place, this is not essentially important to the process. Secondly, I then had no laboratory at my disposal, for this was only built later in Victoria. I therefore had to limit myself to only the most necessary apparatus and reagents which I had brought with me.

tions, I shall briefly describe the main points of importance in the treatment of tea, in order to be better able to explain the similarity, or rather identity, of the two processes.

Dr. Schulte im Hofe.

The freshly gathered tea-leaves are spread out in thin layers and dried until (on folding the leaf) the midrib and (on compressing a handful of leaves) the connecting stalks no longer break. The leaves are then rolled by a mechanical contrivance which causes an alternating, heavy and light pressure to be brought to bear on them in such a way that during the application of the heavy pressure the sap of the leaf is forced out and spread over the surface, to be absorbed by the leaf again when the pressure is relieved. The main object of rolling is to rupture the cells of the leaf, or at least to render them more permeable to air. The time occupied to do this varies between one and one and a half hours according to the nature of the leaf. Owing to the rolling, the leaves become considerably heated and simultaneously the amount of acid and soluble astringent substances is increased. After rolling, the resultant massed leaves are passed through a sieve-like contrivance which loosens them, and then exposed to oxidation in thinner or thicker layers, varying according to the temperature conditions. Oxidation then proceeds rapidly, as, owing to the rolling, access of air to the interior of the leaves is facilitated; the process takes from two to eight hours, according to the temperature and nature of the leaves. Owing to the oxidation of the astringent substances, the green colour of the leaves turns yellow or copper-coloured, but before this stage is reached, the oxidation should be stopped, otherwise the tea becomes over-oxidized, or, as it is commonly called, over-fermented, and thereby deteriorates in quality. After the completion of this oxidation process, the leaves are immediately dried, and the tea is ready for use.

The changes occurring during the oxidation of the tea-leaves entirely correspond, as I show later on, with what takes place in cacao-fermentation. Here the beans, having been removed from the fruit, are packed in casks or boxes or thrown into heaps. After a short time has elapsed alcoholic fermentation sets in, causing the beans to become heated. In order that uniform fermentation may be secured all the beans should be equally brought into contact with the air. To achieve this they are transferred from one box into the next, or the heaps are well turned over with a shovel. As a rule acetic fermentation has already commenced to set in on the second day, owing to which the alcohol formed from the sugar is converted into acetic acid. This is accompanied by a further rise of temperature, the shell of the bean becomes detached (*stirbt ab*) from the cotyledons and the acid penetrates into the kernel or cotyledons. In the case of beans having bluish-violet cotyledons, the colour is changed by the action of the acid to reddish-violet.[1]

[1] Dr. A. Schulte im Hofe: "Das Wesen und der Zweck der Kakao-fermentation," *Der Tropenpflanzer*, 1900, p. 227.

The condition of the cacao beans at this stage corresponds to that of the tea-leaves after rolling, and the increased acidity of the beans was ascertained by analysis in the same way as was done in the tea fermentation experiments.

If the term cacao fermentation be intended to express the alcoholic and acetic fermentation, it is certainly quite correctly applied, but this is not the case if it be extended to the process by which the reddish-violet colour of the contents of the beans (*i.e.*, the cotyledons) is converted into brown, and by which the bitter astringent substances are split up into an insoluble brown one and a soluble, more or less aromatic compound. If one examines the beans at the commencement of the drying process (after being fermented the beans are at once dried by various methods) one will find the fluid that exudes on fracturing the skin or shell begins to turn brown, *i.e.*, to be permeated by small brown particles, a sign that oxidation has already commenced. This has been confirmed by experiments as follows: Freshly gathered beans, released from the husk of the fruit, were freed mechanically from the fleshy pulp and transferred to a diluted acetic acid solution, until the fluid had penetrated into their interior. During this process the bluish-violet colour of the nibs turned to reddish-violet. It is even sufficient to merely cut through a bean and moisten the cut surface with acid to produce this colour reaction. The changes brought about in the bean by alcoholic acetic fermentation may, therefore, also be produced by the addition of acid. Fermentation is, therefore, not absolutely essential. By means of it, however, the acidification is brought about in the simplest and cheapest manner, and the fleshy pulp adherent to the beans is more or less completely removed. The beans, having been treated with acid, were transferred to a flask filled with oxygen. By the action of the oxygen the bluish-violet colour gradually changed to brown. When the acidified beans were broken up and then treated with oxygen, the process took place more rapidly.

By the conversion of the bluish-violet colour of the nibs into a brown one by means of oxygen, it was proved that this process can be brought about by chemical means. In the same way I have proved that, at the same time, as in the case of tea, the soluble astringent substances are converted into insoluble ones. This I have already proved in the manner described in my article on the "Cultivation and Manufacture of Tea in British India and Ceylon,"[1]

The above experiments prove that the oxygen in the air acts on the acidified beans in a manner similar to that in which it acts on the tea-leaves after rolling. Since, however, the latter are specially prepared for this

[1] *See Der Tropenpflanzer*, 1902, vol. ii, p. 92.

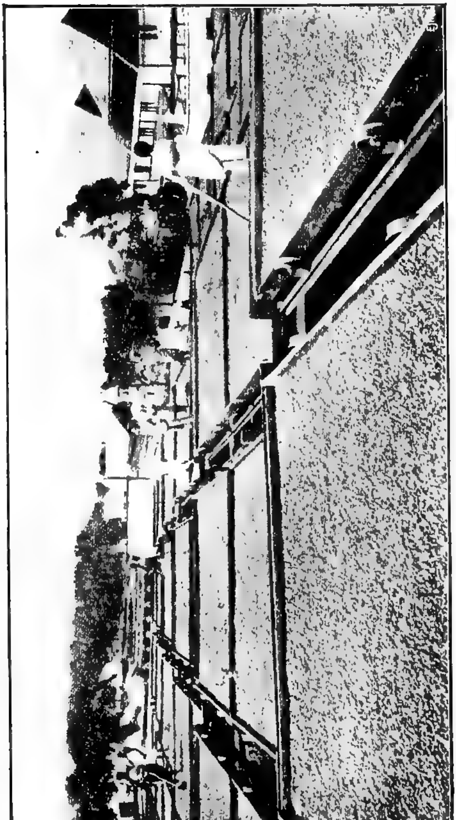
process by being rolled, it is natural that in their case the oxidation process takes place more rapidly. If the process is to correspond to that in tea-leaves, the cacao beans must be ground or broken up. For practical reasons this is, however, impossible with cacao.

Now, if unfavourable reactions are liable to occur even in the comparatively short time occupied in the process of oxidation in the case of tea, such as too marked an acidification and the formation of butyric acid, such changes are still more difficult to avoid in the case of the far more protracted process of the oxidation of cacao. Over-acidification, the formation of butyric acid (which produces a rancid taste, causing a feeling of scratching on the palate), and the development of moulds constitute, therefore, the main difficulties in the proper treatment of cacao beans.

Good, nay even very good results are even now attained very often by the accidental empirical observance of the conditions favourable to oxidation. On the other hand, by the non-observance of these rules, *i.e.*, by the exclusion of oxidation or by over-acidifying, &c., a large quantity of cacao is produced of inferior quality.

A satisfactory degree of acidity was attained, it is true, by the short period of fermentation that at first was generally allowed in the Cameroons, but owing to the rapid subsequent drying in the Mayfarth dryers, the oxygen of the air had no opportunity of acting on the beans, and thus a harsh, bitter and astringent cacao was produced. The sun-dried beans contrasted in a marked degree with the latter, and for this reason there was a tendency to assume that the sun-drying method was the best; a view widely held in other countries also. The beans, obviously, dry far more slowly in the sun than in a Mayfarth dryer for instance, and during the night when the beans no longer undergo the drying process, the oxygen is given an opportunity of acting on the cotyledons. The *temperature* of the beans is, however, not a favourable one for the process of oxidation, and thus such a cacao still remains bitter to the taste. The conditions are rather more favourable when the beans are sun-dried, as they frequently are, on stone or cement drying floors, as then the beans are thrown together in heaps and covered over.[1] By self-heating[2] a temperature favourable to oxidation is thereby attained. Over-heating, butyric acid fermentation and the development of moulds are all avoided by the spreading out of the beans in the sun on the following morning. If, in consequence of rainy weather, or before the beans are fairly dry, they have to be kept for any length of time in heaps, further acidification as well as butyric acid formation takes

[1] As at nights.—H. H. S.
[2] When in heaps.—H. H. S.



Drying Cacao in Trays on Wheels at Agua Ize (San Thomé).

Note the extensive area covered by the trays, and how the flanged wheels run on rails.

place, and the consequent moulds formed from that cannot be avoided. Hence, according to the weather conditions, one may obtain at one time comparatively very good results, whilst at another period a very bad quality of cacao is produced. This was probably the reason for the introduction of appliances such as movable trays, by which the cacao could be rapidly placed under cover when it commenced to rain. By thus sheltering the beans the above-mentioned drawbacks were considerably diminished, but it was never possible to obtain so good a cacao as was obtained by drying on floors when favoured by several successive days of fine weather. At the same time mechanically dried cacao is never so bad as that which has been subjected to several successive rainy days.

In other countries the opinion has gained ground that a better quality cacao could be produced with slow drying by spreading the cacao out in thicker layers. That such may be the case can be easily understood from what has been said above. The slow-drying process gives the oxygen a longer opportunity for acting on the beans; further, the temperature then existing is, as a rule, more favourable for oxidation.

My assumption that, at times, as with tea, oxidation is favourably influenced by higher temperatures, was also confirmed by experiments conducted at the Botanical Gardens in

Victoria. Before the beans that had been fermented in the ordinary manner had cooled down after the first day of sun-drying, they were packed into a cask and covered. On the second day these beans, which were still warm, over 30° C. (86° F.), were again spread out in the sun, and before sunset again treated in a similar manner. In one of the experiments the cacao was damped on the third and fourth day by sprinkling it with water in order to prevent the drying from being too rapid, and to give the oxygen an opportunity of acting on the beans for a longer time at a higher temperature. The cacao thus obtained was tested in Germany and found to be better than that dried in the ordinary way.[1] Estimation of the soluble astringent substances confirmed the fact that, especially in the case of the last experiment, the process of oxidation was more advanced. Although this cacao did not satisfy all the demands that might be made, it nevertheless confirmed the correctness of my assumption, that the oxidation of the astringent substances is an essential point in cacao fermentation.

I had arrived at this point in my studies, when I returned to Germany in 1900. Before continuing my investigations in the Tropics, I thought it advisable to determine the most favourable conditions for the oxidation of cacao by experiments conducted in Germany.

[1] Dr. A. Schulte im Hofe: "Zur Kakao-Fermentation," *Der Tropenpflanzer*, 1901, p. 225.

Studies on Cacao Fermentation conducted in Germany.

Dr. H. Salzmann, of Berlin, kindly placed his laboratory, and Messrs. Theodor Hildebrand and Son in Berlin any quantity or quality of cacao I might desire, at my disposal, for the purpose of this investigation. I had unfortunately neglected to bring some freshly dried, unfermented beans with me. However, I found among the different samples of cacao some beans in which the process of oxidation had only slightly advanced. In some of the samples I even found beans on which acetic ferments had not yet acted. I shall refer to these later.

Carrying out these experiments in Germany had the great advantage that the practical value of the results could always be immediately tested by experts; this enabled one to judge which direction further experiments should take. This essential assistance was given me by Messrs. Theodor Hildebrand and Son.

As space prevents me from giving a detailed account of all the extensive laboratory experiments that I carried out, and the results they yielded, I shall restrict myself to stating the main results arrived at. In the first place, I again proved that a higher temperature accelerates the process of oxidation, and that the latter takes place more rapidly at 50° to 60° C. (122° to 140° F.) than at 30° to 40° C. (86° to

104° F.), but that in the latter case the cacao assumes a better colour.

To determine what exact percentage of moisture the beans should contain was a difficult matter to decide. It must be clear to anyone having even only a slight knowledge of bacteriology, that we are here dealing with conditions exceedingly favourable to the growth of micro-organisms, this being particularly the case at temperatures ranging from 30° to 50° C. (86° to 122° F.). The object of my experiments in this connection was, from the first, to determine the lowest possible degree of moisture at which oxidation was still possible; for, the lower the amount of water present, the less favourable are the conditions for the growth of micro-organisms. On the other hand, I found that the lower the amount of humidity, the slower the process of oxidation became. On the plantations it is necessary to dry the acidified cacao even if only to help the air to obtain access to the interior of the beans. At a percentage of humidity amounting to 20 per cent., the conditions for oxidation to occur were still fairly favourable, but butyric acid fermentation and the development of moulds still occurred very frequently. The latter were practically excluded when the percentage of humidity decreased to 15 per cent.

Having determined the changes taking place in the beans by means of laboratory experiments, I now experimented with larger quantities of cacao in the chocolate factory of Messrs. Theodor Hildebrand and Son. These experiments showed that butyric acid fermentation and the development of moulds were unavoidable when the percentage of moisture was 20 per cent., and hence that oxidation must be carried out at a lower percentage of humidity than that.

I also succeeded in these experiments, as I had done in those conducted in the laboratory, in reducing to a marked degree the bitter, astringent taste so common to insufficiently oxidized beans cured on the plantations, thereby improving the flavour of the beans, and increasing their market value.

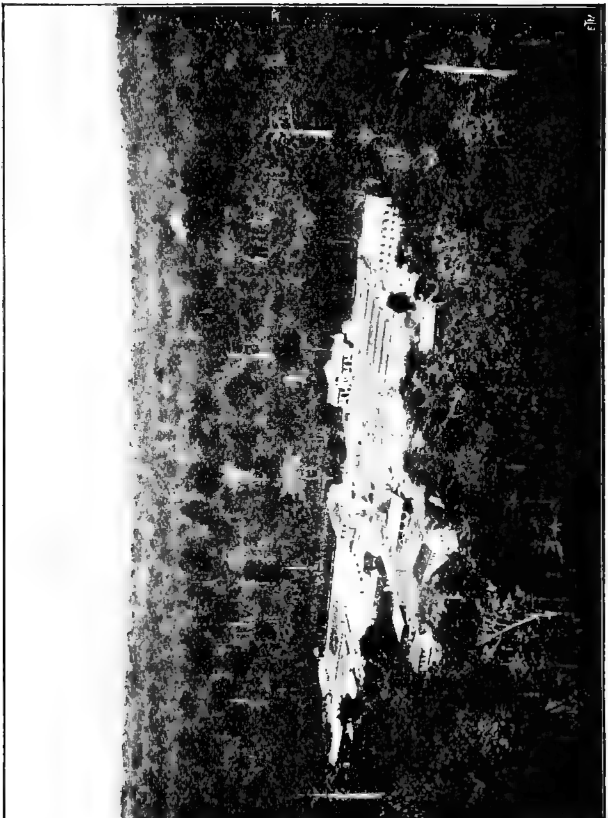
I take this opportunity of expressing my thanks to Mr. Dresel for his valuable assistance in the experiments conducted at Messrs. Hildebrand's factory, for although the object of my experiments and investigations was in the main to obtain practical results, these can only be obtained when the scientist and the practical man work hand in hand. Hence, as was also the case in previous experiments, I have found it necessary, when investigating for industrial reasons into the question of fermentation, to obtain a personal knowledge of the practical side of the matter, and to do this I undertook technical practical work for some time both in breweries and distilleries.

My studies, which started in the Cameroons, and continued in Germany, were thus completed for the time being. By means of them I had proved that cacao fermentation falls into two sections; the first is the process of alcoholic and acetic fermentation; the second that of oxidation, the former having to precede the latter. I do not wish to maintain that the presence of acid is absolutely necessary for the oxidation of the acrid substances to take place, but that only under such circumstances can a good, marketable cacao be produced. Further, I proved that before starting the oxidation process, the beans should, for practical reasons, be partially dried, and that by maintaining a percentage of 15 per cent. moisture or less, the process of oxidation can be extended over a more prolonged period without running the risk of generating butyric acid ferments or the development of moulds; and further, that at higher temperatures, such as 50° to 60° C. (122° to 140° F.), the process of oxidation proceeds more rapidly than at 30° to 40° C. (86° to 104° F.), but that the colour remains a better one at the lower temperature. My next object was to apply my results in a practical way to cacao cured on the estates. Unfortunately the planters in the Cameroons to whom I applied refused to entertain my suggestions, and the Colonial Office also refused to allow me to introduce this method to the Botanical Gardens out there.

I attribute this attitude on the part of the planters and the Colonial Office to the influence of the leading members of the Committee of Colonial Agriculture (Kolonialwirtschaftlichen Komitee). Apparently there was an impression that only such questions of tropical agriculture should be countenanced as had obtained the approval of the Committee, and that the least that could be done in connection with any other investigations and endeavours was to place difficulties in the way. Under these circumstances I was particularly pleased to gain the support of Mr. Monteiro de Mendonça of Lisbon, the proprietor of the well-known cacao plantation, "Boa Entrada" in San Thomé. Just as some years earlier, when engaged in studying the cultivation and manufacture of indigo and tea, I was most kindly received by the English in India, so, on this occasion, it was by the Portuguese. Thanks to this I commenced work in San Thomé in 1903, and the conclusions I had arrived at as the result of the investigations I carried out in 1899 in the Cameroons, and continued in Germany, were fully confirmed.

Researches on Cacao Fermentation at San Thomé.

To enable me to carry out the oxidation process, two oxidation chambers were erected in San Thomé, fitted with a heating apparatus, by means of which the temperature in both the chambers, either singly or together, could, when desired, be raised to, or maintained at,

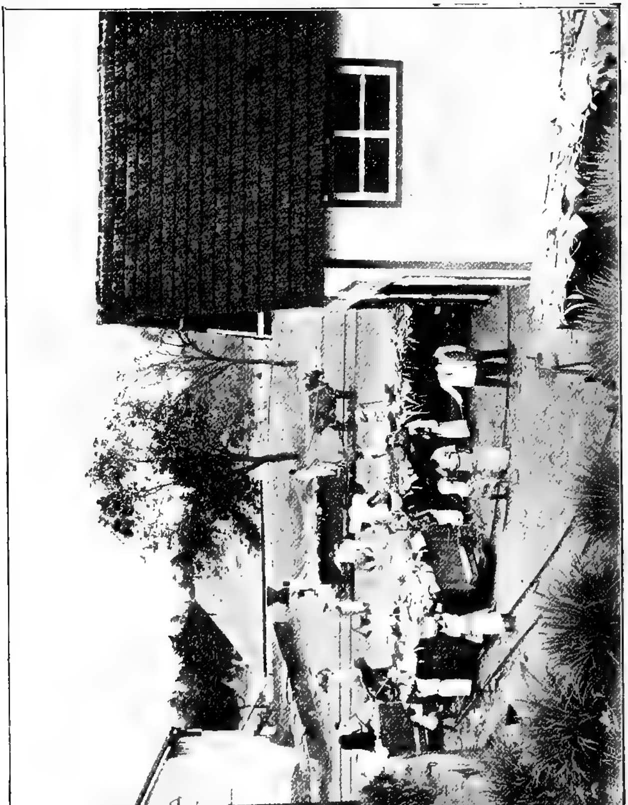


The Buildings on a large Cacao Estate.

Residence, Drying-houses, &c., on Boa Entrada Estate, San Thomé.

any desired degree of heat. These chambers, which were separated by a partition or wall, measured 5·50 m. long, by 1·60 m. wide and 1·50 m. high (say 18 ft. long by 5 ft. 3 in. wide and 5 ft. high). From a furnace at one end of the chambers the heated air was conducted by pipes along the side walls through a tunnel lying at a lower level. At the end opposite the furnace there were folding doors, and a set of 60 cm. (21 in.) gauge rails led into each chamber. The chambers were each capable of accommodating 3 trolleys, fitted with 10 trays each, or 6 smaller trolleys with 5 trays each. The cacao was spread out on the trays in layers about 10 cm. (4 in.) deep, and each chamber took about 1,500 kg. (say 1½ tons) cacao.

The fermentation was carried out by the following method: Immediately after being gathered, the pods were broken open and the contents removed and subjected to an alcoholic and acetic fermentation in boxes (see illustration, p. 36) in the usual way. This fermentation was assisted by transferring the beans each day from one box to another. As soon as the bluish-violet colour of the cotyledons had turned to a reddish-violet, and the beans had absorbed all the fluid possible, they were dried in the sun in the usual way until they only contained 15 per cent. of moisture. Then the beans were spread on the trays in layers 10 cm. (4 in.) thick, the trays placed on the



Cars of Cacao, covered with Banana Leaves, arriving at the Fermenting or Sweating House (San Thomé).

trolleys and the latter run into the chambers, in which the temperature was maintained at between 40° to 50° C. (104° to 122° F.). As there was no great draught, the expenditure of fue was comparatively small.

This oxidation process was allowed to continue until the reddish-violet colour of the beans had changed to brown. The trolleys were then run out of the chambers and the drying of the beans completed, which took but a short time.

In order to ascertain whether, in the case of the freshly gathered cacao also, there was any disadvantage in allowing the moisture to exceed 15 per cent., some beans containing 20 per cent. of moisture were subjected to a precisely similar method of oxidation. Here again, as in the case of the experiments in Germany, the formation of moulds, &c., occurred; also, when on a subsequent occasion a few basketfuls of beans, with 25 per cent. of moisture, were emptied on to one of the trays by mistake, as soon as the oxidation process was completed, the difference was immediately detected, for these beans were covered with mould, whilst the others were perfectly free of it. It is therefore evident, that the moment one is working with beans containing too much moisture, the fact can at once be detected, and it thus becomes an easy matter for the planter to determine whether the work is being done properly or not. I further noticed that when the oxidation process had been properly carried out, the beans were covered by a delicate white efflorescence. This may serve as a means of recognizing whether the cacao has been treated in the above manner or not.

I remarked also that the time required for the change in colour from reddish-violet to brown varied in different beans. As is well known, the same observation has been made in the case of beans treated by the usual methods. This peculiarity probably depends on the varying degrees of maturity or ripeness of the pods themselves, and possibly this is the reason why some planters believe that it is advisable to allow the fruit to continue to ripen in the pod for some time after being picked.

The flavour of each lot of cured cacao was tested after being dried. For this purpose tasting samples were prepared exactly in the same manner as is done in the chocolate factories when testing samples of cacao to be offered for sale. A sample of cacao was roasted, ground, and, for want of a small rolling machine, crushed to a fine powder in a mortar. Exact portions of this powder were weighed off, and boiled in definite and equal quantities of water, and then tested as to colour, aroma and taste. In my first experiments I took samples from the same batch on each day of the oxidation process, and dried them.

The test showed that if the oxidation process was prolonged until all the beans had turned brown, the taste was less full and there was less aroma than in samples containing some of the reddish-violet beans mixed with the brown. In this case again there is an analogy with what is met with in the case of tea. Freshly gathered tea-leaves do not form a uniform mixture, the leaf-buds oxidize more rapidly than the young leaves, and these again more rapidly than the older leaves. It is impossible to oxidize all the different types of leaves separately; and though, it is true, an attempt is made to separate the leaf-buds by sifting after the leaves have been rolled, and to oxidize the two sets separately, even then a mixture of leaves of varying ages remains. Continue to oxidize the tea until all the leaves turn to a yellow coppery colour, and you will find that a large proportion would be superoxidized, with the result that tea so prepared lost considerably in its fulness of flavour and aroma, and it is for this reason that oxidation is stopped before all the leaves have turned yellow. After I had proved that this irregularity in oxidation also occurred with cacao beans, the process was checked as soon as the major portion of the beans had turned brown. It now only remains for the planter to learn by experience when the most favourable stage in the fermentation process has been reached, for this stage will be found to vary according to the different districts in which the cacao is grown, the variety of beans treated, and the method of gathering. It will, however, be necessary for planters to test the different lots as to taste, &c., in the same way as the tea-planter does.

The time required for oxidation depends on the temperature employed and the variety of the bean to be cured. The most suitable temperature to produce a good quality is from 40° to 45° C. (104° to 113° F.). I do not mention any definite time, as I do not wish to encourage planters to work by rule of thumb; the best degree of oxidation and the test by tasting can alone determine this point. At Boa Entrada I used to ferment the beans from two to three days.

The essential principle underlying the method I introduced at Boa Entrada is not based on the oxidation chambers, but on the fact that what is known as cacao fermentation consists of two essentially different processes. The first leads to the acidification of the beans, which object is best attained by exposing the freshly gathered beans to conditions under which the sugar contained in the fruit pulp adhering to the beans becomes converted into alcohol, and the latter is then converted into acetic acid. We must, therefore, provide conditions favourable to alcoholic and acetic fermentation. I shall later on show that this can be done in a more practical manner than by the usual method of sweating boxes at present in use. As soon as the acetic acid has penetrated sufficiently into the cotyledons, fermentation should be interrupted, as otherwise super-acidification may supervene.

The object of the second process is to produce oxidation of the astringent substances contained in the beans, in order to remove the unpleasant, acrid, bitter taste, and simultaneously to develop the aroma, &c. Since an increased temperature favours this process, the beans must be warmed. Further, the advent of air to the interior of the beans must be facilitated; this is achieved by drying the latter.

From what has been said above, it will probably be sufficiently plain that this division of the so-called cacao fermentation into two sections, *viz.*, an alcoholic and acetic acid fermentation and a subsequent oxidation, is something quite new, and rests on a scientific basis. It will also be seen that the preparation of a good quality cacao is based on a correct carrying out of both processes.

Some gentlemen, who visited the Boa Entrada estate in San Thomé after I had introduced this method of oxidizing the dried beans at higher temperatures, criticized the process as being empirical and too troublesome. This merely proves that they looked upon the oxidation chambers erected there as an essential part of the method, but did not recognize the real object of them, viz., to bring about the oxidation of the partly dried beans at higher temperatures. At the same time they admitted that cacao treated by this process was of better quality.

I have already pointed out that by the fermentation and drying methods at present employed, satisfactory results are obtained empirically in some cases, and that quite good cacao can be made from beans having lighter coloured nibs or cotyledons, *i.e.*, such as contain a smaller amount of bitter substances. I propose now to enter more fully into the methods of gathering, fermenting, drying and dispatching the cacao that are usually adopted at the present time so far as they are known to me, and shall also point out how the method I have proposed might perhaps be used without necessitating any great changes being made. Finally, I shall suggest how in starting a new plant or cacao curing installation the method of oxidation I have proposed may best be taken into consideration.

The Gathering of the Cacao.

On smaller plantations it is possible to pick cacao every week, and the pods will then be found to have reached an approximately equal stage of maturity or ripeness, but on larger plantations this cannot be done. In practice, therefore, one can never be in a position to treat pods of the same degree of maturity, and when the pods become over ripe the beans start to germinate inside the husk. They do not therefore remain at the same stage of ripeness for any length of time, as is the case with some other kinds of fruit. Hence even if the beans are allowed to continue to ripen after the pods are gathered, as is done in some isolated cases, no uniform product is obtained. This fact must be allowed for just as it has to be in the case of tea.

The Fermentation of Cacao.

On all plantations, even those worked on the most primitive lines and owned by natives, the beans are piled into heaps or placed in casks, or other receptacles, or special fermentation boxes, as soon as the husk of the pod has been removed. In many cases the natives are in the habit of leaving the beans to their own devices without any mixing, or turning over when being fermented. I have had the opportunity on several occasions of observing in such cases how the acetic fermentation has acted in a satisfactory manner in the upper or outer layers, whilst deeper down the beans have not yet passed beyond the stage of alcoholic fermentation, and that indeed even this has not penetrated into the centre of the beans. The beans thus fermented were then dried, but it must be obvious to anybody that an even sample or break cannot possibly be obtained by such a process; you had in fact a mere mixture of brown, violet and slate-coloured beans. The latter are often described in the trade as "unripe"; to my mind a perfectly false designation, for they are beans that have been completely excluded from fermentation.

In all better managed plantations the beans are turned over by being shovelled or emptied from one box into another whilst the fermentation process is going on. In deciding when this should be done the planter has to judge how long should be allowed before changing the cacao from one box to the other, whether every day or every other day, and what temperature should be maintained in the boxes; in either case the decisions arrived at are purely empirical.

In the Cameroons it was customary at first to allow the cacao to sweat from three to four days, but now the period has been prolonged. In San Thomé the methods employed are more advanced, and the period of fermentation (or sweating) is not always regulated by time, but often by the appearance of the bean, but even here the fermentation is usually allowed to continue too long.[1]

As I have already pointed out, fermentation

[1] I cannot altogether agree with this; at any rate the San Thomé cacao I am in the habit of valuing does not give me the idea of being over-fermented.—H. H. S.

should only be continued up to when the bluish-violet colour of the cotyledons turns to a reddish-violet and the bean has, by absorption, become full of fluid. When only slightly acidified beans are insufficiently oxidized, a harsh, bitter cacao is produced, and it was probably to render the taste milder that longer periods of fermentation were introduced; for during protracted fermentation, especially when occurring at the higher temperatures, oxidation takes place as well. The beans, however, become over-acidified and the cacao thus obtained, although milder in flavour, has a sour taste. Should butyric acid fermentation be added on the top of this, then the sour taste is diminished, but the cacao acquires a rancid flavour, becomes rough to the palate, and darkens in colour. In both cases the aroma is lost. By employing the methods commonly used, therefore, unless the conditions happen to be particularly favourable, either a harsh and bitter,[1] or a sour or rancid cacao is obtained.

The simplest, cheapest, and most certain method of fermentation is that obtained by the use of floors (*tennen-fermentation*). Here the cacao beans are emptied on to covered floors in layers, varying in depth according to the temperature or weather conditions, and turned over at least once a day. In this case

[1] Possibly this is what the trade calls "ham-my" cacao.—H. H. S.

also exact directions suitable for all times of the year and for all districts cannot be given.

The saccharine juice contained in the fruit pulp adhering to the outside of the beans soon commences to undergo alcoholic fermentation owing to the yeast cells that are naturally distributed about them so widely, and as this proceeds the yeast cells quickly multiply. Should the beans only become slowly heated, this is almost invariably an indication that the alcoholic fermentation is only proceeding slowly on account of a lack of yeast cells. Should a batch of well fermenting cacao be at hand, the fermentation of a new batch may be accelerated by collecting the fermenting saccharine juice from this well fermented lot and mixing it with the freshly gathered beans, but this will only be necessary on very rare occasions. A pure yeast culture is at the most of merely theoretical interest,[1] and has no influence on the quality of the cacao. After all, it is only the amount of alcohol necessary for acetic acid fermentation that is required, and for this purpose the yeast cells, which as a rule are present naturally, almost invariably suffice.

On the second or third day after the beans have been placed to sweat, acetic fermentation sets in, causing a further rise of temperature. If the latter rises beyond 50° C. (122° F.), the beans are spread in thinner layers, whilst the

[1] See the other essays on this point.—H. H. S.

acetic acid formation may be increased by using juice flowing from beans already undergoing acetic fermentation.

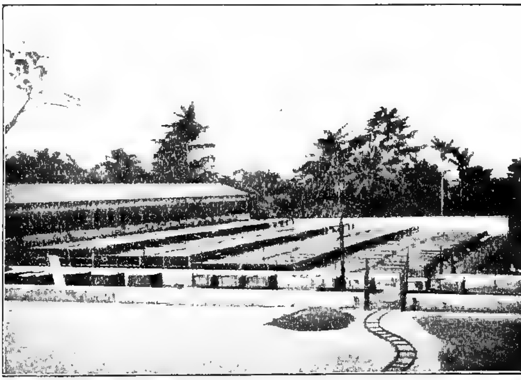
The work on fermentation floors resembles that in a malt factory, except that in the case of cacao the aim is to acidify the produce, and higher temperatures are employed, whilst on malting floors the barley is meant to germinate. As during the sweating process an acid fluid comes away from the beans, this fact must be taken into account, as owing to it the floor should consist of some material that is not affected by acids, and hence cement and lime should, as far as possible, be avoided in its construction.[1]

If only small quantities of cacao have to be dealt with, a wooden trough of suitable dimensions will suffice, and the beans can be turned about by shovelling the cacao from one end of the trough to the other, for one end should always be kept free, and in this way the cacao becomes easily aerated.

At first on the plantations in the Cameroons the cacao was washed after fermentation had been completed, whereby the remains of fruit pulp adhering to the beans were removed. As, in chocolate factories, the shell is removed from the kernel, in any case it is immaterial whether some of the fruit pulp still adheres or

[1] Wood, and especially some native woods, are far preferable, especially as the vinegar or juice tends to pickle and preserve it for a long time.—H. H. S.

not.[1] This fact was soon recognized, and now the beans are not washed but generally dried immediately after fermentation. Only in isolated cases, as when working to produce a



Drying Cacao on Trays on Boa Entrada Estate, San Thomé.

Note how each tier of trays runs out, one under and in front of the other. Each of these can be pushed back in the same way, one under the other, until they reach the roofing seen in the rear.

special quality for market, is washing still practised.[2]

Drying the Cacao.

The process of drying may be a simple or a complicated one, depending on the amount of

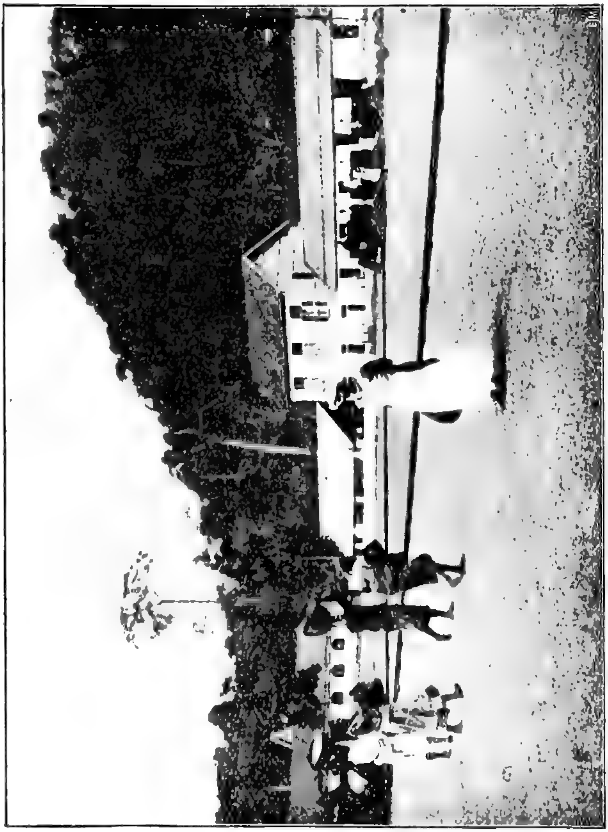
[1] Except that it spoils the appearance of the beans from a selling point of view.—H. H. S.

[2] Ceylon cacao is the typical growth for washed beans. —H. H. S.

rain falling during the process. The most primitive method of drying is accomplished by spreading the beans out on small trays which are placed in the sun during the daytime, and brought in under cover at night or when it rains. In prolonged rainy weather the cacao is sometimes placed on tin sheets or metal plates (*blechplatten*) which are warmed by fire placed underneath them, and is thus dried.[1] In the case of larger crops, this method would waste too much time. Where sun-drying is possible cement or stone floors in the open air are used. This method is an extremely practical one when continuously sunny weather prevails, or, at the most, only passing showers have to be avoided, but not when several successive days of rain occur frequently. The reasons why this is so I have given on p. 85.

To avoid the injurious influence of rainy weather, and still more, to avoid the beans having to remain in heaps for prolonged periods when only slightly dried, large trays were constructed to run on rails, capable of being rapidly moved under cover when it started to rain or at night. A further advance was arrived at when arrangements were made to place three or four trays one over the other. In order that the drying process might be continued on these trays during continuously wet weather, the shed was so constructed that the

[1] I cannot understand in such cases how the beans do not get scorched or burnt.—H. H. S.



CEMENTED BOUCANS OR DRYING AREAS IN SAN THOMÉ, WITH CACAO BEANS BEING SPREAD OUT TO DRY.

The term "buccaneer" was derived from Boucan. It was applied to the men who dried wild-cattle meat on the Boucans (Fr., *boucaner* = to smoke meat) in Hayti, whom Henry Morgan employed because they were so clever with rifle and knife, and always ready to fight and sack a town.

side walls could be easily made air-tight, and then heat was brought to the produce from a furnace at the other end of the shed by passing it, *i.e.*, the heat, through a pipe or pipes placed under the lowest trays. Such a drying shed was first erected in the Cameroons on the Kriegsschiffhafen plantation.

In other countries large stationary platforms (known as cacao-house floors), capable of being used for sun or artificial drying are erected. A movable roof renders sun-drying possible, whilst heating pipes under the floor do the same when artificial drying is needed. A drying-house constructed according to this, the Trinidad (W.I.) system, is to be found in the Botanical Gardens in the Cameroons. It has, however, proved a complete failure owing probably to those using it misunderstanding some detail in the heating, or having omitted its use.[1] At a subsequent date drying-houses were built on some of the estates in the Cameroons, fitted with the movable trays to be met with in the Trinidad drying-houses.

In cacao growing countries where the main crop coincides with the rainy season, sun-drying is practically out of the question, and artificial drying has therefore to be exclusively

[1] Such a system was not considered to have proved successful in Trinidad (W.I.), at any rate not on the San Salvador estate, one reason being that the apertures got choked up and so prevented the warm air getting at the beans.—H. H. S.

resorted to.[1] In the Cameroons an attempt was made to overcome this difficulty, first by using the Mayfarth dryer already mentioned, and later the Guardiola drying drums. A serious drawback to the latter was the fact that some kind of mechanical driving power is required, although this is, of course, of less importance where the drying-houses can be constructed in such a manner that water power may be used. A further drawback is that the beans have to be partially dried before they are placed in the drums or they will adhere in clumps. A third drawback is that by the time the process is completed the beans are apt to break, or at least their shells crack.[2]

In the early days in San Thomé, large drying-houses, or, to be more accurate, drying-barns, 5 to 7 m. (16 to 23 ft.) high, were erected. Small trays, which could be easily handled by one man, were placed in these, one over the other, on ledges at intervals of 20 cm. (8 in.), whilst hot air from a stove was conducted through pipes to the floor of the barn ; but the whole method was very troublesome and complicated, besides which the beans

[1] I must, however, point out that in the same country the rainy periods and the amount of rainfall frequently vary to such an extent (this is the case, for instance, in the Cameroons and San Thomé) that sun-drying may be quite possible in one district, at least for the greater part of the crop, and absolutely impossible in another.

[2] This is not so now, I am told, at any rate not with the "Gordon" drier.—H. H. S.

dried very unevenly and the cost of fuel was comparatively great. Probably it is for these reasons that such drying-barns are not more extensively used.

In 1903 the method of drying the cacao on heated stone platforms was introduced on several plantations in San Thomé. Heated air from a furnace is conducted under a platform 5 m. (16 ft.) long by 2 m. (6 ft. 6 in.) wide, made with the sides raised about 25 cm. (10 in.). The cacao is dried on these platforms in fairly thick layers, being frequently turned during the process. I have been unable to find out any particulars as to the results obtained by such a method.

When in Fernando Po in 1899, I saw on three of the plantations a primitive method of drying by means of tunnels,[1] 10 m. (32 ft. 9 in.) long by 2 m. (6 ft. 6 in.) wide, and 1·75 m. (5 ft. 9 in.) high. These were heated by two pipes running along the floor through which the heated air was conducted from a furnace at one end of the tunnel. In each side-wall there are ten doors, each 1 m. (3 ft. 3 in.) wide; through each of these, eight trays can be pushed and placed on ledges, one over the other. The total area of the trays is 150 sq. m. (180 sq. yd.). Since there is but very little circulation of air in these tunnels, the distribution of heat is very unequal. The

[1] Some think the latest "tunnel" systems will be freely adopted in the future.—H. H. S.

time required for completing the process was stated to be two days.[1]

Consul Spengler, now in Lisbon, but formerly manager of the Monte coffee plantation in San Thomé, introduced a modern type of tunnel-drying some years ago. Independently, and without knowing of this method, I also worked out a scheme of tunnel-drying, which differs from that of Spengler in that a ventilator is attached to one end of the tunnel, and the construction is as follows: Two tunnels, divided by a middle wall, are 20 m. (65 ft. 6 in.) long, 1·5 m. (4 ft. 11 in.) wide, and 1·75 m. (5 ft. 9 in.) high. A 20-cm. or 8-in. gauge rail runs down the centre of each tunnel, the latter being closed at the ends by double doors. In a convenient position at one end of the tunnels is a heating apparatus from which the hot air is driven through the ventilators into the separate tunnels. In order to increase the draught, a flue communicates with the other end of each tunnel, just as in Spengler's method, and this draws off the hot air. Trays filled with cacao are placed on small trolleys and these are run into the tunnels, and as soon as the cacao on the front trolleys are sufficiently dried, these are run out at the other end, where the hot air enters, and the trolleys on which the cacao is not yet sufficiently dry

[1] This is on the principle of the American fruit dryers, and cannot prove a success unless a fan, or other means for providing a forced draught, is supplied.—H. H. S.

are then pushed towards the hot end and a corresponding number of trolleys, with a fresh batch of beans, take their place. Thus the warm dry air first passes over the already partially dried beans and then over the moist ones, ultimately escaping through the flue. The warm air is thus utilized to its utmost extent, and at the same time drying can be carried on rapidly and at a comparatively low temperature. The small amount of motive power required to drive the ventilators can be supplied on most plantations by small water turbines.

Whatever system may be selected, the main thing always is to use the lowest possible temperature for drying, but, above all, any further acidification, or the formation of butyric acid and the development of moulds, must be avoided.

The Oxidation of the Cacao.

Nowadays, industries in which the material used has to be fermented are all worked on a scientific basis. Nevertheless, long practical experience is needed, as, for instance, to produce a good quality of malt or to brew good beer. Such trades require special scientific institutes to which the manufacturers can turn at any time for advice when unexpected results or irregularities occur in their work. Unfortunately, as regards the treatment of cacao, such an establishment is, at present, practically non-existent. The methods in use, therefore, are empirical, and under such circumstances it is a little doubtful whether one ought to publish anything about a scientific method for carrying out the work, and indicate how the oxidation process I have described, may be substituted for the methods of fermenting and drying the beans at present in general use, as by doing so one runs the risk of the essential principles of the process not being sufficiently understood, and this might prevent the work from being properly carried out. If, therefore, in spite of this, I still give some directions, I only do so in order that some of the planters may be enabled to carry out the necessary experiments. I should, however, like to warn my readers against being over-hasty in arriving at conclusions from the results they obtain if these do not work out exactly as they desired or expected. What should be done is to introduce the process on one plantation in each colony, a scientific expert specially trained to the work being engaged to assist, and only when these two, the scientist and the planter, together have thoroughly mastered the process, to then introduce it generally to the other estates. In order that advice might be at hand when required, an expert as described above should be permanently appointed to, and reside in the colony, with a suitably equipped scientific institute placed at his disposal, in which further investigations and experiments could be carried out and checked.

On the plantations in Samoa, Ceylon, and other countries growing a similar variety of cacao, drying on floors suffices for the production of quite a good type of produce. This particular variety may only be slightly acidified and requires a shorter time for oxidation than is necessary elsewhere, say in the Cameroons, for instance. Above all, the cacao must not be allowed to remain in heaps for several days, if it is only partially dried. As soon as the beans have reached a stage where they only contain about 15 per cent. of moisture, the still warm cacao must be piled together in heaps, or put into boxes. The beans need only be kept warm for a comparatively short time in order to reach the desired degree of oxidation.

I have several times handled Samoa cacao, in which the fine aromatic bitter taste had been completely lost owing to over acidification or oxidation. Just as it is exceedingly important to preserve the fine aroma or flavour of teas grown at higher altitudes, since possessing this enables them to sell at prices higher than those realized by the stronger teas grown in the plains, so in the case of Samoa cacao, and others of a similar kind, it is important to fully develop and preserve the pleasant aromatic taste they contain, for just as the finer qualities of tea are mixed with the stronger sorts in order to obtain a palatable marketable article, so are these finer quality cacaos used for blending with other kinds of a stronger flavour in order to produce a palatable and marketable chocolate. It is, therefore, exceedingly important in treating this type of bean to exactly determine the most suitable degree of acidification and oxidation it should undergo in the curing. Until this has been done one is less likely to make a mistake by employing too short a period of fermentation and oxidation for the bean than by making it too long.[1]

In the Cameroons and other places growing similar types of cacao it is hardly possible to obtain a sufficient degree of oxidation by the use of drying floors. A better result will be obtained if, in using the Guardiola method, the drying is checked when the moisture in the beans is reduced to 20 per cent., stopping it when 15 per cent. is reached.[2]

[1] Does Dr. Schulte recognize that Ceylon and Samoa cacao are obtained from *T. cacao* var. *criollo*, and the stronger flavoured kinds from *T. cacao* var. *forastero* and that the first can never altogether become like the second, and only partially so through hybridization? The cacao now coming to market from these centres is often of a darker character, showing that the original *criollo* strain is being lost; such changes, however, are not due to the way in which the beans are cured. —H. H. S.

[2] It will at first be somewhat difficult for the planter to estimate the degree of moisture; but after a little practice he will find this quite easy. In order to recognize whether the correct degree of moisture has been reached, it is only necessary to take the cold bean in one's hand and press it to see the moisture content.

The still warm beans must then at once be transferred to boxes or made up into large heaps, to prevent the beans from cooling, and when this is done the cacao should be protected from cooling down too rapidly. In order that the heat may be retained as long as possible, it would, perhaps, be best to postpone disturbing the heaps until the second day, when they may be turned over with shovels, as doing so lessens the danger of over oxidation owing to the cooling of the beans, provided that oxidation has not already set in to any considerable extent in the drying drum.

The process of oxidation at moderately high temperatures may be more prolonged without running too great a risk, when the drying is carried out in drying-houses on two trays placed one over the other, and, as is done when malting, the partially dried cacao on the upper tray is allowed to fall through to the lower one to complete the drying process. As soon as the cacao is found to contain only 15 per cent. of moisture, it is spread out so as to form a layer about 15 to 20 cm. (6 to 8 in.) deep, and as far as possible the temperature is kept at 40° to 45° C. (104° to 113° F.). Doing this enables one to maintain an even temperature

Again, as soon as the amount of moisture in the beans is excessive, they go mouldy during the process of oxidation: a sufficient indication of their containing too much moisture.

at the same level as long as desired, whereby adequate oxidation becomes possible. As soon as the majority of the beans have turned brown in their interior the drying is complete.

The heated platforms already mentioned are very well adapted for carrying out the process of oxidation. Cacao dried in other ways can also be easily raised to the required temperature. If it is inconvenient to leave the cacao on the platform until it is sufficiently oxidized, it can be placed in suitable boxes, and, should it then cool down too rapidly, be returned to the platform to be warmed up again, as this also brings about a sufficient degree of oxidation.

The above directions should prove sufficient to render it possible for the planter to use such apparatus as may be at his disposal for experimental purposes, but they will not suffice when the entire crop is to be submitted to the process of oxidation. In that case it will be necessary to erect a special oxidation-house. This is best done as follows :—

In the centre of a room 2 m. to 2¼ m. high placed level with the ground, either a stone platform that can be heated, such as I have already described, or a perforated metal floor over hot pipes is erected. On this platform or metal[1] floor the partially dried beans are poured to a height of about 25 cm. (10 in.) and their temperature raised to the required

[1] I would vote against a metal floor.—H. H. S.

height. Along the walls on both sides of the platform run boxes, whose outer walls are fixed, the inner and dividing walls consisting of loose boards fitting into grooves, so that they can be adjusted to any height required. As soon as the cacao has reached a temperature of 45° C. (113° F.) it is poured into the boxes and covered over. The next day it is transferred to the next box, and this process is continued until the desired degree of oxidation has been attained. Should the temperature of the beans sink to about 30° C. (86° F.) before the process of oxidation is completed, the cacao is warmed up again. But since the temperature of this oxidation-house is fairly high, there is but little risk of the beans becoming too cool.

The size of such an oxidation-house will naturally depend on the quantity of cacao to be cured; a good guide is to calculate 1 cubic metre (35·315 cub. ft.) to about 500 kilos of cacao (1,100 lb.). Hence a platform 2 m. (6 ft. 6 in.) wide by 5 m. (16 ft. 3 in.) long, able to take a layer of cacao 20 to 25 cm. (8 to 10 in.) in depth, will serve to warm 1,000 to 1,250 kilos (19 to 24½ cwt.), for which oxidation boxes of about 2 to 2½ cubic metres (about 70 to 87·5 cub. ft.) capacity will be needed.

Should a tunnel-drying plant be available, it would be a convenience to build the oxidation-house in such a way that the trolleys can be run straight into it from the drying tunnel. For this purpose the oxidation-house should be so arranged that the rails run along the narrower space on one side of the platform, whilst the oxidation boxes are arranged along the other and wider one.

When oxidation has been completed the cacao must be completely dried; since, however, there is but little moisture left to be removed, the process can be rapidly carried out, and this can be done, if necessary, in the oxidation-house.

Tasting the Cacao.

As has already been stated, every tea-planter is in the habit of daily tasting the tea, after it has been prepared ready for shipment, in order to make certain of its quality and also to ascertain whether its preparation has been properly carried out. Experience is, of course, required, but for cacao it need not be as great as that of the tea taster, who has to estimate the approximate market value of the tea. It will suffice if the cacao planter can determine how the quality of his cacao compares with that previously shipped, as well as with those of neighbouring plantations; this being so he should test his produce in a similar manner to the tea-planter. In the case of tea the matter is somewhat more complicated owing to its being separated into different qualities by sifting, whereas in the case of cacao only one sample requires to be tested. In the case of tea, however, a tasting sample is easily prepared; 120 c.c. of freshly boiling water being poured on to 3 grm. of tea, and allowed to stand for four minutes, after which the infusion is poured off the leaves; whilst compared to this the preparation of a sample of beans for tasting is more troublesome. On p. 98 I mentioned how I introduced the tasting test for cacao in San Thomé. The apparatus used was cheap, but the beans had to be pounded (*zerreiben*) up in a mortar and this was a very troublesome process.[1] I should strongly advise the use of a small rolling machine, such as is used for this purpose in chocolate factories. In preparing the cacao for tasting, 50 grm. of beans are roasted in a small drum, such as is generally used for small quantities of cacao. It will be found that the roasting can be most conveniently done on plantations over a small petroleum stove. It is very difficult to make a definite statement as to how long and at what temperature the cacao should be roasted; this must be learnt by experience. As a rough

[1] And yet on many of the estates in Trinidad we often had to pound up each morning, before breakfast, the beans to be used as chocolate during the day. This was done in the well-known wooden mortar which stands on the ground, whilst the tall pestle or rammer is worked by the operator, standing, in the same way as the men in London and elsewhere use a stamper to lay flag-stones, wooden pavements, or cobbles.—H. H. S.

guide, I may say that the roasting should be stopped when the shells tend to spit or crackle (*platzen*), which may be recognized by a crackling sound. After roasting, the shells must be removed, and after cooling the beans are broken up in a coffee-mill to about the size of buck-shot ; these are then rubbed into a fine powder by being passed through a machine with rollers. Six grammes of this fine powder are mixed with 100 c.c. of water and then brought to the boil.[1] The colour of the infusion, the taste, and aroma are the points by which the quality is judged.

The Export of the Beans.

It would be an ideal state of affairs if a plantation could produce cacao in bulk of uniformly good appearance and flavour all the year round. But this is as unlikely to occur in the case of cacao as it is with any other plantation product. The great value attached by the trade to the proper packing of their purchases and to the goods being graded according to quality, &c., is seen to a very marked degree in the case of indigo. From each plantation in Bengal samples of each day's product, marked with consecutive numbers, are sent after the crop to the broker in Calcutta, and the entire output is packed according to his instructions.

Tea is also packed according to quality,

[1] Half water and half milk may also be used.

which is marked on the outside of each case. A sample of each quality is sent to the broker and a similar sample retained by the planter.

Now, although on a well-managed cacao plantation, provided with modern machinery, there can never be such great differences in the quality of the produce as occur in the case of indigo and tea, far more attention should still be paid to this point when shipping the cacao than is done at present. To-day the demand is for large parcels of uniform quality, so that all shipments should be as large as possible. It is not, therefore, advisable to put each day's produce up into separate bags for shipment, but to bulk the total output. The cacao can be kept in separate heaps, if nearly of the same quality, until the next shipment has to be made, but when this takes place, it must then be carefully bulked before being bagged, so that the quality will be even throughout.

Samples should be forwarded of each separate shipment, and, if there are different qualities in that shipment, then send samples of each quality to the head offices, consecutive numbers being used; duplicate samples are then kept at the plantation, so that should some particular lot find special appreciation in the market, or should some complaint be made about any lot, it will be easy for the head office to refer the matter back to the estate. The planter could then taste his duplicate sample, and he would thus gradually gain a knowledge as to what kind of goods are in demand. The duplicate samples should be carefully preserved from the damp by being packed in metal boxes or in suitable glass receptacles.

I need hardly mention that the packages *i.e.*, the bags, shipped should be uniform in shape and weight.

The Fermentation of Coffee.

When, in 1902, I had brought my investigation relative to cacao fermentation and oxidation to a successful issue, it was natural that the idea should strike me to extend my experiments to coffee. In this matter, however, I could obtain no definite results in Germany, so I renewed my experiments in San Thomé, using freshly gathered coffee. I found that, contrary to what occurs in cacao, acidification had an unfavourable influence on the quality of coffee, for it slowly caused the beautiful greenish-grey colour to again become the yellowish-white of the freshly gathered beans, in which case an infusion of the roasted beans tasted flat and had no body.

In my first experiments I treated the freshly gathered beans, after freeing them as much as possible from the fruit pulp, just as I did with the cacao beans; that is to say, I subjected the coffee-beans to an alcoholic and acetic fermentation, and allowed the oxygen of the air to act on the washed and partially dried beans at a temperature of between 40° and 45° C. (104° to 113° F.). The result of these experiments was as previously mentioned. It sometimes happened that some of the beans only showed white spots, which grew larger if the beans were left standing. In isolated cases I came across such spots on fully cured coffee that had been stored for some time on the plantation. The yellowish-white colour of the coffee, as well as the white spots on the isolated beans, were caused by acidification.

If non-acidified, partially dried beans were kept for some time at a temperature of 40° to 45° C. (104° to 113° F.), a sufficient amount of air being allowed to reach them, the yellowish-white colour of the freshly gathered beans turned into a greenish-grey fairly rapidly, and this colour remained. In treating coffee, therefore, care should be taken that no acid can penetrate into the kernels or cotyledons of the beans, which is enclosed in a parchment-like skin.

On plantations fitted with modern machinery the method of procedure is as follows: By a mechanical contrivance the parchment covering the coffee beans is separated from the fruit, and the beans are then fermented and washed. This fermentation facilitates the removal of the remaining slimy fruit pulp, and thereby renders the parchment-like skin more permeable to air. Should acid fermentation take place, the coffee may very likely be damaged and so be less valuable. Although it is true that the acid cannot apparently penetrate the parchment-like covering of the coffee beans as easily as it does the shell of the cacao bean, since fermenting the coffee greatly facilitates its being washed, it is practically impossible to avoid having to prepare the coffee in that way.[1]

In San Thomé a method that completely differs from the above is employed as a rule. The coffee fruit is spread out on cement floors in the open air in fairly thick layers. There it is left for weeks, only being occasionally turned over with shovels. The beans gradually die, and only after they have done so does the actual drying commence. The beans are not left spread out, but are gathered up into heaps or rows in the evening, and spread out again the next morning, and during this process a

[1] According to Dr. Ure, coffee contains: vegetable fibrine, fatty matter, caffeine, legumine, and it is claimed that owing to the pressure and friction which take place in some of the mechanical peelers and polishers, the coffee gets excessively heated, and the oil or fatty contents are brought to the surface of the beans, and gradually evaporate when the coffee comes out of the peeler and is exposed to the atmosphere, losing thereby its natural colour very quickly. According to Messrs. McKinnon and Co., Ltd., of Aberdeen, this excessive heating can be avoided, as by the simple though effective method, introduced in their machines, of circulating cold air between the internal parts of the machine, a brilliant and lasting polish and colour is imparted to the beans.—H. H. S.

rise of temperature takes place. After being dried the bean is separated from its parchment-like covering and any of the dried pulp (*Fleisch*) that may still be adhering to it. This process is at least the one I saw used on Boa Entrada plantation, where the coffee was of very good quality. On beans that had been stored for a longer period I found the spots already referred to on isolated beans, and I attribute their presence to damage done to the parchment-like covering during the drying process.

By this method, as practised in San Thomé, the object of the treatment, though carried out empirically, is to warm the partially dried beans during the process of oxidation. As results prove, a very good quality coffee may be produced by these means. It is certainly true that by the more modern method—the removal of the pulp immediately after gathering—a good result can be obtained more rapidly and with greater certainty, so long as acidification of the beans is avoided and the oxygen of the air is allowed to act on them for a sufficient length of time. As soon as the acidification is too great—*i.e.*, if the acid is allowed to penetrate the parchment-like skin and attack the bean itself—the coffee will taste flat to the palate and the liquor has no body, and if the oxidation process is not carried sufficiently far, a harsh, bitter-tasting coffee is obtained.

The Fermentation of Tobacco.

In connection with my investigations regarding cacao and coffee fermentation, I made some experiments on tobacco fermentation in Germany. Unfortunately I have not had any opportunity of becoming acquainted with tobacco fermentation carried out on a large scale. To judge by the results I have obtained in my investigations into the fermentation of indigo, tea, cacao, and coffee, I think myself justified in assuming that in the case of tobacco too much importance is also attributed to ferments. I was indeed of the opinion that in the case of the fermentation of tobacco, as with the other products, the oxygen in the air plays the most important *rôle*, and that the packing together of the nearly dried leaves in heaps has for its aim the production of a temperature suitable for the process of oxidation. I further gathered that the packing and repacking (*umpacken*) of the heaps was not only done in order to avoid both the production of too high a temperature as well as the formation of butyric acid and moulds, but also in order to bring the leaves into contact with the oxygen of the air. The heating of the tobacco heaps is, of course, brought about by the influence of micro-organisms, and it is the sole object of the process just described to bring this about, *i.e.*, to raise the temperature. If the leaves contain too much moisture, too great acidification sets in, and if there be an insufficient supply of air, butyric acid fermentation, &c., will take place. In order to avoid these, the leaves have to be partially dried, but still kept moist enough for oxidation to become possible. The production of good tobacco depends on proper attention being paid to these conditions for a sufficient length of time, and on stopping the fermentation as soon as a sufficient degree of oxidation has been reached. Since the desired temperature is caused by micro-organisms, naturally their conditions for growth must be taken into consideration. If the necessary temperature can be supplied artificially, the micro-organisms can be dispensed with.

Seeing this, I therefore tried the following experiments: Some tobacco leaves, having varying degrees of moisture, were exposed in a large glass receptacle to a temperature of between 45° to 55° C. (113° to 131° F.). In order to ensure that they had access to sufficient oxygen, the leaves were exposed to the air daily, whilst with the control-tests, this airing was omitted. Having determined by repeated experiments the proper degree of moisture, I allowed the process of oxidation to continue for varying periods. By this means I was able, after treating the leaf for fourteen days at temperatures between 45° to 55° C. (113° to 131° F.), to obtain a tobacco that was declared to be of good quality, and which kept perfectly well. Leaves subjected to the oxidation process for shorter periods were declared to be unripe, and sharp in flavour.

The freshly-gathered and dried tobacco-leaves used in my experiments were kindly supplied to me by Herr J. Hammerschlag, manager of the Kaiserliche Tabak-Manufaktur, Strassburg, who also submitted the tobacco leaves fermented by me to expert tests, the results of which I have given above.

I have therefore proved that with tobacco also, fermentation plays only a subsidiary part, the object of which can be attained by artificial heat, but that the main results in the curing are attributable to the oxygen in the air. The essential principle of tobacco fermentation is then to allow the oxygen of the air to act on the leaves under conditions favourable to oxidation—that is to say, at moderately high temperatures.

I have mentioned my researches on coffee and tobacco fermentation, in order to show that in their case the oxygen from the air also plays the same *rôle* that it does with indigo, tea, and cacao fermentation, or, rather, oxidation. In actual practice it is true that in the case of indigo the oxidation takes place in a watery solution, but if the leaves of the indigo plant are strongly compressed—in other words, if they are treated as one does when rolling tea-leaves—oxidation will also occur with indigo leaves as well, in fact it takes place very rapidly; and in some countries indigo is prepared in a primitive manner, similar to above. As the oxygen takes longer to obtain access to the interior of the cacao and coffee bean, the process of oxidation lasts much longer. The same seems to be the case with tobacco leaves. If one could treat these as one does tea-leaves, *i.e.*, if the oxygen could obtain easier access to the interior of the tobacco leaves by some mechanical process corresponding to the rolling of tea-leaves, its ability to do so would certainly be able to greatly accelerate oxidation. I succeeded in shortening the time considerably by simply maintaining the conditions favourable to oxidation.

These notes, like the investigations, are, of course, in no wise complete. It is, as a rule, far more difficult to adopt scientific results in actual practice than to explain empirical methods scientifically.

CHAPTER V.

BY DR. J. SACK.

WHEN one considers how the cacao crops in Surinam were handled in the past, as compared with the present, one comes to the conclusion, that since the commencement of the cacao plantation industry in this colony —it was in the year 1773 that the first shipment of cacao to Holland took place—the mode of fermentation has scarcely changed at all.

Formerly the seeds were placed in one big heap in the shed, and covered with banana leaves, and this method of fermentation is still resorted to occasionally. The cacao was left to sweat for five or six days, the heap being turned over each morning. After this the damp seeds were thinly spread over the floor of the drying attic of the shed, and finely sifted ash or powdered clay was scattered over them.

Here the seeds remained until they became dry, which was a matter of five weeks at least. During that time the seeds were repeatedly turned over, and if any maggots were found on the cacao, it was sprinkled over with salt or brine.

It is remarkable that at that time the sun's rays were considered to be highly injurious to the cacao, hence the beans were dried in lofts or attics, which, while being as airy as possible, were yet secluded from the sun.[1]

DR. J. SACK.

As regards the process of drying, the methods followed at the present day, when rapid drying is aimed at—either by mechanical means or in

[1] The cacao used preferably to be shipped in vessels which also carried sugar, as it was believed that both the aroma and the taste were enhanced by the presence of sugar.

the sun — are very different to those utilised in the past.

This rapid drying is not resorted to because it is considered that better cacao is obtained by its use, but because the old method would take up too much room in the sheds, now that the cacao plantations have increased so much in size. In the old days indeed, cacao was a secondary product of the coffee plantation, in fact even at the very commencement of the industry, the cacao was sometimes dried in the sun when the coffee crops were abundant.

The mode of fermentation, however, has practically remained the same, except that now the beans are usually placed in a special fermentation or sweating-house; that is to say, a stone building, roofed with tiles, and divided into five to eight compartments or boxes made entirely of wood.

In each of these sweating-boxes the cacao remains lying in a heap for the space of one day, to be turned into the next the following morning, when at the same time care is taken that the beans which were at first on the top now go to the bottom.

The floor of the boxes, which is also of wood, is bored with a number of holes; it is built over a cement floor which slopes slightly forwards. This enables the water or juice, which exudes from the fruit pulp by reason of the pressure of the heap, to flow into gutters alongside of the boxes, and thence outside.

The fermentation takes from five to eight days in all, according to circumstances, and the planter can see by the look of the beans whether they are sufficiently fermented or not. The process is thus exactly the same, practically, as it was about a hundred years ago.

Very little is actually known of the changes that take place in the beans except that the temperature rises during the fermentation, and that it is necessary to turn over the heap, or to shift it from one compartment to another in the sweating-house so as to prevent the rise of temperature from becoming excessive; further, that during the fermentation the slimy pulp which envelops the seed becomes loosened and fluid so that it is able to run off as a liquid; and that the seeds themselves change colour, *i.e.*, from pale violet to brown, while they are changed from a fleshy leathery substance to a brittle one, and the pellicle of the seed, after the fermentation, becomes a loose and brittle skin surrounding the cotyledons. One can well say, therefore, that although this process has been applied for many years when preparing the beans, very little is known so far concerning the changes which the fermentation brings about in the cacao.

But besides these changes there must be others more important, which, however, are less easily perceptible; and these, still unknown, changes must be those without which the unfermented product is unsuitable for the manufacture of cacao.

One may thus safely say that, for the present, it is difficult to assert with what object the cacao is fermented, and as long as this is the case, there can be no question of arriving, along scientific lines, at an improvement in the sweating process, whereby a product of higher commercial value would be obtained.

The following are the results of a few experiments made with a view of explaining certain problems arising in connection with the fermentation of cacao beans.

In answer to the first query, viz.: *Is the fermentation of the cacao due to a chemical or biological process?*

It is conceivable that the fermentation is the result of chemical reactions, which take place in the substances contained in the pulp or the seed, without bacteria, fungi, mould or other forms of life playing a part therein. If this is the case, then the fermentation process is due to chemical action.

It is, however, also conceivable that forms of life as mentioned above, attack the pulp, multiplying greatly, and that they constitute the primary cause of the first fermentation process. If this is the case, the fermentation must be due to a biological process.

The latter supposition at once appeals to us as being the most likely, since the soft pulp, which contains a considerable amount of water and sugar, is recognized as an excellent form of nourishment for moulds and fungi; a test, however, was first necessary in order to decide this positively.

For this purpose four baskets were taken, each filled with 7 kilos of cacao. These baskets were placed upon stones to allow the liquor to drain away.

To the baskets Nos. 1 and 2 nothing further was added; to the contents of basket No. 3 was added a certain quantity of formaldehyde, and to the contents of basket No. 4 some chloroform. Now formaldehyde and chloroform are both substances which exercise a stupefying or even deadly effect upon all forms of life, but do not disturb chemical combinations; therefore, if the fermentation is due to a chemical process, the temperature in the four baskets would have risen to the same level; and if to a biological process then in that case the temperature in baskets Nos. 1 and 2 would have risen, and that in baskets Nos. 3 and 4 would have remained at the level of the surrounding atmosphere.

In process of time the temperature in baskets Nos. 1 and 2 rose to 40° C., while that in baskets Nos. 3 and 4 remained at the level of the surrounding atmosphere, that is to say 28° C. In baskets Nos. 1 and 2, where the fermentation was thus in full operation, some chloroform was placed, as a further proof, whereupon the temperature after some hours dropped from 40° C. to 28° C., and fermentation ceased.

From this test it thus follows *that the fermentation of the cacao beans is not due to a chemical but to a biological process.*

In answer to query No. 2: Does *the fermentation require the admittance of air?*

Four cylinders were filled, each with 4 kilos of cacao. Each of the cylinders had a tube attached to allow of the drainage to run away.

Cylinders Nos. 1 and 2 were open at the top, and drilled bamboo canes pushed in between the cacao, so that a sufficient quantity of air could penetrate. Cylinders Nos. 3 and 4 were tightly closed.

After a time the contents of cylinders Nos. 1 and 2 duly began to ferment, while the cacao in cylinders Nos. 3 and 4 began to decompose; this experiment was repeated several times, but each time the air was excluded the fermentation ceased and the cacao commenced to decompose.

This test therefore proves *that the fermentation process requires the admittance of air.*

In the laboratory the best fermented cacao was obtained from the baskets, as they were open all round, and the air could thus penetrate freely, and in studying the process of fermentation on the plantations, it appears that with large heaps the top layer ferments the best, and that the bottom of the heap, where the air cannot penetrate, does not ferment at all.

It is thus proved that turning over the heaps, that is to say, transferring them from the one sweating-box to another, whereby the layer that is at the top goes to the bottom, is not without good reason; in fact it is necessary in order to ensure that the beans are evenly sweated throughout, and to arrest decomposition.

Query 3.—*Is the rise of temperature due to the conversion of the sugar contained in the pulp?*

The supposition that the rise of the temperature is caused by the conversion of the sugar in the pulp, arose from the observation that, after the fermentation, the pulp contained no more sugar, while the air was pervaded by a strong smell of acetic acid; an element readily produced from sugar.

Supposing this theory is correct, there should be no rise of temperature if the seeds are placed in the sweating-box after the sugar has been removed from the fruit pulp.

In order to prove this, two baskets were filled with cacao in the same way; No. 1 contained cacao to which nothing had been done; No. 2 contained cacao which had previously been washed. The contents of basket No. 1 proceeded to ferment in the usual way, while the contents of basket No. 2 did not ferment at all, until after it had been sprinkled over with a solution of sugar. Simultaneously with the disappearance of the sugar, however, the presence of alcohol and acetic acid was observed. From this test, and also that on page 139, it is thus seen that the rise in the temperature of the cacao in the sweating-boxes is caused by a fermentation process, whereby the sugar present in the fruit pulp changes into alcohol and this again oxydizes into acetic acid. Both the alcohol and the acetic acid were chemically shown.

Experience shows indeed that when much rain falls[1] during the gathering of the cacao, the sugar is washed out of the cacao and it does not sweat properly; but we soon also learn that this drawback may be remedied by adding a certain quantity of molasses after the cacao has been taken to the sweating-house.

During the laboratory experiments the temperature in the baskets could not be raised above 40° to 42° C., while that in the sweating heaps on the plantations usually represents 42° to 45° C.; this is easy to understand, as with the baskets, the surface is too large in proportion to the quantity of cacao and there is thus much loss of heat.

The foregoing relates entirely to the processes which take place in the pulp during fermentation, and which we may collectively call the external fermentation; on the other hand, we have the internal fermentation, that is to say the processes enacted in the bean itself.

[1] It should here be remarked that the seeds on most plantations are sent into the sweating-house already stripped of their husks, which is done on the estate, and the contents are then taken in baskets to the fermentation house.

The phases of the external fermentation, as observed with the tests described, may be contained in the following :—

Immediately the seeds are placed in the sweating-boxes, the fungi and bacteria surrounding them, and which are to be found upon the cacao, change the sugar out of the pulp into alcohol, thence into acetic acid, subject to the necessary development of heat.

To what form of life they belong may be gauged with a tolerable degree of certainty, as the changing of sugar into alcohol, thence into acetic acid, is a well-known process.

The decomposition of sugar into alcohol is probably due to a fermentation fungus; from sugar and water there arise alcohol and carbonic acid gas.

The decomposition of alcohol into acetic acid is probably caused by a certain kind of bacteria. It is an oxidation process, that is to say the alcohol unites in this way with oxygen, and that according to the following formula :—

$$\underset{\text{Alcohol}}{C_2H_6O} + \underset{\text{Oxygen}}{O_2} = \underset{\text{Acetic acid}}{C_2H_4O_2} + \underset{\text{Water}}{H_2O}.$$

Consequently oxygen is required for this decomposition, which is the reason why, as we could see from the test on page 140, the fermentation needs the action of the air. With the decomposition of the alcohol into acetic acid heat develops.

And now to proceed to the internal fermentation, or the processes enacted in the bean itself.

As long as the bean lives but remains in a dormant state, no chemical changes of any consequence take place, as the various substances contained in it do not come into contact with each other. The seed, however, is no sooner dead than the substances of which it is composed begin to react upon each other.

The seed remains alive until the high temperature brought about by fermentation kills it; and in order to determine at what temperature this takes place, the following tests were made:—

The seeds of four ripe cacao pods were thoroughly mixed and twenty of them planted; as they all germinated they may be taken to represent good germinative seed.

Ten units were submitted to a temperature of 43° C. for three hours, whereupon they were left to germinate, which they all did.

Ten units were submitted to a temperature of 43° C. for six hours, and then left to germinate; of these only four germinated, and after having been heated for nine hours not one of the seeds germinated.

Ten units were heated to 44° C. for six hours; the germs of these seeds all proved to be dead.

In the sweating-boxes the temperature on the third day is usually 45° C., and hence from the above test it may be concluded that by the fourth day all the seeds would have been dead, and so from this moment one may conclude the internal fermentation commences.

Change of Colour of the Seed.

Seeing that with the fermentation of the pulp no substances arise which could be expected to exercise any influence worth speaking of, it seems probable that the changes which take place in the seed during fermentation depend upon the mutual action of the substances which are actually present in the seed itself. With the change of colour (from violet with the unfermented to brown with the fermented seeds) this indeed was proved to be the case.

When crushing cacao seed in a mortar one can already see, during the process, the violet colour changing into brown, which gets darker and darker the longer the cacao is left standing, and from experiments it was further proved that the brown colour only results with admission of the air; as a matter of fact, this is also the case with the fermentation of the beans, the brown colouring working from the outside to the inside; at the same time it appeared that this discolouration did not take place after the beans had been placed for some time in boiling water, but when, however, a few fresh beans were rubbed through this boiled mass the brown colouring showed itself after a time. This phenomenon led one to suppose that the action was due to the working of enzymes.

It is difficult to give a concise, and at the same time a good definition of what is understood by an enzyme, but, speaking generally, one may say that enzymes are substances of vegetable or animal origin, which have the power of causing reactions between certain substances, without themselves playing any part in the composition of the substances formed by the said reaction; they are thus able, in minute quantities, to manipulate the decomposition of great quantities of these same substances; the enzymes are made harmless at a temperature of 100° C., most of them at a lower temperature still, viz., between 65° C. and 70° C., while the temperature at which the enzymes exhibit the greatest activity (the so-called optimum temperature) lies, for the most part, between 45° C. and 60° C. As regards the chemical composition of the enzyme nothing is known so far.

In order to be positively certain that the discolouration is actually due to the presence of an enzyme, attempts were made to isolate same. This was done as follows: The cacao beans were thoroughly washed with water, so as to remove the sugars, acids, &c., whereupon they were crushed to pieces, and steeped into alcohol so as to be able to remove the seed pellicle easily. The seed pellicle contains much slime, which would obstruct the removal of the enzyme by water very considerably, so for this reason it was removed. The alcohol was rapidly poured off, and the kernels exposed to the air until the alcoholic smell had disappeared; this took place within a few hours; the beans were then reduced to a pulp and ether poured over them, and then run off to remove the greater part of the fat.

Having again been dried in the air, the cacao was mixed with water, and, after being shaken, left to stand for six hours; it was then filtered through sieves and afterwards through linen. Whilst being filtered alcohol was added, and the fine flaky precipitate, which sinks rapidly, freed by pouring off the fluid on top. The residue was washed with alcohol and ether, and dried in the air, and a light brown mass containing much nitrogen was obtained.

About half a gramme of this residue was obtained from several kilos of seed. The material was not further refined, as the working of ferments is strongly retarded with this operation of repeated solution and precipitation.

Now, as already mentioned, the finely crushed beans do not discolour after having been placed in boiling water, but they do if a few fresh beans are mixed with them. In lieu, however, of intermixing some fresh beans, the enzyme containing residue was added, and after a few hours the discolouration set in.

As a further check the residue, at another test, was heated for five minutes to 100° C. before adding the violet mass; here after standing for days there was not the slightest trace of change of colour.

From these tests it follows that the discolouration of the beans, which die at a temperature of about 45° C. during the fermentation, is caused by a substance contained in the seed itself, and which must be an enzyme, seeing that it can be destroyed by boiling heat, is precipitated by alcohol, and causes the discoloration by the medium of a minute quantity. The temperature at which the enzyme is destroyed appears to be somewhere about 70° C.

For the purpose of ascertaining the activity of the enzyme-containing residue, a few further tests were made. In these it was noticed that cane-sugar did not split, an invertase thus appeared to be lacking. Amygdalin, however, did so.

This observation gave us an idea as to the nature of the reaction which causes the beans to turn brown.

In the beans, the above-mentioned glucoside[1] does not exist, but another, *i.e.*, cacaonine, is

[1] By glucosides are understood those substances which by the action of acids, alkalis or enzymes become divided, so that in addition to more or less compound bodies a kind of sugar, usually dextrose, forms. Glucosides appear almost exclusively as plant substances.

present, as has been demonstrated by Hilger;[1] this cacaonine has as formula: $C_{60}H_{86}O_{15}N_4$, and shows upon analysis one molecule cacao-red, six molecules grape sugar and one molecule theobromine.

We have already said that the admission of air is necessary to bring about the discolouration. This becomes clear when one considers that, as shown in the above analysis of cacaonine, oxygen is necessary.

One molecule theobromine has the following composition:—

$C_7H_8O_2N_4$ six molecules glucose, 6 $C_6H_{12}O_6$ $=C_{36}H_{72}O_{36}$; one molecule cacao-red: $C_{17}H_{22}O_{10}$.

In all these contain, 60 atoms C, 102 atoms H, 48 atoms O, and 4 atoms N; this sum thus contains 16 atoms H, and 33 atoms O, more than a molecule cacaonine.

These 16 atoms H, and 33 atoms O, are produced by 8 molecules water and 25 atoms O.

The formula of the enzymitic division of the glucoside cacaonine thus becomes:—

$$\underset{\text{Cacaonine}}{C_{60}H_{86}O_{15}N_4} + \underset{\text{Water}}{8\ H_2O} + \underset{\text{Oxygen}}{25\ O} =$$

$$\underset{\text{Theobromine}}{C_7H_8O_2N_4} + \underset{\text{Dextrose}}{6\ C_6H_{12}O_6} + \underset{\text{Cacao-red}}{C_{17}H_{22}O_{10}}$$

The chief thing in this reaction is the origin of the theobromine, the alcaloide, which

[1] I had no literature at my disposal upon the subject of cacaonine and cacao-red, except that contained in Zipperer. *Die Schokoladen fabrikation* 2 Auflage, Berlin, 1910, p. 50.

imparts to the cacao its irritating and bitter characteristics.

So far the cacao-red has been considered to be the substance which gives the manufactured cacao its characteristic aroma and taste, and in order to ascertain whether this was correct, the cacao-red was prepared in the manner indicated by Hilger and Lazarus. On doing so, however, it proved to be a perfectly odourless and tasteless powder, so that one cannot ascribe the aroma and taste of the manufactured cacao to this substance.

What did appear was that the aroma of the cacao was considerably increased by the process of fermentation. Fresh unfermented beans, when subjected to boiling, do not smell. It must, therefore, be concluded that the aroma is caused by a substance which, like the cacao-red, first originates with the fermentation process.

The fact that fermented cacao, when subjected to boiling, smells strongly, led to the supposition that the substance in question was an ethereal oil, since ethereal oils have the peculiarity of evaporating with steam.

In order to trace this, a large quantity of ground cacao that had been fermented was distilled by steam. The distillation was again distilled to a smaller volume, and this operation was repeated several times. In this manner a drop of oil was obtained, which strongly resembled cacao in its peculiar smell and taste.

During the distillation the laboratory and the entire surroundings were pervaded by a strong smell of cacao. The yield was extremely small, and it may be estimated that 20 kilos of cacao will produce 1 c.c. of cacao oil. This experiment at the same time made it quite clear why the old method, by which the drying was done slowly, yielded a product which far surpassed in quality the cacao that was rapidly dried, for with a slow process of drying the reactions will continue for some considerable time. With rapid drying they will speedily cease.

The above may be summed up as follows :—

With sweating the beans, an alcoholic fermentation in the pulp first takes place through the agency of ferment fungi, whereby the sugar contained in the pulp is split into alcohol and carbonic acid; the alcohol with the addition of oxygen is further oxydized into acetic acid, which causes a strong rise of temperature. This is the external fermentation. This causes the temperature to rise to about 45° C., when the seeds or beans enclosed in the pulp are killed. After this has taken place, the substances within the bean itself commence working upon each other. This is the internal fermentation. Subject to the influence of an enzyme present, the cacaonine is split into cacao-red, theobromine and dextrose, while at the same time an etherial oil is formed.

Moreover with the fermentation the useless sugar-containing pulp, which is so detrimental to the keeping of the cacao, disappears.

Loss by Washing the Cacao.

A few determinations were made in regard to the greater loss of weight the cacao sustains after fermentation, if it is washed and then dried, as compared with the method of drying it immediately after fermentation.

In Surinam one usually estimates that the loss through washing is very considerable, it even being admitted to be as much as 15 to 18 per cent.

I found, however, that this depreciation only came to 4 to 5 per cent., except in a solitary case of badly-sweated cacao that was dirty, when it was found to be 8 per cent.

In practice these figures will be lower still, as small lots such as I washed will be more perfectly and thoroughly treated than large quantities. Taking this into consideration, the figures obtained by me compare favourably with those given by Preuss[1] in regard to the loss by washing, *i.e.*, 4 per cent.

When taking into consideration that buyers in Surinam only pay 2 cents per kilo more for washed cacao than they do for unwashed, it is evident that with a low price of 55 to 60 cents, a loss of profit ensues, seeing that 2·2 to 2·4 cents already is lost by the washing, and only 2 cents recouped; moreover this does not include the washers' wages, and other costs necessitated by the process.

[1] Preuss, "Reise nach Central- und Süd Amerika," 1901, p. 176.

CHAPTER VI.

Forming with Chapter VII., by Dr. Lucius Nicholls, the Joint Prize Essay mentioned in the Preface.

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Scope of Suggested Improvements.

APPROACHING this subject from a strictly utilitarian point of view, it is necessary at the outset to admit the defined limitations with which we are beset when striving to introduce improvements in the quality of the cacao by adopting the best methods of fermenting and curing the beans. The changes that may be induced in cacao by such methods constitute a beneficial action the measure of which can be most accurately gauged by exactly that difference in price which cacao buyers in the terminal markets enforce between unfermented, carelessly cured cacao and the highly fermented, well-cured produce from the same variety of tree and place of export.

With the Calabacillo and Amelonado types of cacao from Brazil, Africa, West Indies, &c.,

&c., that constitute three-fourths of the production of the world, the extreme difference in their value when prepared by the methods now in general use, as compared with the improved methods described here and elsewhere, may be estimated to-day (June, 1911), at about 5s. to 6s. per cwt.

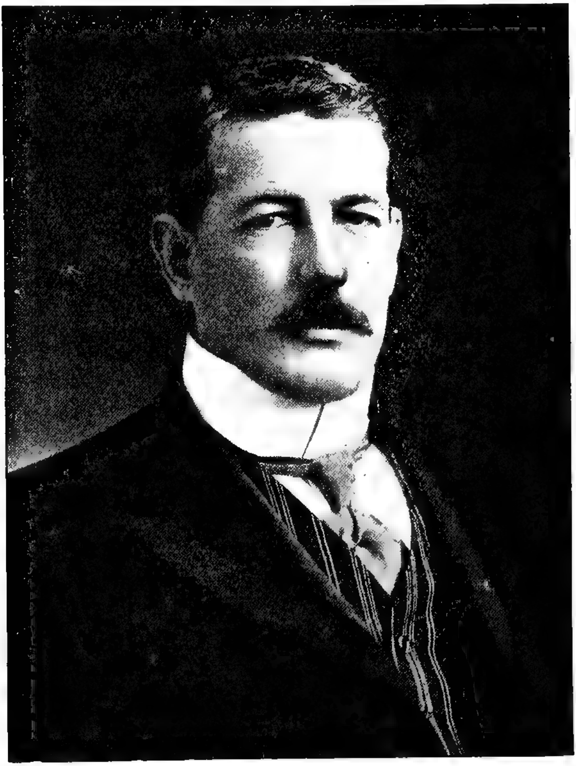
In the Forastero, Criollo and Pentagona types from Trinidad, Ceylon, Central America and Samoa, &c., &c., the difference would appear to be even less: this is doubtless due to the fact that the planter who aims at producing a high-class cacao would not spoil it by poor curing; also, that the fermentation of these types is more simple.

It is impossible to ignore the fact that taking the world's production of cacao, no single instance arises of a low-class cacao being transformed by curing methods into a high-class article,[1] and conversely, one seldom sees Criollo or Pentagona types so spoilt by curing as to seriously reduce their value.

That the value of any quality may be enhanced by careful treatment, and lowered by indifferent methods, is apparent, but it is equally apparent that the enhancement of

[1] This is true, but, at the same time, it is agreed that with the introduction of the best methods of seed-selection, cultivation, and curing, an indifferent class of cacao can be improved out of all comparison with the original stock, as has been proved with the Grenada cacao of to-day compared with the beans that came to market in 1883 and 1884.—H. H. S.

values by good curing has hitherto been limited ; within the difference of price I have named if badly "weathered" or "sea-



[*Elliott & Fry.*

MR. GEORGE S. HUDSON.

damaged" parcels be eliminated from the outlook, as they naturally would be.

It is possible that the inoculation method of fermentation recommended in this essay will extend this limit of difference upward by a few shillings per cwt., but beyond this, if higher prices are desired, better varieties of cacao must be evolved by seed-selection, intensive cultivation, and the other means well known to all plant-breeders.

The curing of cacao is in the hands of two distinct classes, *viz.*, planters, who cure their own produce, and merchants who purchase cacao more or less cured from the small proprietors and complete the process—generally in an indifferent manner whereby the value of their purchases is materially reduced.

Planters' cacao, generally classed in Prices Current as "Fine Estates," has the advantage of being in the planters' hands from the first to the last stages of curing; and throughout the world, and especially in the West Indies, it is wonderful how "evenly" a sample of cacao is turned out by all planters whose trees are mainly of an Amelonado type with a sprinkling of Calabacillo and Forastero. Where the proportion of Forastero is considerable (as on many, if not all, Trinidad estates), then a somewhat higher quality is produced. Where Criollo and Forastero hybrids predominate, as in some Ceylon marks, then the price is usually 20 per cent. to 30 per cent. higher, and the really high-class Central American or Ceylon growths, composed of nearly pure Criollo or Pentagona types, may sometimes sell at double the price of a well-cured Amelonado sample. In comparing the "Fine Estates" marks of St. Thomé, Accra, Cameroons, Bahia, Grenada, Jamaica, St. Lucia and Dominica, there is between the best and the worst a difference in quality that most manufacturers do not value at more than 2s. 6d. per cwt., and more frequently the difference does not amount to more than 1s. or 1s. 6d. per cwt.[1] In some instances the size and quality of the seed may influence this result, but in most cases it is simply a question of the care and intelligence expended on the processes of fermenting, drying and polishing the beans previous to shipment.

Taking planters and their cacao as a class, the good cacao with the bad, and the careful man with the *laisser-aller* man, there seems to be every probability that the adoption of improved principles in curing, notably Dr. Nicholls' inoculation by means of a ferment, will result in each and every planter obtaining

[1] This is not entirely correct, but quite near enough for the present discussion; at the same time it is interesting to note the differences in quotations on June 16 of the following typical growths:—

		1913	1912
Trinidads—London	...	72/- to 78/-	65/- to 68/-
Grenadas—London	...	67/- to 73/6	56/- to 62/-
Accras—Liverpool	...	58/- to 63/-	52/- to 58/-
Trinidads—Havre	...	Fcs. 85 to 89	78 to 81
Haytians—Havre	...	„ 68 to 82	57 to 71
Venezuelan—Havre	...	„ 85 to 180	73 to 200

an increased price averaging 2s. per cwt. net. The question that each planter is apt to ask himself on this subject is, "Is the game worth the candle?" Well, on a crop of 300 bags (of 180 lb. each) it means an extra net profit of £45 to men who are already turning out a relatively good sample. Many estates could improve the price they realize by twice as much again, *i.e.*, 4s. cwt., but, writing as an old agricultural instructor, I am more sanguine of inducing the man, who is already doing creditably, to reach up to higher results than of inducing the man who is in the habit of throwing away £50 a year by exporting poor cacao to amend his ways.

Turning to the merchants' part in cacao curing, where the reward offered for good work is so much larger, and the men engaged in it are supposed to be very keen on an extra profit, one should hope for good results, were it not that the merchants' past record in this matter is such an unpromising one. It is not unusual for a single cacao-buying firm in the West Indies, Brazil or West Africa, to purchase, cure and export many thousand bags of cacao each year. Owing to the prevalence of cacao stealing, most cacao-producing countries have laws prohibiting the purchase of freshly picked cacao, and, although this complicates the curing question for the merchant, yet one must acknowledge the extreme usefulness of this precaution in bringing offenders to justice;

it compels the thief to keep the cacao he has stolen in his possession twenty-four to thirty-six hours, and this frequently proves his undoing. The usual procedure of a small proprietor having cacao for sale to a merchant is to "sweat" it one night (which entails no rise in temperature, and is merely equivalent to a draining process), expose it to one day's sun when it is bagged, and next day, perhaps, slightly sprinkled with water to make it weigh a little more, it is then sold to the merchant. In other cases the drying is continued until it is more or less "dry" in the accepted term (generally less), and the produce then sold to the merchant, who exports it in this condition as cured cacao. It is then, usually, very unattractive, of a dirty grey colour, insufficiently dried, more or less mildewed, and containing much of the placenta from the pod. Small wonder that it sells at a low price, one is only surprised that it does not fetch an even lower figure. In some cacao-buying stores an attempt is made to produce fermentation on the partially dried bought cacao, by throwing it as purchased into large packing cases, and leaving it there for a night or two to take its chance of fermentation. Its chance is infinitely small; such fermenting germs as the cacao carried away from its brief sojourn in the "sweating-box" are killed by the sunning, and as one seldom sees the "Cacao Fly" (described by Dr. Nicholls) in well-scavenged towns and villages, there is hardly a chance of fermentation taking place.

To cacao-buying merchants, then, Dr. Nicholls has pointed a way towards first-class results, by the isolation and preparation for everyday use of a pure cacao ferment containing those yeast forms which our experiments have proved to be the most vigorous and beneficial; and further, by providing a prescription (which any chemist should dispense for a few pence) of a suitable medium that will enable this ferment to flourish by spraying or sprinkling the combined ferment and medium on either freshly picked or partly cured cacao. It is not unreasonable to hope that with the co-operation of Government Agricultural Departments in cultivating and distributing this ferment from their laboratories, the preparation of merchant's cacao should be revolutionized, and that of planter's cacao much improved. On a very moderate estimate the merchant should, by this process, allied to better drying methods, increase the value of each 1,000 bags he exports by £300. On the supposition that cacao-buying firms handle half the cacao output of the world, it can easily be seen that the potentialities of Dr. Nicholls' formula would run into larger figures of export values than I care to estimate.

It is a matter of common belief among cacao men that the manufacturers are not averse to a large quantity of low-class unfermented cacao coming into the market at a low price. If this is so, I will say, for their consolation, that although I may appear enthusiastic as to results of the discoveries reported in the essays contained in this book, yet it is a foregone conclusion that no bait or reward for good work is likely to ensure the entire disappearance from the market of carelessly cured cacao.

It would prove a grievously mistaken idea to imagine that just a sprinkling of this magic essence on a heap of neglected cacao seed would, without further effort, transform it into a high-class parcel. I do not apologize for mentioning this obvious fact, for how often is that attitude not taken up in the manuring of cacao? Just a little of the magic powder sprinkled on the ground and crops should be doubled!! Unfortunately, it is not quite so easy as that. The preparation of a good sample of cacao is quite simple, but it does demand a certain amount of care and attention in every detail.

The margin of profit in the cacao-buying business must be materially reduced by the expensive and careless methods used, not to mention the chances of loss by theft and "weathering." The usual procedure is to spread the seeds out on tarpaulins (which are costly appliances) in the sun each morning, collecting them again each evening under cover. It is true the drying is generally completed on large garret floors at little expense, but no planter could afford to deal with large and very large quantities of cacao in this manner.

The merchant should have several different sweating boxes to suit the different degrees of dryness in the cacao purchased, and to him may be recommended, even more than to the planter, the advantages that vacuum drying holds in requiring a minimum of fuel, economy of time (cacao coming from the sweating boxes in the early morning can be bagged and shipped by midday), theft and wastage reduced to a minimum, as all operations are finished within four walls in a few hours. At a glance it is obvious that the merchant can considerably reduce the capital employed on "cacao account" by owning a vacuum dryer; also, he can reduce his risk of the market going against him by two or three weeks. In fact, it would revolutionize the business; profit and loss on this account could be estimated at any moment, and revision of buying prices made to suit the cabled market reports. A machine-driven cacao polisher should also be included in the equipment; it effects within half an hour, at a cost of a penny or two, the value of a day's work for two men, and should certainly increase the value of a merchant's cacao by 1s. to 2s. per cwt. It is time, therefore, that the cacao merchants abandoned primitive methods and came abreast of the times by adopting one or other of the various time, labour and money-saving appliances now on the market.

Before proceeding to treat the question of cacao curing in detail I think a few words would be useful regarding the small cacao producer's share in this matter. I refer to the man who always sells his cacao to the merchant. Perhaps it is necessary to first dispel the illusion that the prosperous merchant gets fat on the profits from this trade. Whatever the result may be elsewhere, it is not so in the West Indies, where cacao buying yields a very moderate profit in comparison with the time, labour and money invested in it. It is more often looked upon by the merchant buyer as a means of remitting money to Europe at a small profit instead of buying bank bills at a premium, and the extra "turnover" of business with the agent in Europe all helps to grease the wheels of finance. In referring to the low class of native cacao throughout the world there is an implication that the native is the individual to be blamed for this result. I would not like to become his champion, but it is only fair to state that, as matters now stand, the game is all in the hands of the cacao buyers, and they, by uniting, can call whatever tune they wish as regards the condition of the cacao when brought to them for sale within the legal restrictions. It is probable that two nights' sweating and one day's sun would not interfere with the prospects of turning out a good sample, and would give ample chance of convicting a cacao thief. It may be briefly stated that when one considers all the difficulties of his case, the small native grower is not in a position to economically turn out fine parcels of cured cacao, and if he were he would not do it.

Practical Estate Cacao Curing.

Picking Unripe Pods.

In the valuations of Mincing Lane brokers on "Fine Estates" West Indian cacao (excluding the "fancy marks" of Trinidad and Montserrat) it is common to find the words "part unripe" insisted on and repeated over long periods. No doubt the same comment is applied to similar cacao from Bahia, the West Coast (Africa) and St. Thomé. On examining samples of this cacao, viz., fine West Indian, there will be found a certain percentage of the seed (say 10 per cent. to 20 per cent.) that are flat. On "breaking" these seeds, although the break is more brittle and the testa or skin of the bean separates more easily than that of similar beans of unfermented cacao, yet they exhibit an undesirable compact fracture of violet colour uninterrupted by the lacunæ or air spaces found between the convolutions of the cotyledons of higher class cacao. Even the cacao highly fermented by Dr. Lucius Nicholls' process still contains a similar proportion of these flat seeds. While there is therefore every excuse for the brokers to attribute this flatness to unripeness, yet I am convinced they are almost entirely wrong in their diagnosis. Many examinations of the heaps of cacao pods in the fields have convinced me that these, as a rule, on a well-conducted estate, do not contain more than 1 to 2 per cent. of unripe cacao, and further it can be ascertained that this extreme flatness and solid fracture is a characteristic of the lowest type of Calabacillo cacao, and is not to be found associated even with the unripe beans of higher types. It will therefore only be just for cacao brokers, buyers and manufacturers to absolve the planter from this particular sin of picking unripe cacao—for although it is impossible to always avoid picking an unripe pod, yet even the most ignorant peasant knows that such a practice is undesirable—and in future to attribute this undesirable quality to the fact of the beans having been picked from a Calabacillo type of tree.

Removal of the Placenta in the Field.

I would emphasize the desirability of making the cacao carriers or basket fillers free the seed entirely from the "fibrous heart" or "placenta," a proportion of which is too often carried in with the cacao. Where a rotary or vacuum dryer is in use this becomes almost essential to economical work, and a little drastic supervision and fines at the outset soon accomplish this object. Failure to observe this involves increased cost of transport, and loss of valuable time and labour in the drying house in "cleaning" the cacao.

Separation of Qualities in the Field.

In the economical working of an estate it has not been found profitable to separate the one or two unripe pods and the small proportion of more or less "brown" or "black rot" pods from the general "sweating box"; yet one cannot but see that a "counsel of perfection" would demand this sacrifice. There can be no doubt, however, as to the propriety of separating rat-eaten collections of seeds from the general bulk.

Criollo or Pentagona types cannot be profitably fermented together with coarser qualities, the former requiring only three to four days in the fermenting box, and the latter five to eight days: apart from this difficulty no one possessing any modicum of common sense would mix high-class cacao with an ordinary estate lot, thus reducing the value of the better seed by perhaps 50 per cent. Separation of these varieties should occur at planting time, or failing this in the pod heaps before "breaking."

Measuring "Wet" Cacao.

For three reasons it is necessary to ascertain the weight and volume of the cacao as it is placed in the "sweating" boxes, viz.: (1) To ascertain the annual yield from each particular field of cacao, (2) to find out if the cost of picking operations is not excessive, and (3) to be in a position to check the weight of dry cured cacao turned out in comparison with the amount of raw or "wet" cacao entering the sweating boxes. The latter reason only is germane to this essay. The adoption of some package of standard measure is necessary, and, in the West Indies, the North American flour barrel is recommended as a uniform measure, being cheaply and easily obtainable and replaceable. Both the head and bottom of such a barrel are removed, and it is placed, supported by two short lengths of board which constitute a false bottom above the uncovered (No. 1) sweating box. When filled it is easily emptied by drawing away from underneath it one of the short boards, when the contents fall into the sweating box below. For more accurate measurement it is convenient to theoretically divide the barrel into twenty-four parts—thus three-fourths of a barrel would be $\frac{18}{24}$, half a barrel $\frac{12}{24}$, and one quarter of a barrel $\frac{6}{24}$. Subdivision may be carried further by a knowledge of how many cacao baskets go to a barrel: thus if four baskets usually fill the barrel, half a basket would equal $\frac{3}{24}$ of a barrel, somewhat less than half a basket would count as $\frac{2}{24}$, and a lesser quantity just covering the bottom of an ordinary cacao basket would be equivalent to $\frac{1}{24}$ of a barrel. The barrel is generally "heaped" to the natural angle of wet cacao, forming a mound the centre of which is some 6 in. higher than the top circumference of the staves. Such a "heaped" barrel would contain an approximate weight of 300 lb. of cacao; but the factor of weight is far too uncertain a one to be used in checking wet cacao, for it is obviously a hopeless task to accurately weigh a material from which juice is continuously exuding. A delay of a quarter of an hour would make an appreciable difference in the weight of freshly picked cacao, but very little difference in its bulk: therefore, in its wet state, bulk or volume is a preferable measure to weight.

Ratio of Uncured to Cured Cacao.

Some few years ago the Agricultural Departments of the West Indies were concerned in arriving at a true ratio in the weights of uncured to cured cacao, and the results of experiments towards this end were published from the Agricultural Stations of Trinidad and Dominica, and other sources. They all varied considerably, but I am convinced that they were all honest attempts to create a fixed ratio. They were equally correct and equally incorrect, for a fixed ratio under all conditions of air humidity and soil moisture, if attained after many years' experiments, would partake so much of the nature of a general average as to be useless for everyday work.

Where the flour barrel measurement is used the following ratio can be relied on as a result of over twenty years' records by the writer. As just stated, a barrel holds approximately 300 lb. wet cacao to start with :—

One barrel wet cacao picked during the wet season equals 100 lb. to 106 lb. dry cured cacao. One barrel wet cacao picked during medium weather equals 106 lb. to 110 lb. dry cured cacao. One barrel wet cacao picked during dry season equals 110 lb. to 120 lb. dry cured cacao.

These records are based on returns from a rather clayey soil, and a type of cacao in which yellow Amelonado predominates; it is probable that a somewhat better ratio would be obtained from a lighter soil, even although the rainfall (about 100 in. in this case) were heavier.

In three experiments to determine approximately the percentage of weight of cured to wet Amelonado cacao, care having been taken to include all the fruit juices, the following results were obtained :—

Quantity experimented with, 200 lb. wet weight, in all three cases.

(1) Fermented seven and three-quarter days, maximum temperature 113° F., loss in sweating 55 lb., curing and drying 79 lb., leaves 66 lb. dried cacao.

(2) Fermented six and three-quarter days, maximum temperature 109° F., loss in sweating 46 lb., curing and drying 79½ lb., leaves 74½ lb. dried cacao.

(3) Fermented seven and three-quarter days, maximum temperature 106° F., loss in sweating

54 lb., curing and drying 72 lb., leaves 74 lb. dried cacao.

The average dry return from these three lots of 200 lb. wet cacao was nearly 72 lb., or a percentage of 36 per cent., a result considerably lower than that hitherto generally accepted. Taking the average weight of a barrel of wet cacao at 300 lb., and the average return of dry cacao from it at 110 lb., the result works out very close to 36 per cent., and confirms the above experiments which were conducted in mediumly wet weather.

In four experiments of fermenting and curing Pentagona cacao, the fermentation was thoroughly effected within four days, and the net return of dried beans varied from 27½ per cent. to 29 per cent. of the wet cacao treated.

Is Fermentation Profitable?

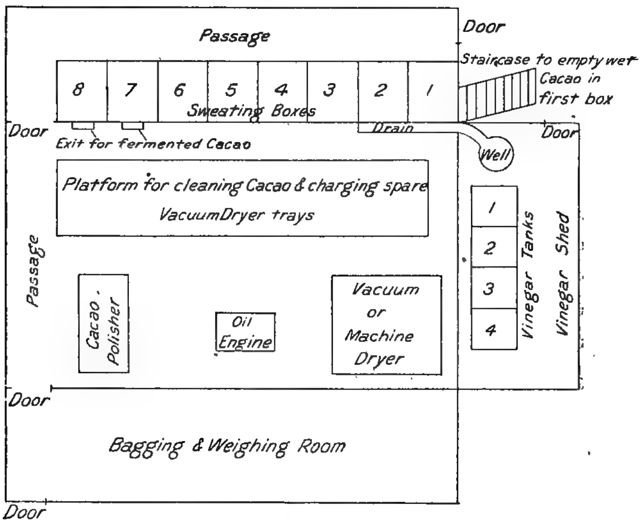
In order to ascertain this point, two lots of 100 lb. each of wet cacao were cured without any fermentation beyond placing them to drain for one night in a sweating box. After sun drying in the usual way the average result showed 39 per cent. of dry cured cacao, or 3 per cent. more weight than in the case of fermented cacao. Taking the value of the unfermented cacao at 50s. per cwt. (June, 1911) and of "Fine Estates" fermented cacao at 56s. per cwt., we find the 39 lb. of unfermented to be worth 17s. 6d. gross, and the 36 lb. of fermented to be worth 18s. gross, showing a profit of 6d. per 100 lb. wet in favour of fermented, or about 1s. 6d. per cwt. dry cured. The actual expense of curing unfermented cacao is not smaller than that incurred in thoroughly fermenting, polishing and curing, for owing to the toughness of the cuticle of unfermented cacao this product takes at least seven days more to dry than fermented beans, and the cost of drying, labour and space for this period must be taken into the calculation. These experiments, therefore, confirm the profitableness of fermenting cacao, as by doing so the planter obtains a better product of greater value.

Fermenting Receptacles.

If one may credit the literature on this subject, it would appear that almost every class of receptacle—from a hole in the earth to the most highly ingenious sweating boxes (one of which is evidently designed to "cook" the cacao with a uniform temperature of 140° F.)—is used in one part of the world or another. In actual estate practice there are, however, very few modifications in fermenting boxes, and it is noticeable that the larger the estate the more simple are the receptacles. For estates producing less than 300 bags per annum a row or (incomplete) circle of seven or eight wooden boxes, each capable of holding a maximum day's picking, is all that is necessary, provided drainage is arranged for the juice from the first two boxes to be run off; curved glazed earthenware tiles embedded in concrete, to form an open channel, being best. Open concrete drains are usually provided, but the acid in the undiluted juice eats into the concrete in a few years. It is advisable that the boxes be raised 18 in. from the ground for drainage purposes in the first two boxes, and also in the case of the last one or two, so that baskets may be placed under the exit to facilitate the removal of the fermented cacao to the curing house. It is necessary to remember that the weight of a full box of cacao is not insignificant, and one must therefore provide adequate support beneath. In boxes with a capacity of not more than seven barrels of wet cacao (say 2,000 lb.) good 1-in. boards may be used without any frame-work. In calculating the capacity of sweating boxes an allowance of 6 cubic feet or a little less per barrel of wet cacao (= 300 lb. wet or 110 lb. dry) will be found ample space for all the boxes, as the bulk of the fermenting cacao does not greatly vary. Beyond seven barrels capacity it would be advisable to use uncovered concrete tanks, lined with wooden boarding or slate, and whether wooden or concrete boxes are used the dividing partition between the boxes should consist of loose boards lifting out of a grooved slot to facilitate "changing" the cacao from one box to another. In the last one or two boxes of a series (which should never be less than six and preferably eight) a frontal sliding door, about 12 in. to 15 in. wide, should be arranged to extend to the bottom of the box to serve the double purpose of ascertaining the bottom heat of the cacao (as frequently this becomes cold, discoloured and mildewed, while the top is still warm and of a desirable colour) and of expeditiously emptying the box. In shape no advantage is gained in departing from the square. Wooden covers are unnecessary as regards fermentation, but are frequently used with padlocks to prevent theft; for fermenting purposes the best cover is a thick layer of wild plantain or banana leaves. Devices, other than that mentioned, for facilitating "changing" of boxes are not recommended. Iron rails are in time affected by the acid juice, yet it is questionable whether any economic substitute can be found for them in building wooden boxes. In considering the building to contain these boxes the following recommendations are made: "Ruberoid" or some other "Giant Paper" roof, with full boarding underneath. Concrete or tile floor. Steep concrete drains communicating with an adjacent watercourse[1] if vinegar is not to be manufactured, the smell of decaying cacao juice being most objectionable. Plenty of head room

[1] This strikes me as tending to lead to friction on other estates or properties where the polluted water may pass.—H. H. S.

over first box to facilitate measurement of cacao and to ensure cleanliness and order inside the building, and an arrangement whereby carriers of cacao may deliver their load to the sweating box without entering the building. An ideal system of cacao-curing buildings under one roof would be:—



In such a building, all under lock and key, with clean concrete floors, and secure from adverse weather conditions, two charges of cacao per ordinary working day (or three charges working overtime) might be passed through the vacuum dryer and polisher, and each day's output from the sweating boxes bagged and sewn up the same day.[1] Economy would be exercised in time and all the advantages secured that this saving entails, such as land space, expenditure, supervision, labour, pilfering, and wastage. The building need not be an expensive one ; its capacity to deal with a crop would be in proportion to the size of the sweating boxes and the vacuum or machine dryer, and it should turn out the highest possible grade of cacao in the most unfavourable climatic conditions. Vacuum and machine drying and polishing will be dealt with in their place in this essay, also the non-advisability of washing or grading cacao.

Slate Sweating Boxes.

Before leaving the subject of sweating box construction it will be useful to mention some experiments on the writer's part to provide a smooth, continuous and more cleanly surface for the interior of sweating boxes than wooden boards. It is obvious to anyone with experience in this matter, and Dr. Nicholls has also commented on it from a bacterial point of view, that the worn surface and crevices of boards form an ideal breeding place for mildew and other undesirable germs which persist and multiply even when the boxes are empty.

[1] No matter how pressed for time, however, the cacao must be absolutely cooled before being bagged, otherwise it will develop exterior moulds.—H. H. S.

Also, it is difficult to keep such a surface clean and free from larger insects, cockroaches, &c., &c. In considering what acid-resisting smooth surfaces could be substituted for wood, the writer has passed over such materials as glazed earthenware, enamelled iron and "Ruberoid" in favour of planed slate. In order to test the properties of this material he constructed a slate sweating box of 1 in. planed slate with sloping floor and liquor exit. It was rather elaborately made with rounded corners and acid-resisting cement for joints, and was consequently more expensive than it need have been. However, planed slate in slabs is not an expensive material: I refer to the sort of thing supplied for old-fashioned public urinals. I have carefully experimented with this box, contrasting temperatures with wooden boxes, and am quite satisfied that in slate we have an ideal surface to make permanent linings for the interior of concrete sweating boxes in place of the loose wooden casings now used on most large cacao estates. Litharge mixed with liquid glass solution makes a suitable cement for joints. Possibly ½-in. or ¾-in. thick slabs would serve under these circumstances, but I am afraid slate would be too heavy and breakable a material for the sliding up partitions between the boxes; however, the lower 18 in. of this inter-partition should not be removable and could be made of slate while the upper part could be made of wood lined with "Ruberoid" as a single panel.

Fermenting Cacao.

The biological, entomological and chemical aspect of this process is fully dealt with by Dr. Nicholls in the next chapter, in this one the practical everyday side of the subject is treated.

The following axioms are submitted as having been borne out by the writer's experiments :—

(1) The higher the temperature attained and maintained for some days by primary natural fermentation, the better the class of cacao turned out. (The maximum limit of temperature attained by the writer's experiments was 119° F.)

(2) The addition of Dr. Lucius Nicholls' pure ferment and yeast food solution induces a higher and more prolonged beneficial fermentation.

(3) The daily "changing" of cacao from box to box by a wooden spade, thereby transferring the bottom seeds to the top, is most necessary to attain the best results.

(4) Beneficial fermentation ceases as soon as the bottom of a box falls belows 100° F.

(5) The larger the quantity of cacao fermented the quicker is a high temperature attained and lost; but small quantities, while requiring a longer period, can be fermented just as efficaciously as large.

(6) The preservation of heat and moisture by a thick leaf cover is a most necessary part of the process, but where a pure ferment is not added, the cover can be beneficially omitted from the first and second boxes to allow the "cacao fly" freer access to the beans to deposit fermentation germs on them.

The actual process of work in the sweating house is small and may be described as follows: The current day's picking of wet cacao invariably goes into No. 1 sweating box, and for the sake of clarity we may assume the picking commences on Monday. On Tuesday morning Monday's picking is overturned into No. 2 box, leaving No. 1 box empty to receive Tuesday's picking. On Wednesday morning Monday's picking is again inverted into No. 3 box, Tuesday's picking into No. 2 box, and No. 1 box is always kept free to receive the current day's picking. This process is continued until Monday's picking reaches the fifth, sixth, seventh or eighth box, and the bottom temperature is found to be rapidly declining when it is removed from the sweating box to the drying house. Where large quantities of cacao are fermented under "Fine Estates" conditions of curing (without the addition of a pure ferment), the first day's picking, say Monday's, will generally come out (from the sixth box) on Saturday morning, and is not unusually the worst fermented batch of the picking owing to the boxes being "cold"—

which in scientific language means "sparsely inoculated with beneficial ferments and largely inoculated (from the sides of the 'clean' boxes) with moulds and mildews." The first lot of cacao, if sufficient in quantity, can, at the expense of a day's delay, eventually attain a temperature that defeats the mould and mildew, and this high temperature and acetic acid of the second and subsequent batches completely routs these undesirable guests, and thus completes their fermentation in one day less than the first batch. If, however, the bottom temperature of the last box is allowed to fall below 100° F. the moulds and mildews immediately reappear, and this will mean discoloured, dark, ugly cacao already infected with mildew germs. With sun drying in unfavourable weather, mildew is most frequently communicated from the cracks in the drying floor to the moist seed. It is easy under these circumstances to perceive the advantage of maintaining thorough cleanliness in the interior of sweating boxes, of doing away with covered boxes and dark corners, and adopting single-piece sides of a smooth material that will not harbour spores.

It is necessary to maintain perfect drainage of the acid juice from the first two boxes. This is sometimes attained by a movable wooden grid or grating with spaces that retain the smallest seed while allowing the escape of the liquor. For wooden boxes a simple and efficacious plan is to pierce the bottom with a sufficient number of $\frac{1}{3}$ in. auger holes. For concrete boxes a bottom sloping down to a long narrow slit of an exit is preferable.

Much inadequate fermentation of cacao is due to an insufficient and carelessly arranged leaf cover. It is a simple matter to observe with a thermometer the loss in heat that takes place in five minutes by the removal of the leaf cover from a box of strongly fermenting cacao; such a loss immediately reacts on the fermenting organisms, lessening their beneficial action. Of course, heat is only a symptom of beneficial fermentation, but it is the most important symptom and its readings spell either success or failure. The most suitable covering for sweating boxes is the leaf of the wild plantain (*Heliconia bihai*), commonly called *Balissier* in French patois. Other leaves used in the West Indies are banana, plantain and tania. When fermentation proves difficult and incomplete it is much assisted by lining the bottom and sides of the box with wild plantain or banana leaves. As the heat generated in the first and second boxes is generally not much in excess of the atmospheric heat, the omission of the leaf cover from those boxes is recommended as allowing free access to the "cacao fly" (described by Dr. Nicholls), and thereby ensuring a more complete inoculation of the fermenting yeasts.

Another most important factor is a thorough and daily "changing" of the cacao. Although I had followed this practice for over twenty years, yet I never grasped its full significance until I instituted a thorough examination of fermenting temperatures. In one or two instances, through carelessness or over-pressure of work, the sweating box attendant for a single morning omitted to "change" the spare fermenting boxes with which I was experimenting: in every such case there was a marked loss of temperature. Even when "changing" had been conscientiously performed, plunging the thermometer, say twenty times, in different parts of a fermenting mass of cacao on the third or fourth day, when high temperatures are commencing, would result in six or seven different readings, with perhaps as much as 5° F. difference between the maximum and minimum; this demonstrates that fermentation does not take place as a uniform, continuous process throughout a box, but rather as the result of numerous independent colonies of yeasts, all working towards the same object but with varying results. It was made amply clear to me that although the "breaking bulk" process known as "changing" resulted primarily in a loss of temperature, identically the same as occurs from the removal of the leaf cover, yet within a few hours the thorough mixing and diffusion of the fermenting yeasts results in the temperature rising much higher than was the case when the box had been left "unchanged." It is a necessary part of this process that the bottom layers of cacao are always inverted to the top and *vice versa*. A wooden spade made for this purpose should always be used; not only is it lighter and more convenient to handle, but the contact of fermenting cacao with iron results in a stain on the cacao seed.

Negative Experiments.

Before leaving the subject of fermenting, it may prove useful to those interested in this matter to mention two experiments that were tried with unsuccessful results.

The first was simply pouring back again and again over the cacao the exuding liquid that oozed from the bottom of the box. There was no sign of increased or prolonged fermentation resulting from this procedure. The maximum temperature attained was 109° F. with 300 lb. of wet cacao, and it commenced to fail on the sixth day.

The second experiment was based on the assumed possibility that fermentation was prematurely checked by the production of acetic acid. It is a common phenomenon with quickly multiplying micro-organisms that, as a result of their rapid labours, their environment is self poisoned by the production of some substance which, as the quantity increases, becomes inimical to their welfare and eventually destroys them. As acetic acid is produced in quite perceptible quantities by cacao fermentation, an attempt was made to neutralize the acid by spraying the cacao with some cheap alkaline solution, such as dilute lime-wash. About 300 lb. of wet cacao were experimented with, and control experiments were also conducted under the same conditions. The result was that the temperature was lowered throughout the course of the experiment by about 2° F. (reaching a maximum of 111° F.), and that fermentation was not prolonged beyond the usual time. The resulting sample showed a lighter colour than ordinary well fermented cacao, but otherwise had a good "break" and taste. In unwashed samples the presence of lime was perceptible on the exterior of the seed. Some 5 gallons of lime-wash, composed of sixteen parts water to one part lime, were sprayed on during five days.

Temperatures with Ordinary Fermenting Methods.

The following table gives a fair idea of cacao temperatures under ordinary estate conditions of fermentation. The average air temperature was 78° F. and the average humidity 79. The boxes were changed daily and readings taken at 7 o'clock each morning.

It is noticeable that the smaller quantities require more time to complete the process, but it does not follow that a more moderate fermentation continued over a longer period is not as efficacious as the higher temperatures and shorter period of the large lots.

CACAO TEMPERATURES—FAHRENHEIT.

$\frac{3}{4}$ day	$1\frac{3}{4}$ days	$2\frac{3}{4}$ days	$3\frac{3}{4}$ days	$4\frac{3}{4}$ days	$5\frac{3}{4}$ days	$6\frac{3}{4}$ days	$7\frac{3}{4}$ days	Quantity wet	Box
°	°	°	°	°	°	°	°	lb.	
(1) 85	96	110	117	114	{ 110 top, 106 bottom }	—	—	2,000	Wood.
(2) 84	95	110	112	115	114 top ...	—	—	2,000	,,
(3) 69	90	112	119	117	115 top ...	—	—	2,000	,,
(4) 87	105	115	116	117	114 top ...	—	—	2,000	,,
(5) 88	106	116	119	116	116 top ...	—	—	2,000	,,
(6) 76	81	90	109	108	108 ...	102 top	—	200	,,
(7) 79	90	94	101	117	114 ..	109 top	—	400	Slate.
(8) 78	87	88	101	109	108 ...	105	94 top	300	,,

TEMPERATURES WITH DR. NICHOLLS' FERMENT AND SOLUTION.

Conditions identically as above.

CACAO TEMPERATURES—FAHRENHEIT.

$\frac{3}{4}$ day	$1\frac{3}{4}$ days	$2\frac{3}{4}$ days	$3\frac{3}{4}$ days	$4\frac{3}{4}$ days	$5\frac{3}{4}$ days	$6\frac{3}{4}$ days	$7\frac{3}{4}$ days	$8\frac{3}{4}$ days	$9\frac{3}{4}$ days	Quantity wet	Box
°	°	°	°	°	°	°	°	°	°	lb.	
(9)*71	82	87	108	112	*111	114	113	110	96 top	300	Slate.
(10) 80	88	96	114	*108	111	113	108	—	—	200	Wood.

In these two experiments the ferment and solution (from $\frac{1}{4}$ pint to $\frac{1}{2}$ pint in each case) was sprinkled on the cacao on the three days marked with asterisks; on two of these occasions the temperature was undoubtedly failing, but recovered immediately after the addition of the yeast culture and its food solution.

The cacao resulting from Experiment No. 10 showed the effect of fermentation by this method; it is probably worth 1s. to 2s. per cwt. more than that produced by the other experiments. Unfortunately, a prolonged spell of exceptionally wet weather prevented a favourable sample being obtained from Experiment No. 9.

Two other experiments, in adding to fermenting cacao pure cultures of two other varieties of wild yeasts, isolated by Dr. Nicholls from fermenting cacao, did not yield such good results as those detailed, and it was therefore demonstrated that the variety of yeast used in Experiments 9 and 10 was the best.

It is obvious, if Dr. Lucius Nicholls' method of fermenting with a selected pure yeast is to come into general use on cacao estates and with cacao-buying firms, that the business of producing and distributing this yeast at a nominal price must be taken in hand by the Government Agricultural Departments now existent in almost every cacao-producing country. This paper will probably have demonstrated that this scheme for the improvement of cacao fermentation at least merits a continuance of experiments by the mycologists of the different Agricultural Departments, and that in the event of their conclusions showing the desirability of pure yeast inoculation (which process in kindred trades where fermenting is practised has entirely superseded all other methods) a very strong case will be established for the cheap distribution of the materials recommended. It is also greatly to be desired that investigation on this subject be continued by experts interested in tropical agriculture, for it is not contended that the last word has, by any means, been said on the subject in this essay.

Drying.

As shown in previous figures, some 25 per cent. of weight is evaporated during fermentation, and about 39 per cent. during subsequent curing, leaving a residue of about 36 per cent. cured cacao (of ordinary type). These figures are only approximate, and are quoted merely to give a clear view of the process.

It is suggested here that the improvements in cacao curing which may be effected will lie principally in the direction of:—

(1) The constant production of a high-class sample irrespective of weather.

(2) Economy in working expenses.

(3) Economy in utilizing a limited labour supply.

(4) Saving in wastage and pilfering.

(5) In greatly expediting the whole process, thereby saving both time and money.

The expense of fermenting cacao efficiently stands in a very small proportion to the entire cost of curing. Taking the actual labour wages for curing cacao as costing 1s. 6d. per cwt., it is probable that of this amount one penny per cwt. would cover the cost of fermentation. It is obvious, therefore, that when studying economy the cost of fermentation stands as a negligible quantity in comparison with drying, polishing, &c.

Drying appliances and methods are quite as numerous as the different types of fermenting boxes, but in actual estate practice quite 90 per cent., if not more, of the world's cacao output is dried in the sun. Some few estates combine sun drying with a hot-air chamber for wet weather and to enable them to continue drying during the night in times of crop pressure, and within the last ten years many of the larger estates in the West Indies have, at a cost of £1,000 to £1,500, established rotary drying machines, which force heated air through the constantly agitated cacao, completing both the curing and polishing process in thirty-six hours' continuous working. A fourth method worthy of notice is vacuum drying, which I believe has only been experimented with on one or two cacao estates throughout the world. I shall deal as briefly as possible, without "scamping" the subject, with these different methods, endeavouring to indicate what I venture to think are the best types.[1]

SUN DRYING.

To a superficial observer the thought will easily occur, that, "surely in a tropical climate no drying power could be cheaper than the sun." It is necessary, however, not to overlook the fact that in the average cacao climate $\frac{1}{4}$ in. of rain per twenty-four hours, or 90 in. per year (that is, roughly, four times the rainfall of London), is the usual precipitation; further, that in most parts of the cacao-producing world the period of heaviest rain occurs identically with the period of heaviest pickings, and then it not infrequently happens that rain falls almost incessantly for a week or more. In the absence of sun for this period, and with an atmosphere in which the hygrometer readings show saturation point for days at a stretch, it may readily be believed that the most perfectly appointed sun-drying house (commonly called "boucan" in the West Indies) fails to comfort its possessor whose fermenting boxes keep on delivering cacao to

[1] Since these notes were written, other processes have, of course, been introduced, or at least discussed. —H. H. S.

the drying trays, where it accumulates, blackens and commences to smell abominably while the powerless planter paces his verandah and scowls at the weather. It is a situation known to every strenuous cacao planter, and in time we learn to take it philosophically—or arrange for hot-air drying. I have not led up to this situation with the view of inciting sympathy, or entirely to decry sun drying, but rather to suggest that if fermentation can be continued during this weather, beyond the usual five or six days, and continued to nine days or more by the help of the inoculation of active yeasts and a food solution for them sprinkled on the cacao, the situation would lose much of its depressing influence, and the produce would be rather benefited than depreciated in value.

Sun drying, however, as an auxiliary to more modern methods, and as a standby in case of accidents and machinery breakdowns, is most useful, and, by reason of the large amount of capital already invested in "boucans," cannot be disregarded. Cacao planters are somewhat conservative, and it is probable that on small estates sun drying will always be the method of curing employed.

The type of "boucan" recommended is the large, simple, sliding roof pattern, so often seen in Trinidad, but with a smooth concrete floor and side border in place of the usual pitch pine flooring and sides. The flooring should not be elevated more than is necessary from the land.

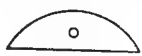
Compared with the type of "boucan" consisting of a number of trays on wheels, the sliding roof pattern may not be the cheapest house to build as regards providing so many superficial feet of drying space for so much money, but it will be found the cheapest house to work, and that point is infinitely more important than initial cost. The roof should be covered with light galvanized iron sheets, 28 gauge. The span should be from 16 ft. to 20 ft., and the length should be just as long as will allow of one man pushing each half roof to and fro easily. This will depend on the skill in construction, lightness and trueness of the roof, and the iron rails and style of wheels used, 50 ft. length being taken as a minimum; the outside rails should be supported on concrete pillars. This type of "boucan" may be multiplied to meet the needs of a large estate. The advantage of economy in working is all in favour of the large floor space; small trays involve too much labour in constantly shifting the cacao from one tray to another, to make room for new batches as curing progresses, and also involves too much dropping of seed on the ground in the process. It is quite impossible to efficiently deal with mildew on a wooden drying floor, consequently batch after batch of cacao coming from the fermenting boxes receive their inoculation of mildew, which lives on the skin of the seeds, until more or less efficiently removed by polishing, and even that does not always prevent this blemish from sometimes penetrating to the interior of the seed. It would probably be useful to follow the procedure used in military stables, and incorporate an appreciable quantity of powdered sulphate of copper in the upper "rendering" of the concrete floor. Where a wooden floor already exists, a covering of very thin copper sheeting, with as few joins as possible, would probably prove advantageous. The idea is to provide a surface free from cracks, in which mildew spores cannot persist, and which can be effectively cleansed with a bucket of water and a hard broom.

As to the space required per 100 bags of cacao, no hard and fast rule can be adopted. Some estates get more than half their crop within a few months of the year,[1] other estates with lighter soil and younger trees divide the crop much more equitably throughout the year. Again, some estates near the sea-coast or on flat, open land get much more sun and less rain than other plantations situated up in the hills. Without auxiliary artificial heating probably 5 superficial sq. ft. per cwt. of dry cacao produced would not be excessive. With an auxiliary hot-air chamber or machine, probably

[1] The Gold Coast returns, for instance, show that out of an export of about 40,000 tons cacao, some 28,000 tons, or 70 per cent., were exported in the four months November-February.

3 ft. per cwt. would suffice. Where drying conditions are favourable these figures may be reduced by about 25 per cent.

Briefly described, this well-known sun cacao-drying process is as follows. The fermenting boxes are examined about 6 a.m., and if the cacao is fit to go out on the "boucan" it is carried in baskets over the short space separating the "boucan" from the fermenting house and deposited on the drying floor or trays. It is then raked over until the seeds lie two or three deep. When this work has to be done, one of the end pieces of a barrel head, in shape



THE PALETTE.
Made from the end piece of a barrel head.

describing a quarter circle (see illustration), is mounted on a rough straight handle of convenient length, and the straight edge is used to rake the seeds smooth. In order to allow the bottom of the floor (now completely obscured by damp cacao) to dry out and become warm in the sun, the cacao is, at half hour intervals during the first morning, heaped into small ridges a few inches apart, for which purpose the sharp points of the quarter circle are used, exposing each time a different surface of the floor between the ridges. When the cacao is more thinly deposited on the drying floor, this process of ridging is unnecessary, but the seeds are continually being turned by hand or some wooden instrument, such as the "palette" shown on p. 192. It is impossible to get too much sun on the cacao during the first day or two[1]; the more sun and the more frequently the cacao is turned the better the sample, provided fermentation has done its part. The cacao should be "picked over" during the first day, all "placenta," empty seed skins, pieces of pod, leaf and other foreign matter removed, and all adhering beans separated from one another. On the morning of the second day, unless conditions of sun, evaporation and mildew infection have been very favourable, an almost imperceptible film of mildew is present on the seeds which later on becomes quite unmistakable. On the morning of the fourth day "dancing" or "polishing" is generally done, which process, as described later on, removes the mildew more or less efficiently, and substitutes an attractive gloss. Another three to four days' good sunning with the cacao, frequently placed four to five seeds thick, completes the drying, although quite frequently in unsettled weather the entire process of

[1] I always found it better to close the house from 11—2 during the first day, and from 11—1 the second day, as the excessive heat on the beans fresh from the sweating-box caused them to shrivel and go "lean."—H. H. S.

drying occupies a fortnight or more. Of course there is thorough protection from rain during the whole of this period. The test of thorough drying is made by breaking a number of seeds across the thumb-nail and observing the condition of the heart of the seed. If this appears slightly lighter in colour than the rest of the seed, or shows signs of moisture on the indentation of the thumb-nail into the centre of the seed, then further drying is required. On the other hand it is easy to over-cure cacao, losing thereby considerable weight with no corresponding advantage of increased price. A good easy "break" or fracture across the thumb-nail is the distinguishing mark *par excellence* of well-fermented cacao: it implies a certain degree of plumpness, of air spaces between the convolutions of the cotyledons, and an easy separation of the outside shell from the kernel—all of which tell of thorough fermentation. For the average "fine estates" cacao a well-polished mahogany colour is esteemed, as showing thorough fermentation, but it must not degenerate into black. For higher class cacaos, such as Criollo and Pentagona, a more attractive red, *i.e.*, more of a cinnamon tint, may be aimed at.

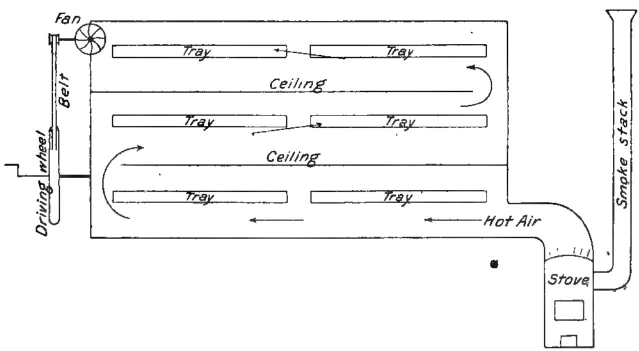
Artificial Drying Apparatus.

"Whitfield Smith" Hot-air Dryer and its Modifications.

Under this name I refer to the drying

arrangement erected at the Botanic Station, Dominica, by the Imperial Department of Agriculture for the West Indies. Its idea originated with Mr. Whitfield Smith, now Commissioner of Carriacou. As erected at Dominica, the building consists of a large open shed covering an inner wooden building containing six large cacao trays on wheels and rails, arranged in three planes of two trays each, with an outer extension of iron rails whereby the six trays can be pulled out and their contents thoroughly turned over and picked over without danger of wetting from rain. There is, however, no arrangement by which sun heat may be utilized. The interior building, with its tray shutters, is made air-tight as far as possible, and at one end hot air is led into the lower plane of two trays from a No. 28 iron "Comet" stove (made by the J. L. Mott Iron Works, 84, Beckman Street, New York—cost about $40); this hot air is confined to the lower plane by a ceiling until it reaches to within 18 in. of the end of the building, when this space is left open in the ceiling to allow its ingress into the second or middle plane of two trays. The ceiling above this middle tier is also closed to within 18 in. of the opposite end, thus forcing the hot air to travel over and under the trays, and the process is repeated in the top plane, at the further end of which is placed an 18 in. Blackman ventilating fan (cost about £5, without driving wheel), worked by hand power, which assists materially in drawing the heated air through the building. The driving wheel should be 5 ft. in diameter, with a central grindstone handle, and built locally of wood—lead being added to the driving rim. The following rough sketch of the inner building may assist in giving a clearer idea of the process.

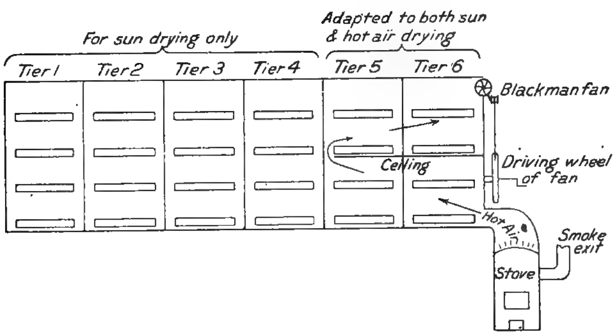
In the original idea, as explained above, it



Plan of the "Whitfield Smith" Hot-air Dryer.

has not been largely followed in the West Indies, although it has many advantages. Its weak points are expensiveness in labour, fuel, and supervision, taking into consideration that it would probably take three to four working days of ten hours each to completely dry a charge of cacao, and that at least two men would be required, and about one cord of firewood, value 4s. to 8s.

The writer has adapted the following modification of the above plan to a portion of an old-fashioned sun-drying "boucan," with a capacity of six tiers of four trays each, or twenty-four trays in all. The interior compartment of eight of these trays (*i.e.*, two tiers) has been made air tight (with double walls filled with sand), and fitted with specially tight shutters and hinged steel rails that obviate the necessity of any rail hole in the shutter, yet allow of the trays being run out into the sunlight when the shutters are removed and the hinged rails swung into position. It was found that a single ceiling in the centre of the tier broken by an 18-in. space at the end furthest from the stove acted better than a ceiling over each plane of trays. The diagram of the "boucan" is, roughly, thus :—



Mr. Hudson's modification of the "Whitfield Smith" Hot-air Dryer.

This arrangement must be regarded as an

additional help to drying and an insurance against the "weathering" of cacao during rush of crop and very wet weather. It is unnecessary to use it more than two or three months in the year and then seldom in the day time, but generally between the hours of 4 p.m. and 10 p.m. The tray flooring consists of copper wire mesh with ¼ in. apertures supported by wooden battens, and the hot air chamber is principally used for drying cacao quickly after polishing, thus retaining its gloss and attractiveness. Its recommendation lies principally in the fact that the two tiers adapted to hot air drying are quite as capable of taking advantage of sun heat and wind evaporation as the remaining four tiers of the "boucan," and the change to hot air drying is effected without shifting the contents of the eight trays. This factor, allied to the small cost entailed in the arrangement, constitutes its advantage and economy. The trays each measure 12 ft. by 6 ft. Two men are employed in the evenings to tend the stove and turn the driving-wheel of the fan at a cost of 6d. each. Three to four cords of firewood prove sufficient to deal with 100 bags or more of cacao. In the morning it is usual to find the cacao quite warm, although fan and stove operations have been suspended since 10 p.m. The maximum heat advocated is 130° F., but usually 110° will be found sufficient. I do not advocate this scheme as by any means a perfect one, but it is economical to apply to existing "boucans," cheap in working and satisfactory in results. This statement does not by any means obviate my objections to the relative expensiveness of labour on "boucans" containing a series of small trays, but only illustrates how to make the best of existing sun-drying buildings.

Rotary Hot-air Dryers.

For large estates, producing over 500 bags, the "Gordon" Machine Dryer (Messrs. John Gordon and Co., 9, New Broad Street, London, E.C.) seems to have almost a clear field and no competitors, although very many of the most intelligent planters prefer to rely on hot-air chambers of varying construction, but all embodying the same principle as the "Whitfield Smith" chamber, or very nearly approaching it. One can only imagine from the expensive plants of "Gordon" Dryers one sees being installed on large properties at Grenada, Trinidad, and elsewhere, that these machines give satisfaction when large crops have to be dealt with. The plant, including buildings, varies in cost from £350 to over £1,000, and is capable of treating from four to thirty bags of dry cacao in one charge with continuous working of thirty-six hours.[1] The sample turned out is an attractive one, as a

[1] In Grenada, I am told, only twenty-two to twenty-six hours are necessary.—H. H. S.

polish is secured at the same time by the long-continued slow rotary motion. It is also claimed that there is an advantage of resultant weight over sun-drying by this process, and its users more or less endorse this claim. The machine may be briefly described as one or two large cylinders rotated slowly by a steam engine which also works a powerful hot-air fan. These cylinders have a hollow axle, with radial perforated tubes through which the hot air is forced in all directions from the interior to the exterior of the slowly moving cacao. There are also specially designed protuberances from the core that facilitate the thorough mixing and polishing of the mass. I have seen several of these machines at work and they have given satisfaction, although considered to be distinctly costly. Points that have been raised against them are: the large amount of wood fuel they consume, and the liability of boiler tubes to burn out and require replacing within two years. On many thoroughly developed estates in Grenada the fuel question is becoming a serious expense and difficulty, but in less developed cacao countries fuel should be plentiful for many years to come. It must be noted as a very salient feature of the subject that most estates possessing "Gordon" Dryers are usually content to use them as a "stand-by" and cure a large proportion of their crops by sun-drying.

For smaller properties the "Hamel Smith"

Rotary Cacao Dryer is a machine that has lately been put on the market and promises good results. It is extremely difficult for the planter to become conversant with the advantages and defects of new machinery of this kind, unless individual planters take the risk of ordering some of these promising, but untried inventions. As an instance, the Gordon machines have been on sale for twenty years, but it is only within the past five years that they have become appreciated in the West Indies. The work of testing new inventions of this kind should be taken up by the agricultural bodies for the guidance of the agricultural community, as it is hardly fair to individual inventors, makers or planters, to leave them to bear the cost of experimental work whereby all benefit, if only by ascertaining that the machine cannot be used with advantage.

Vacuum Cacao Dryers.

I am strongly of opinion that the ease, economy and certainty of drying cacao *in vacuo* will eventually cause it to supersede all other methods on estates producing 100 bags or more annually. In West Indian central sugar factories no other method of boiling sugar but in vacuum pans has been entertained for the past forty years; and although many of these factories cannot afford highly paid engineers, yet the difficulty of obtaining an efficient vacuum (which is the generally expressed objection to this system) has not been found a prohibitive factor or even one entailing difficulty. It may be imagined that this process of evaporating, or concentrating in vacuum, is a new and untried one, but as a matter of fact hardly any sugar factory is complete without a vacuum dryer or concentrating pan. I have before me a list of the manufactures in which the vacuum process is used, but I fear it is much too long to inflict on my readers; it may be said to comprise nearly all the vegetable products of the world, and of its economy as regards fuel, labour, time, space, supervision, and money, in comparison with all other systems of drying and concentrating, not a doubt can exist.

In 1908 the writer arranged for a cacao-drying trial in vacuum in his presence at the works of Messrs. George Scott and Co., Ltd., London. Two barrels of nearly ripe cacao pods were sent to England in the cold-air chamber of a Royal Mail steamer, and arrived in good condition. The seeds were then soaked in water, drained, and placed in a vacuum dryer made by that firm. A vacuum varying from 28 to $28\frac{1}{2}$ was established, and the interior heat was regulated to 95° to 100° F. Two trials were made, and in each the dryer was opened after five hours, when the cacao was found to be slightly over-dried. Considering the cacao had not undergone regular fermentation the sample proved quite satisfactory. The makers were of opinion that with fermented cacao and a constant vacuum of 28, drying would be efficiently performed in three and a half to four hours, and I quite agree with this opinion. During the time the cacao was drying the only work entailed on the attendant was to regulate the temperature and see that a good vacuum was maintained. This trial quite converted me to the advantages of a cacao vacuum-dryer, and pointed out possibilities and benefits non-existent under other systems. Makers of vacuum dryers claim that owing to low temperature, rapidity of drying, and absence of hot-air currents, the essential oils and volatile salts forming the aroma and flavour of cacao are retained, and also the plumpness of the seed and its attractive colour. This claim has much to recommend it. Also, with a given vacuum and uniform temperature identical results could always be obtained within a definite period, and a rule of thumb method adopted by the untrained native attendant whereby the difficulty of curing successive batches of cacao to a recognized standard of colour, dryness and appearance would disappear. The space occupied by such a plant is very small, consequently there would be economy in buildings, also in fuel, in water, in wear of machinery (as nearly all parts are stationary), and one man could lift the drying trays out, and put a fresh set in, do all the necessary work of refilling a set of spare trays for the next charge whilst the first charge is being dried, close the air-tight door, start the exhaust pump, and regulate the temperature. At first glance it would appear advisable to use a rotary vacuum cylinder in place of a stationary rectangular vacuum chamber in order that polishing might be effected at the same time as drying, but, taking into consideration additional difficulties in preserving a good vacuum in a rotary machine, and the fact that four hours' slow rotating would not perceptibly polish the seed, one is forced to conclude that with the beans placed three or four deep on the trays it would be necessary to break the vacuum after about one and a half hours' drying, and pass the beans through a polisher for ten minutes to give them the best appearance, and prevent them adhering to one another, and then return them to the dryer to complete curing. If cacao "washing" were economically possible, polishing might be saved and the drying process in vacuum carried out straight to its end, when a very slight hand manipulation would serve to separate adhering seeds. With the necessity of polishing, an average day's work would hardly cover more than two charges of the dryer, but during crop pressure three charges per diem might be put through. This point is of importance in establishing the size of dryer necessary for an estate, and due regard must be paid to the fact that the average "boucan" attendant is very dilatory unless under direct supervision of the "boss." In computing the drying area necessary it is safe to assume that on most estates two-fifths of the crop is reaped within two months, or, say, fifty working days; therefore a 250-bag estate would require to dry 100 bags within fifty days, a 500-bag estate would require to dry 200 bags within fifty days, and so on. Taking two bags a day as a minimum day's picking, even on a 100-bag estate (bags of 200 lb. dry) we should require to deal with about 1,200 lb. wet cacao per diem, or about three charges of 400 lb. each, at the busiest time. Messrs. Scott's No. 1 machine would contain 400 lb. wet cacao each charge, with a tray surface of 56 sq. ft., and the beans 2 in. thick.[1] Such a dryer would cost about £140[2] complete in England. The next size, No. 2, can take 600 lb. per charge, and with three charges per day would dry three

[1] There must surely be something wrong here, but although we returned the MS. to Mr. Hudson to be corrected, he still passed these measurements. It is impossible, however, for 400 lb. wet cacao to be spread over a space of 56 sq. ft. by 2 in. thick.—H. H. S.

[2] I believe these figures no longer hold good, even if they were correct at the time. The Passburg Dryers, at any rate, cost to-day (May, 1913) as follows: No. 9, to take about 3 cwt. wet cacao, £360; No. 12, to take 5 cwt, £430, deld. f.o.b. Hamburg. For such sizes this works out at about 1 lb. of fermented beans per sq. ft. of heating surface, so that the price gives some idea of the capacity of each size of stove.—H. H. S.

bags of 200 lb. each, and would cost about £210 in England. It is obvious that if we can cope with times of pressure, the rest of the year's crop can be easily safeguarded. The machines of Emil Passburg, of Berlin, are more expensive, but it is only fair to say that their reputation is very high. Apparently Passburg's machine, capable of taking 3 cwt. of wet cacao in one charge, costs £300 in Berlin without boiler or pump, while a Passburg dryer to contain 13 cwt. per charge is quoted at £700[1] complete with boiler, pump, and extra trays; one pump and condenser can, however, be used with three or four drying chambers for very large crops. This latter machine should turn out six and a half bags of 200 lb. each of dry cacao per day, and should therefore be able to handle a crop of 800 bags per annum; its cost, therefore, in comparison with the price of Gordon dryers, does not seem excessive. The Passburg dryers have apparently gained repeat orders from cacao estates in the Cameroons and West Africa, and they are also used for rubber drying in the Malay States. It is quite possible that difficulties may arise at the outset in the manipulation of these dryers, and it is this fear that deters planters with little or no engineering experience from putting down their hundreds of pounds for new machinery. I again suggest that it is the business of the different State-

[1] This ought to be about £825.—H. H. S.

aided agricultural departments and societies to try preliminary experiments with these machines, and according to results report favourably or unfavourably upon them. It is more than probable that the makers would be only too pleased to co-operate in these trials with a view to lessening the cost. The prospect of taking one's cacao from the fermenting box at 6 a.m. and getting it dried, polished, bagged up, and carted away by the afternoon will appeal to most planters as a most desirable state of things, which we may hope some day to realize, as others are apparently doing even now.

Washed Cacao.

While one cannot doubt that the large cacao buyers in Europe and the United States are trained, keen experts at their trade, it is a curious point to the planter that they will pay 2s. per cwt. more for "polished" or "clayed" cacao, which only improves the superficial appearance and adds to the weight without improving the quality in any appreciable degree, and yet can only be induced to give the same advance on ordinary prices for "washed" cacao, which, according to general observation, frees the beans from gums and other extraneous matter (which should be of no use to the manufacturer) to the extent of from 4 per cent. to 15 per cent. in dry weight. My own experiments place the loss in weight resulting from washing at 7 per cent. Only on the assumption (which we hesitate to accept) that the testa or seed skin, with its adherent matter, is used indifferently with the seed contents in manufacturing chocolate or cocoa, can one justify this valuation. In consequence of this anomaly, cacao washing is only practised with the higher grades of Ceylon, Central American and Samoan cacaos.[1] It does not pay the producer of West Indian, Brazil and African cacao to lose 7 per cent. in weight and gain 2s. per cwt., even at the present depressed value of cacao, and it is distinctly unfortunate for both producer and manufacturer that such is the case. We contend that if the manufacturers see their way to pay, say, 55s. per cwt. for a sample of unwashed, polished "Fine Estates" Grenada or Bahia, they should also be in a position to offer at least an equivalent of 7 per cent. more for a good sample of "washed" cacao, or, say, 58s. 6d. per cwt., for they get 7 per cent. more cocoa and 7 per cent. less skin and other detrimental matter. There is little doubt that a "washed" cacao is a finer product than "clayed" or "polished" seed. Owing to the early removal of pulp, gums, and products of fermentation from the seed skin there is very little tendency to mildew,

[1] That is to say for Criollo, *i.e.*, the thin-skinned variety.—H. H. S.

which subsists principally on these unnecessary substances.

The process of airing "washed" cacao differs somewhat from that heretofore described. On the morning of the day previous to that on which fermentation is anticipated to be complete (*i.e.*, twenty-four hours earlier) the cacao is removed from the fermenting box and thoroughly washed. It is then exposed to the sun for a few hours, and while still slightly damp and heated is returned to a sweating box lined with large leaves and carefully covered until next morning, when a further fermentation will be found to have taken place. It is then placed on the drying trays, when it will only mildew under the most adverse conditions (in which case it is again washed), and given good sunny weather, attains a thorough degree of dryness within four or five days. The colour of the beans is a clear, attractive red, and they retain their plumpness and good "break."

Claved Cacao.

This process consists of sprinkling a very finely powdered red earth on the seeds on or about the second or third day of drying and working it into the cacao by trampling with bare feet. It imparts a characteristic dull red uniform colour to the sample, and this appearance is recognized as being distinctive of a certain class of Trinidad and Venezuelan cacao.

Beyond possessing a deterrent effect on mildew it cannot be said to constitute an improvement in curing, neither does it add materially to the weight, as the quantity of powdered earth used rarely exceeds 1 per cent. of the cacao weight, the value of which does not cover the cost of the materials plus the labour involved. Originally this plan was practised by a few estates turning out a superior high-class sample, and the higher prices obtained were doubtless more due to this fact than to the addition of coloured earth. Nowadays many shippers of inferior cacao use "clay," and it is no longer a hall-mark of good quality; its use, therefore, is not recommended.[1]

Feet Polishing, or "Dancing."

Cacao is generally fit for "polishing" on the morning of the third or fourth day's drying. If attempted at too early a stage the gloss attained will be poor and evanescent owing to the presence of too much moisture in the seed, while if delayed over long the seeds become too brittle and are liable to crush under the process of polishing, which consists really of rupturing the oil cells just beneath

[1] Unless it is to hide outer defects of the beans; the tendency of late has been to send less clayed cacao, especially Venezuelan, to market. One of the leading American makers seems to be especially averse to pay for the extra weight, even if it only amounts to 1 per cent., as Mr. Hudson claims.—H. H. S.

the surface of the seed skin by applying considerable friction to the mass of cacao. To obviate crushing and to allow the seeds to glide easily over each other they are slightly damped by sprinkling water on them just previous to polishing. One pint of water per hundredweight should be ample. The operation of dancing is sometimes performed on the flat surface of drying trays, or on a floor in the drying house, when in addition to the "dancers" it is necessary to have other attendants to continuously sweep back the cacao under the feet of the polishers. A more economical way is to utilize some receptacle with curved, bowl-like sides so that the cacao automatically falls back under the "dancers'" feet; for this purpose the old-fashioned Muscovado sugar boiling iron "tayche" is remarkably well suited and is much in favour. The labour involved before the seeds attain a good "gloss" is rather tiring, as each batch of cacao of say 2 cwt. will take two men half an hour or longer to polish. On many estates it is performed by "task" work at the rate of 3d. to 4d. per bag of 180 lb. (dry weight), and then, of course, the work proceeds more expeditiously, but there is every temptation to add too much water to quickly attain a fictitious polish which is not retained permanently. The gloss should proceed from the ruptured cells permeating the seed skin, and giving it a darker, shiny, and much improved appearance from which signs of mildew have disappeared, except in very badly mildewed cacao, where evidences of it may still be seen persisting in the deeper wrinkles of the seed. When sun-drying is relied on, it is necessary that polishing should not be continued much after mid-day, in order that the seed may receive sufficient sun heat when replaced on the drying floor to preserve their gloss and obviate any further chance of mildew during the night, which would entail another "dancing" next day. It is a tedious, annoying, wasteful and unprogressive manner of effecting work which can be as efficiently done in ten minutes by a machine at a saving in expense, an improvement in the product, economy of supervision, and the liberation of many workers for more useful estate work.

Machine Polishers.

Within the past three years two machines for polishing cacao have been placed on the market, both of which have proved their capability of polishing from two to two and a half bags (of 200 lb. dry weight) of cacao in ten minutes; there are also smaller hand machines of the same types, the utility of which is as yet doubtful. The two successful machines are both worked by small oil engines, or any other available power.

The *Malins-Smith Polisher* consists of a wooden cylinder to which, by means of a countershaft, two separate actions are communicated—viz., a slow revolving action fifteen times a minute to the cylinder, in the interior of which six wooden sticks or spindles are geared to revolve at the rate of 360 times a minute. The writer purchased one of these machines from the makers, Messrs. J. Gordon and Son, London, for £40, but owing to unsatisfactory workmanship and materials great difficulty was at first experienced with this machine, which is unfortunate, for Mr. Malins-Smith's invention is a very simple and good one. However, by employing a more powerful engine[1] and running the machine constantly, either empty or with small loads of cacao, the working has gradually become easier and is now satisfactory. A single machine at "Diamond" Estate, Grenada, handles easily a crop of 1,100 bags. The choice of a good oil engine of suitable horse-power is half the battle with these machines, and the advice of the inventor (Mr. W. M. Malins-Smith, Grenada) should be taken on this point. Contrary to what one might expect with rapidly moving parts, there is less crushing of seed with machine polishers than by the old-fashioned foot method.

The *Barnard machine*, invented by Mr. George Barnard, of St. Lucia, consists of a slowly revolving iron cylinder in the lower half

[1] Insufficient horse-power was the trouble throughout, I believe.—H. H. S.

of which four rubber-clad metal feet work quickly to and fro on eccentrics. I hear the highest reports of its efficiency and believe the price of the 2½ bag "Barnard" machine, made by Messrs. Gillespie Bros., London, to be somewhat less than that of the "Malins-Smith."

We thus have two machines which, when properly put on the market, are quite capable of polishing about 500 lb. cacao (dry weight) in ten minutes, at an expenditure of about one halfpenny for gasolene or kerosene. Allowing time for filling and emptying the machines, starting the engine, &c., from twenty minutes to half an hour should be occupied with each charge, and one man only is required in attendance. The principal advantage, however, lies in the fact that by 8 a.m. each morning all polishing is finished, and the cacao is again in the sun, minimizing chances of a second attack of mildew and practically guaranteeing the retention of a fine gloss on the seeds and a consequently better sample and higher price. By their use the "dancing" gang would be practically abolished. The whole cost of such an installation may be taken (including the best type of oil engine) at £100, equivalent, at 6 per cent. interest and 6 per cent. depreciation, to an annual charge of £12 a year on initial cost. Taking this into consideration, plus the cost of motive power and lubricating oil, &c., &c., we have no hesitation in affirming that estates producing 200 bags and over will find it economical and convenient to polish by machinery.

Bagging.

It is unfortunate that the term "bags of cacao" is used so largely in cacao statistics and estate returns, for it is susceptible of the most elastic interpretation. Thus a St. Thomé bag weighs 60 kilos, or 120 lb., and the Trinidad and Grenada bag is generally conceded to be 180 lb., while many cacao bags weigh as much as 240 lb. It would certainly be better to talk of cwts. or kilos, than of bags of cacao, unless some definite standard of weight is implied by that term. Taking into careful consideration: (1) The cost of the bag; (2) filling, sewing and marking; (3) transport to shipping place; (4) cost of warehousing and shipping; (5) freight rates; (6) dock charges; (7) deductions for tare and tret on London and Havre basis; and (8) public sale charges, it will be found that the bigger bag, not exceeding 229 lb. gross, favours economy from beginning to end. The empty bag should weigh slightly under 3 lb.,[1] and the London account sale net weight, allowing 2 lb. for "tret," should work out at 2 cwt. per bag.

[1] This is too light for a bag capable of holding over 175 lb., which should weigh $3\frac{1}{2}$ to $3\frac{3}{4}$ lb., otherwise it would be too thin to stand the knocking about the bags get *en voyage* and might burst, causing the beans to leak out.—H. H. S.

By-products.

VINEGAR.

A careful measurement of the liquor oozing from cacao fermenting boxes gives 4 imperial gallons, or about 20 litres, of juice per bag of 200 lb. dry. Thus for every 100 bags produced there would be 400 imperial gallons of juice to deal with in the first instance. This quantity would be reduced by evaporation, fermentation, and filtering over at least two months' treatment, so that it probably would not yield more than half its original measure, or 200 imperial gallons of vinegar. Assuming that a fair vinegar was turned out, and taking into consideration the quality and price of the English malt and French wine vinegar now generally exported to the Colonies, the producer of cacao vinegar might reasonably expect to receive 2s. to 2s. 6d. per gallon wholesale. This would represent a gross return of, say,[1] £20 per 100 bags cacao at 2s., or £25 at 2s. 6d. per gallon. Very occasionally one meets with cacao vinegar that appeals to the palate as the very perfection of vinegar; although it is not deficient in strength (as

[1] If, therefore, taking one centre alone, Trinidad exported 300,000 bags of cacao in a year, as it could and should do, the vinegar forthcoming should, on the above basis, be worth 3,000 × £20 = £60,000 at least, and perhaps £75,000. This is not at all a bad sum for a by-product at present running to waste, and by doing so proving an expense and a nuisance. —H. H. S.

Dr. Nicholls' analysis shows) its great points are exquisite mellowness and freedom from all "bite." The secret of this chance production of quality is probably the correct ferment and age—and by age it is not sought to imply any length of time exceeding twelve months, but probably less than that period—further, the improvement in quality does not date from filtering and bottling, but rather occurs in "bulk," when the vinegar still retains its fungoid accretion floating on its surface, vulgarly known as "the mother." Householders all over the world would gladly pay 1s. per litre for this superior quality of vinegar, and the supply could not meet the demand. On the other hand, there is no natural demand whatever for the cloudy, half fermented, unpleasant looking cacao vinegar one frequently finds exposed for sale at 6d. to 8d. per bottle; unless the outturn of a superior article is aimed at it would be better not to attempt vinegar-making. A uniform-sized, clear glass bottle, with attractive label and capsule, should be part of the outfit for a retailer. There is nothing that so effectually hinders the sale and success of local products as an appearance of being carelessly and hurriedly prepared and cheaply "put up" for sale; the natural appearance of cacao vinegar being of a clear rose colour, its attractive appearance is a considerable asset in its favour in comparison with other vinegars.

I cannot pretend in this essay to any satisfactory knowledge of vinegar manufacture, but the following points may prove worthy of consideration of prospective manufacturers. Having secured the most favourable ferment, very much depends on the fermenting tanks used; this is where the amateur manufacturer invariably gets wrecked. Wooden receptacles are entirely unsuited; under the influence of cacao vinegar the best casks become rotten and pierced by worm-holes within a few weeks. Quite as unsuitable are glass demijohns or earthenware jars with contracted necks. After standing a few weeks a flat fungoid growth will be seen floating on the vinegar surface, and this gradually increases in size. This fungus in narrow-necked receptacles prevents the clear liquid being poured off, and in fact one cannot produce clear, bright vinegar by pouring. The vinegar when thoroughly mature and clear, and ready for bottling or sale, should be siphoned off, as taps would always prove troublesome. Possibly the more cloudy remainders might be efficiently dealt with by one of the filters in use in kindred trades, such as Macqueen's "Filtre Rapide," and other devices used in bottling wines and spirits, such as "finings" of white of egg and isinglass. It is probable that a portion of the fungoid growth from a superior mature sample of vinegar would be the best method of infecting a new batch of juice with the same ferment. There is, undoubtedly, much room for useful experimenting in the direction of vinegar-making in the Tropics. It is probable that a series of four tanks built of concrete, and lined with glazed earthenware or slate, fitted with acid-resisting joints, would fulfil an ordinary estate's requirements. They should have tight-fitting covers to exclude dirt, dust and vermin.

Cacao Alcohol.

The fermenting juice of cacao fulfils all the conditions necessary to the making of a potable spirit by distillation, and even of the making of wine. Unless, however, a superior and high-priced liquor were produced (and hitherto all cacao literature is silent on this point) it is probable that its production would not be profitable.[1] It would be most interesting to ascertain what sort of a new drink cacao juice is capable of producing, and it is a matter that a Tropical Agricultural Department with a little initiative might well follow up, containing as it does the prospect of creating a market for several hundred thousands of gallons of liquor

[1] In Pará, I understand, many of the planters pay more attention to producing an intoxicating drink from the green cacao than to the commercial beans themselves. I am told that the characteristic flattened shape of Pará cacao is due to the pressure it undergoes in the cylinders made of Indian woven matting, which by means of weights, or hand-pulling at the end (as when making "farine" or cassava, which has to be freed of its poisonous juices), squeezes out almost the last drop of liquid in the mass.—H. H. S.

now running to waste. A distiller could probably purchase all the cacao juice produced in his locality for 3d. per gallon, or about the price of Central Sugar Factory molasses used for inferior qualities of rum, but a gallon of cacao juice would by no means produce the same amount of alcohol as a gallon of molasses; it might, however, yield a spirit of superior quality, and probably would do so.

Cacao Jelly.

An edible jelly is occasionally made from cacao juice to which an equal bulk of sugar is added. Its manufacture is almost identical with the well-known method of making guava jelly, but that made from cacao juice cannot compete with the characteristic, delicious and luscious flavour of well-made jelly from guavas. Beyond a sub-acidity it is almost characterless in taste, so might, on that account, form a basis for added flavourings.

CHAPTER VII.

Forming with Chapter VI, by Mr. George S. Hudson, the Joint Prize Essay mentioned in the Preface.

BY DR. LUCIUS NICHOLLS.

FERMENTATION is the reduction of substances of high molecular composition to those of a less complex nature by the agency of micro-organisms, and this has a wide range in commercial preparations, where both the physical and chemical changes are of value, thus: the making of bread, the preparation of all alcoholic beverages, cheeses, tobaccos, vinegars, and even the tanning of leather are dependent upon it. In all these trades certain definite organisms must be employed to bring about the required result, and these are usually present naturally; but this is not always the case. Science in this, as in most other subjects, has in recent years thrown light upon much that was perplexing, and its explanations of the changes which take place in fermenting matter have been of much assistance to some of the interested trades. It was the genius of Pasteur which first explained the so-called "diseases" of wines, in which, instead of a proper fermentation taking place, souring occurred. This he showed to be due to the presence of undesirable organisms; soon after this, methods were discovered by which the organisms that brought about the required changes could be separated from the more adventitious ones. This was a great stride, but it has not yet been fully utilized or even appreciated.

The "sweating," as the fermentation of cacao is called, is brought about by some of the many varieties of yeasts, and to a greater or less extent by other organisms, acting upon the saccharine pulp which surrounds the seed.

If a minute fragment of baker's yeast is shaken up in a little water, and a drop of the resulting emulsion is placed under the microscope, it will be seen to consist of many thousands of round or oval cells, each of which is an independent organism which has the power of growth and reproduction. The latter is brought about by what is known as "budding": a small protuberance appears on the surface of the cell and continues to increase in size until it is as big or nearly as big as the cell from which it springs; it then splits off, and thus two cells are formed, each of which again starts budding. In very actively growing yeast this form of reproduction takes place about once every half-hour and thus theoretically by geometrical progression one cell will give rise to a million and more in ten and a half hours. In double this time there will be produced over a million millions of cells. From this it is easy to appreciate the great and rapid changes which take place in fermenting matter, for each cell has the power of secreting a minute amount of a substance

Dr. Lucius Nicholls in Gymkhana Costume.

known as a ferment, and it is this which brings about the changes; thus the ferment produced by yeast, called zymase, has the power of transforming sugar into alcohol with the liberation of carbonic acid gas and energy—the latter appearing partly as heat. It is this energy which is required by the yeast plant to carry on its vital processes; the formation of alcohol as it accumulates becomes detrimental to the cell.

Again, if a small fragment is taken from the pulp in a mass of sweating cacao, smeared upon a microscopical glass slide, stained and examined under the microscope, a large number of yeast cells are seen in their various stages of growth and budding (fig. 1, *A*); besides these, a number of rod-shaped bodies, minute

SMEAR FROM CACAO SHOWING INVOLUTING YEASTS.

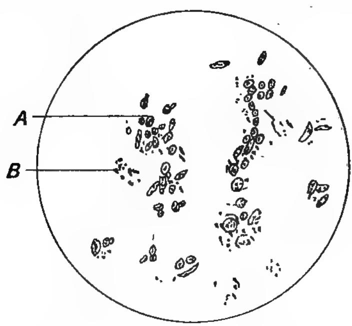


FIG. 1.—*A*, yeast cells, among which are other organisms; *B*, group of acetic acid producing bacilli.

dots, or elongated organisms are also noticed (fig. 1, *B*). These vary in number according to the stage of sweating; in the early stages they are usually few in number, in the later stages there are many of them. If we compare this yeast with baker's it will be found that they differ from one another in shape, size, and general appearance.

There are a number of varieties of yeasts, and many can be found in sweating cacao taken from different situations. But, as found in association with cacao, since they are usually of a fairly definite type, an attempt has been made to regard them, irrespective of minor differences, as one species, and to apply the name *Saccharomyces theobromæ* to these.

The isolation and cultivation of these yeasts and other organisms will be described later; it is intended to show first of all how these organisms naturally get into the husked cacao.

If the interior of a sweating-box is scraped and some of the scraping is examined under the microscope, there will be seen to be present a large number of yeasts and other micro-organisms; from this it is obvious that as soon as fresh cacao is mixed up in these boxes, these organisms will immediately start to multiply and bring about their concomitant changes in the suitable pabulum supplied. This is not the only way in which organisms arrive in, and distribute themselves through the cacao. Obviously, there are few, if any, present in new boxes, or most of them will have died out if the boxes are not used for a long time. In these cases there is often difficulty in getting the sweating to start. When it finally commences the organisms have been brought by a variety of ways, some are air-borne, others are present in the dirt on the hands of the workers, others again are carried to the beans by the agency of flies. In the present system employed I believe this last is of the greatest importance; it is not, however, without its disadvantages, as will be shown later. In many places this carriage of yeasts to cacao by flies is the most unvarying factor.

In order that a rapid and effective fermentation may take place, it is necessary that a fair number of organisms are early and evenly introduced; for this the condition of the atmosphere is far too variable, because the number of air-borne organisms depend upon the wind, the degree of humidity, and the amount of rainfall.

Around cacao boxes in the West Indies will always be seen innumerable small flies, and if the sweating cacao is carefully examined numbers of small maggots, the larvæ of these flies, will be found. So rapidly does this fly develop that the third day after the deposit of the eggs the maggots crawl to some dry surface on the boxes or their lids, and there their integuments harden into a puparium, and in a few days the flies emerge; a week is the average length of time occupied by the entire development from egg to fly.

This little fly is depicted in fig. 2. It is named *Drosophila melanogaster*. Fig. 2, *A*, represents the fly greatly enlarged, *B* representing the actual size, about a twelfth of an inch in length. The males can be distinguished from the females by the lower segments of

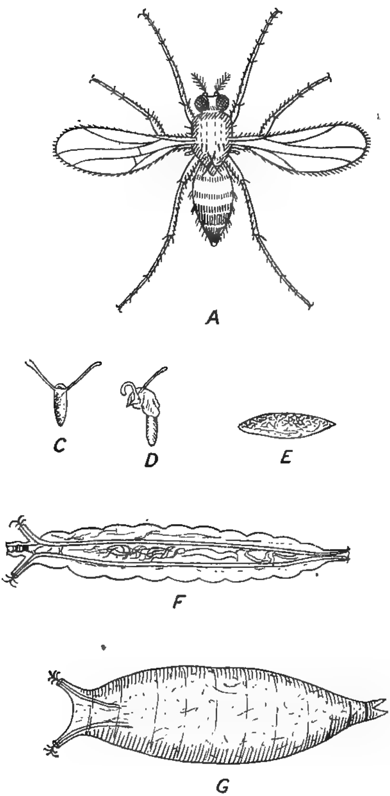


FIG. 2.—*A*, cacao or vegetable fly (*Drosophila melanogaster*), × 25 ; *B*, actual size ; *C*, egg of fly ; *D*, egg shedding case ; *E*, first stage of development ; *F*, fully developed larva or maggot ; *G*, pupal case.

the abdomen being black and the antennæ more plumose.

The colour of the fly is a dusky brownish yellow, and the eyes a bright red to reflected light. The venation of the wings is simple, consisting of five longitudinal and two transverse veins, the latter cross between the second and third and the fourth and fifth longitudinals. The eggs are just visible to the naked eye; they possess two curious prolongations, which are attached to an egg case, and this is easily removable (fig. 2, *C* and *D*). The larvæ are amphipneustic (fig. 2, *F*).

The two following experiments show the action of these flies in conveying organisms to cacao:—

(1) Four pods were taken, and two small areas at each end of them were sterilized and a small hole was drilled by a red hot iron. Into these holes sterile glass rods of an eighth of an inch bore were driven and moved freely about, so as to leave a small unoccupied space opposite their entrance on the inside of the pods. In two cases the ends of the rods were protected against the entrance of the flies by tying two or three fibres of thin cotton over them.

The four pods were now placed in a cage with a large number of these flies, which had been obtained from a number of places. On the next day they were seen crawling into the two unprotected tubes and thus into the pods.

The four pods were opened in six days, the two to which the flies had access had undergone fermentation, the other two were much the same as freshly picked pods.

(2) The second series of experiments consisted in using fine netting through which the flies could not crawl. Small new wooden boxes were filled with beans and the netting placed over them. In some of these a few meshes of the netting were so enlarged that these flies could just crawl through, whilst others were thoroughly protected from the flies, but to all intents and purposes not more protected from the air than the former.

The results were a little variable, as regards actual time and degree of sweating, but in all experiments better and quicker fermentation took place in those which were not protected from the fly.

Yeasts and other organisms can always be isolated by cultural methods from this little fly.

From these experiments and observations I conclude that this little fly is of value in that it is always present, that it conveys the causal organisms of fermentation to cacao, and its larvæ in crawling through and through the fermenting mass distribute the organisms evenly.

These flies are seen in association with all decaying vegetables and fruits, such as plums, bananas, and bread fruits, and from these, yeasts and other organisms can be cultured.

Chemistry of Cacao.

I shall confine myself principally to that chemistry which is concerned with the fermentation of cacao.

Many analyses of wet cacao have been made by Harrison, Bamber, Silva, and others, and of cured cacao by Zipperer, Muter, and Wanklyn; the most noticeable point of their tables is the extreme variations. Thus cacao butter varies from below 40 per cent. to above 50 per cent., and all the other constituents vary to much the same extent. The causes of this are various, depending upon the variety to be treated, the locality in which it is grown, its cultivation, the nature of the season (whether it has been wet or dry), the amount of fermentation that has taken place, and the degree of moisture present.

Some of these factors are irremediable even if it is desirable to produce a uniform cacao for the markets.

Fermentation takes place to its greatest extent in relation to the saccharine pulp which is adherent to and surrounds the testa of the seeds. I have analysed a number of samples of this obtained by straining fresh beans through muslin; they varied to a considerable degree in composition.

I have, therefore, given three columns: the first is the minimum, the next is the maximum, and the third the round figures which for practical purposes can be taken as the averages :—

	Minimum	Maximum	Average
		Percentages	
Water	79·73	88·5	80—90
Albuminoids, astringents, &c.	0·56	0·72	0·5—0·7
Glucose	8·34	13·12	8—13
Sucrose	0·40	0·95	0·4—1
Starch		Trace	
Non-volatile acids (reckoned as tartaric)	0·25	0·42	0·2—0·4
Iron oxide	0·03	0·03	0·03
Salts (potash, soda, calcium and magnesium)	0·40	0·45	0·4—0·45
Volatile acids	*Nil*	*Nil*	*Nil*
Alcohol...	"	"	"

Harrison gives a table in which the compositions of sweatings are stated to contain acetic acid and alcohol. This shows that his samples had undergone slight fermentation, for these bodies are absent from the fresh fruits.

Now the amount of acetic acid and alcohol present depends entirely upon the amount of fermentation which the sweatings have undergone; thus, if the sample unpreserved is examined one day and again the next, a great difference in the quantity of these will be found. The sugar disappears and gives rise to acetic acid and alcohol, and the amount of these depends upon the varieties of organisms present. The amount of acetic acid may be 4 per cent. or more.

The sweating of cacao is in fact the fermentation of the sugars of the saccharine pulp. The organisms acting on this, proceed to convert the glucose into alcohol and acetic acid; this takes place with a rise of temperature, which falls when most of the sugar is converted into these two bodies.

This produces important changes in the testa and kernels of the seeds; some of these are obvious, and others are shown by careful examination and analysis. The first question to decide is exactly how these changes take place, and in what way substances pass the exterior and the interior of the seed.

If fresh beans covered by their pulp, and other beans in various stages of fermentation, are placed in different solutions of salts or other chemicals, removed at various times, washed well in distilled water, and their kernels carefully extracted and analysed, these chemicals will be found to be present; the amount that has reached the kernels depends on the degree of fermentation that the beans have undergone; fermented beans have a far greater proportion of these, *i.e.*, alcohol and acetic acid, in their interiors than unfermented beans.

From this it is shown that the fresh saccharine pulp and testas allow but limited penetration, whereas the testas of fermented beans have become good diffusion membranes, allowing matter in solution to pass freely to and from the kernels. It was at one time thought that whatever passed into or out of the bean did so by the hilum; this may occur to some extent, but that the whole testa acts as a diffusion membrane is shown by the following experiment: Beans were soaked for a few days in a solution of potassium ferrocyanide, they were then washed and cut in half, the cut surface was carefully scraped, and a minute drop of ferric chloride was placed in the centre; as it spread it formed prussian blue with the potassium ferrocyanide which had penetrated the bean. The prussian blue is very deep through the testa and that surface of the kernel which is in contact with it. The irregular arrangement of the two convoluted halves of the bean allows substances that have penetrated to distribute themselves fairly thoroughly throughout the kernel. It, however, takes some time for matter to penetrate entirely throughout the seed. Thus in fig. 3 spot *A* is reached several days before spot *B*.

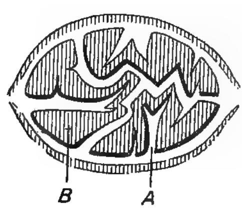


FIG. 3.—Section of cacao seed showing the convolution of its cotyledons.

Now in the majority of cases yeasts and other organisms are absent from the interior of the beans, but zymase, the ferment secreted by yeast, can be demonstrated in the interior of the seed; in this situation it will carry on its usual action, and bring about changes such as the reduction of sugar. It must be remembered that many germinating seeds possess enzymes, whose actions are to reduce substances to a more assimilable condition for the nourishment of the young plant. The action of these can probably be excluded in fermenting cacao, and the enzymes present in the interior of the beans have diffused in from the exterior fermenting matter.

It is the penetration of exterior enzymes and the general diffusion of the products of fermentation which bring about the changes in the interior of the bean. Now there are water, sugars, salts, alcohol, acetic acid, tartaric acid, enzymes, carbon dioxide and other diffusible and soluble substances, passing in and out of the skin of the bean, which has become a diffusion membrane under fermentation.

From this, some of the changes which occur are obvious and can at once be demonstrated by analysis, other changes are brought about by the temperature reached by the fermenting mass.

Physical Changes which are brought about in the Beans by Fermentation.

If beans which have been fermented and dried are compared with uncured beans many differences are apparent: the former appear more rounded and plumped up and of a dark brown colour; this is due to the formation within the kernel of carbonic acid and volatile substances such as alcohol, which tend to disintegrate the various portions of the bean and thus plump it up. The latter are of an uneven light colour and appear shrunken: upon breaking them it is found that the bean is tough and the fracture is delayed, its interior colour is a harsh purple and has not suffused to the testa, which is very adherent to the kernel and has little masses of unremoved saccharine pulp attached to it. In the sweated seed the fracture is easy and sharp, showing it to be of a very brittle nature, the interior colour is a rich chocolate, the kernel is not adherent to and is easily removed from the testa.

The Losses and Gains in the Constituents of Cacao when undergoing Fermentation.

It is practically impossible to estimate the exact losses and relative gains in cacao beans undergoing fermentation; the reason being that there is no unvarying factor present, from which we are able to get the proportions.

It has been usual to consider the fats in cacao as remaining unaltered in amount during fermentation and drying, but although they are the least affected of the constituents there is undoubtedly a slight loss. The melting point of oleum theobromæ is from 28° to 32° C. (82°—90° F.) and the higher of these temperatures is always reached not only in the fermentation, but also during the drying and dancing processes; the result is that the fats ooze through the testa and thus to the trays and the sides of the dancing vessels.

Oleum theobromæ is, however, the only constituent which is entirely absent from the sweatings of the second and third days of fermentation; it must therefore, for purposes of analysis, be considered a fixed quantity, and the proportions of the sugars, theobromine, cacao red, &c., to the fats be gauged in the fermented and unfermented beans of the same sample, for this is the only way of deciding the approximate amount lost from the kernel of the bean during fermentation.

Glucose.—The percentage of this in the uncured beans may be said to vary inversely with the percentage of sucrose (cane sugar) present. The two together form 1 to 1½ per cent. of the cacao. In the well-fermented dried beans there is only a trace of glucose present. In other samples it may be found that there has been only a slight loss, or perhaps even a gain; the reason of this is that the sucroses and starches have been converted into this sugar, which in its turn has not undergone further fermentation, or else some of the sugar in the saccharine pulp which has a high percentage has diffused in.

Sucrose.—This is always absent from the cured cacao, having been inverted to glucose and thus to alcohol and acetic acid.

Starch.—This is from 10 per cent. to 12 per cent. of the cured cacao. There has been a slight loss; this is dependent on the degree of fermentation.

Theobromine and Theine.—This was estimated by Kunge's method; in three samples two showed a slight loss relative to the fats and the third showed practically no loss.

Cacao Red. — Determined by Zipperer's method: the possible errors in the technique for estimating these complex products render it impossible to gauge very small losses. The fact that cacao red can be found in the later sweatings shows that there is some loss.

Albumen, *Fibrin*, *Gluten*, &c., show a slight loss.

Bitter Principle.—The nature of this and its analysis have not yet been determined.

If cacao beans are broken up, an equal quantity of water added and the mass filtered, the bitterness will be found to have come away with the small quantity of water; if the filtrate is now boiled with a very dilute mineral acid it ceases to be bitter.

Undoubtedly bitterness is lessened by the fermentation of the beans. But as the bitterness can be easily got rid of by the manufacturer, it does not appear desirable to carry fermentation to the stage of putrefaction when this bitterness disappears.

Salts.—These remain practically constant. A small amount probably diffuses out from the kernel.

Acetic Acid, Alcohol and Acetic Ether.—These diffuse into the bean from the exterior, also small amounts are formed in the kernel.

These bodies tend to disappear if the beans are kept for a length of time. Perhaps a few others are formed, in which case the beans (all else being equal) would improve with keeping.

Summary of the Changes which take place.

(1) The testa is rendered more brittle and acts as a diffusion membrane. Cacao red and other constituents diffuse into it.

(2) The kernels assume a diffuse chocolate colour, are plumped up and become less adherent to the testa; this is the action of the volatile substances and the carbonic acid gas.

(3) The sugar and, to some extent, the starch are converted to lower products, such as alcohol, acetic acid and carbonic acid gas.

(4) The fats are lost to a very slight extent.

(5) Theobromine and cacao red are also very slightly lost.

(6) Some of the bitter principle is reduced or diffuses out of the bean.

(7) Acetic acid and alcohol become present in the kernel.

The Isolation and Cultivation of the Organisms which Ferment Cacao.

The principle of the cultivation of organisms is to provide them with a medium which contains only food material and substances which are favourable to them.

The medium must vary with different classes of organisms: thus yeasts will flourish upon saccharine media in which there is an absence of proteids; other organisms, such as those which putrefy meat, will not flourish upon this, but require the presence of peptone or some other proteid.

Many media can be prepared upon which the organisms that ferment cacao will flourish.

I have found the medium with the following composition, the most useful for practical purposes:—

Magnesium sulphate	...	0·5 grm.
Calcium sulphate ...	...	0·5 ,,
Calcium phosphate ...	...	0·75 ,,
Potassium nitrate ...	...	0·75 ,,
Sodium chloride ...	...	0·5 ,,
Iron perchloride ...	...	0·05 ,,
Potato (finely cut up)	...	2 oz.
Glucose	...	50 grm.
Agar	...	15 ,,
Distilled water ...	...	1,000 c.c.

This forms a moist, solid medium upon which yeasts, bacteria and moulds flourish luxuriantly.

It is boiled, filtered, poured off into test tubes, and sterilized in an autoclave; some of the tubes are sloped (*vide* fig. 4, p. 240), others are kept for plate cultures.

I use another medium which contains starch, alcohol and only a small quantity of sugar, for the purpose of isolating acetic acid bacilli and cocci.

The method now pursued is to obtain Petri plate cultures from sweating cacao. A platinum loop is sterilized and pushed into the deeper layers of the beans in a sweating-box; when it is withdrawn, the small amount of matter adherent to the loop is shaken up in a saline solution, and various dilutions of this are made. These dilutions are now either shaken up in the molten agar media at 45° C. and

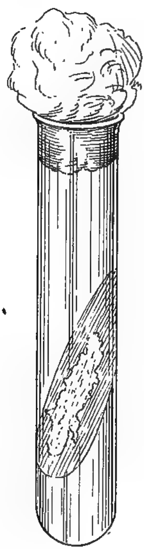


FIG. 4.—Sloped agar tube showing yeast growing on the sloped surface.

poured on to Petri's plates, where they are set into solid media, or else the dilutions are poured over the surface of media which have already set on these plates. These plates are now incubated at between 37° and 40° C., and in twelve hours small white colonies will be seen appearing. What has happened is that in the dilutions the organisms were widely separated, and thus, when mixed with or passed over the solid media, they fell in different places and thus each organism grew into an isolated colony.

These colonies are each touched with the point of a platinum needle, and the point smeared upon the sloped surface of medium in a test-tube (*vide* fig. 4); this is incubated, and the next day a luxuriant growth of a separated organism is present in the tube. Thus there has been isolated an organism in pure culture. Now its action can be tested upon various substances, such as sugar or the saccharine pulp of cacao.

By these methods the organisms which are present in the sweating-boxes on the different days can be isolated and their actions tested. By the number of colonies of yeasts and other bacteria, the proportions of these to one another can be gauged on the different days.

At the same time that cultures are taken from the sweating-boxes, smears are made on microscopical slides from the adherent pulp; these are stained with carbol thionine blue, or some other aniline dye, also by Gram's method, and examined under the microscope, using magnification power of 1,000.

By the nature of the organisms present the fermentation of cacao might be divided into three stages:

(1) The yeast stage, in which the vast majority of the organisms present are "wild" yeasts.

Fig. 5 is a smear showing the rapidly growing cells of this stage.

(2) The acetic acid producing bacteria stage.

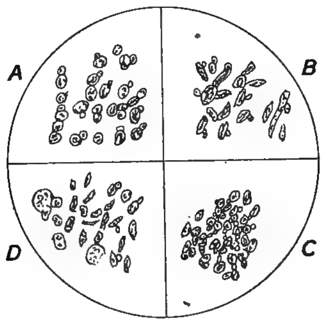


FIG. 5.—*A*, baker's yeast; *B* and *D*, two varieties of yeast found in cacao; *C*, an actively growing cacao yeast.

This sets in as the fermentation reaches its height. Fig. 1, *B* shows these organisms becoming numerous and the yeast cells lessening.

Fig. 6 shows three of these isolated by cultural methods; two are bacilli and one is a micrococcus.

(3) The commencing of a putrefactive stage; this occurs at the end of fermentation, when the yeast cells are disappearing, and a large number and variety of bacteria and moulds appear.

In this stage it is not always easy to isolate the yeast cells by cultures, as they themselves are being attacked and broken up by smaller organisms.

A colony of yeast growing upon a solid medium is fairly easily distinguished from a colony of acetic-acid-producing or other bacterium.

Colonies, on a solid medium, of the wild yeasts, including *Saccharomyces theobromæ*,

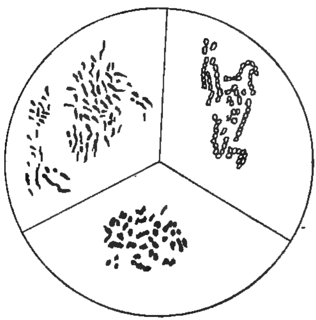


FIG. 6.—Three forms of acetic acid producing bacteria.

consist of a central, heaped-up, granular portion and, spreading away from this, a lighter, thinner, radiating zone; after a few days the colonies lose the outer zone and assume a white, opaque, granular appearance. These are easily distinguished from most colonies of other organisms, which usually possess a shiny smooth-looking appearance.

Sometimes it is found that the bean does not undergo its proper and usual fermentation;

especially is this the case when using new boxes. If on these occasions a bacteriological examination is made, it will always be found that there is a preponderance of other organisms and a scarcity of yeasts.

Again, occasionally the cacao nearest the sides of the boxes blackens; an examination of this shows a large number of fungi and bacteria which have invaded the material, and consequently the yeast cells are degenerating and being broken up.

A large amount of unsweated cacao is placed upon the market; most of this comes from peasants and petty proprietors. It is bought by the merchants from these people in a moist, rather dirty condition with much of the saccharine pulp still adherent to it. In most cases it will not sweat when subjected to the usual procedures.

A proper and thorough fermentation can always be started by employing cultures of yeasts; sweating will proceed as well in new boxes as in old, and even a properly cured sample can be obtained from peasant's cacao, provided too much of the saccharine pulp has not been removed.

It can be shown by carefully excluding other organisms that "wild" yeasts, and these only, are all the organisms which are required for the production of a proper fermentation in cacao.

Instead of trusting to chance to bring the right yeasts to his boxes, it is urged that the planter should employ cultures for the starting and prolonging of fermentation. If cultures of yeasts are well mixed up with fresh beans, sweating starts sooner and continues longer, and a better sample is obtained than by the ordinary process. The reason is that the yeast cells obtain the first chance and then extraneous organisms cannot so easily get the upper hand.

If it is desirable to prolong fermentation it can be done in this manner: a solution containing 5 per cent. glucose and $\frac{1}{20}$ per cent. each of calcium phosphate, calcium sulphate, magnesium sulphate, potassium nitrate, and sodium chloride is poured over the beans on about the fourth day, when the temperature begins to fall; the temperature will now rise and fermentation will be continued for about two days longer than usual. The cost of this solution would be the price of about 2 oz. of beet sugar, for the salts of this strength cost practically nothing, and the two resulting pints of this solution would be nearly sufficient for the contents of two large sweating boxes.

If samples prepared by cultures of yeasts are examined, the perfect break, the through and through colour, and the ease with which the testa separates from the kernel show them to be far better than the average sample.

If planters used a definite culture of yeast a more uniform and thoroughly sweated sample of beans would be placed upon the market.

The cost of cacao yeast would be very small, or a planter could prepare his own; the following would be a practical method to be pursued by a planter to obtain a yeast culture in bulk:—

To 1½ gallons of water are added ½ lb. of sugar (preferably glucose) and 1 oz. of a 10 per cent. solution of the plant salts—*i.e.*, magnesium sulphate, calcium sulphate, calcium phosphate, potassium nitrate, and sodium chloride. This solution could be made up by any chemist at cost price, 6d. for 10 oz. The 1½ gallons are now boiled, poured into a clean pail and allowed to cool. As soon as it is cooled, with a clean spoon two or three beans are removed from the centre of a mass of cacao which has been fermenting for three days and these are stirred into it. The top of the vessel is now protected by tying over it a muslin cloth. In a few days there will be a white layer of yeast upon the surface of the solution and another at the bottom of the vessel.

To the beans as they are placed in each sweating box one pint of the thoroughly stirred solution is added, and sweating will start almost immediately, as shown by the rise of temperature.

Thus the cost of the yeast would be about the price of half a pound of sugar; this would represent the quantity necessary for about four bags of cacao. Thus a dozen pounds of sugar would be sufficient for the preparation of one hundred bags of cured beans.

By taking samples each time for the preparation of the next yeast the required ferment could be kept going indefinitely; but it would be better to obtain a pure sample for the preparation from a laboratory.

It now has been shown that if cacao is to be sweated upon scientific principles, the proper fermenting organisms must be supplied, for in this way a definite and thorough fermentation will always take place.

There has been much discussion as to what is really required in the finished product, which is placed upon the market; here the decision obviously rests with the manufacturers and those who buy for them: however, it is for the planter and scientist to point out all probable possibilities to them.

From the nature of the case the changes which can be brought about in the interior of the bean by fermentation have very strict limitations. There seems to have been a desire to get rid of the bitter principle; this appears unnecessary, as it is easily dealt with by the manufacturers, and can only be removed in the whole bean by carrying fermentation to the stage of putrefaction: that is, when the organisms themselves are acting in the interior of the bean and not their enzymes only, as should be the case in fermentation.

Again, when putrefaction takes place and the bean is dried, the loss of weight is such that any increased price obtainable is insufficient to render the process profitable.

The question of temperature must now be considered. This depends upon several factors, such as the organisms present, the size of the sweating-boxes, and, to some extent, upon the variety of the cacao and the nature of the season.

The temperature does not rise as high with yeasts as with some other organisms, and when it rises to a great height it falls very rapidly.

Yeasts are killed by an exposure to 133° F.; for one hour at 120° F. the action of zymase (the ferment of yeast) almost ceases. The optimum temperature, that is, the heat at which they flourish best, is well below 110° F. But a temperature of this degree is undoubtedly required in sweating cacao to diffuse the fats and aid the chemical and physical changes. It is, therefore, a temperature below 120° F. and above 110° F., which is the best, for it will not impede the action of the yeasts, and will prevent the flourishing of many adventitious organisms which require a lower temperature. There are other organisms which raise the temperature of a sweating mass higher than is done by the yeasts, and if it is found that a sweating-box gives 120° F. or more when yeast cultures are used, it means that there is some contamination; the cure of this is the thorough cleaning of the box.

Apart from these factors the question of temperature is best dealt with by actual experiments to decide the temperature at which the best sample is produced.

It will be found that the use of yeast cultures produces a uniform sweating with a uniform temperature.

Cacao Sweatings.

The juice which runs away from the sweating beans is on almost all estates allowed to waste.

Mr. Hudson has calculated that for every 100 bags of 200 lb. which an estate produces there are 600 gallons of this fluid.

From the nature of the fluid, containing about 12 per cent. of sugar, so far as I can see at present only two commercial preparations could be prepared—an alcoholic beverage or an acetic acid condiment, that is, vinegar. The former would be extremely difficult to prepare, whereas a high-class vinegar can be made with ease.

Here, again, much depends upon the presence of the right organisms, as the following experiment shows: Four samples of the same sweatings were placed in equal-sized vessels, to three were added various cultures of acetic acid-forming bacilli and cocci, to the fourth nothing was added (it must be remembered that acetic acid-producing organisms are always present in sweatings). The tops of the vessels were protected by tying cloth over them. At the end of three weeks they were estimated for acetic acid; one gave 2·8 per cent., another 3·1 per cent., a third 4·1 per cent., and the last, to which no culture had been added, 2·5 per cent. The third gave the strongest sample, and others similar to it could be obtained by using a small piece of the surface film of organisms to start the fermentation. Thus once a good sample is obtained the organisms from this can be used to prepare any quantity.

It is desirable to protect all fermenting sweatings from flies and other insects that are attracted to it, and also as much as possible from the higher moulds. The fermentation should take place in large flat vessels, so as to have a large surface of fluid for the growth of micro-organisms as a top layer. After about two months the vinegar can be decanted off, strained, and bottled.

The following table shows the comparison of this vinegar with others sold at the present time :—

	Specific gravity	Extract	Acetic acid	Original solids and acetic acid	Ash
Wine Vinegar:					
Maximum...	1·021	3·19 %	7·58 %	11 % approx.	0·68
Minimum ...	1·012	1·38 ,,	4·44 ,,	6 ,, ,,	0·16
Mean ...	1·017	1·93 ,,	6·33 ,,	8 ,, ,,	0·32
Spirit Vinegar:					
Maximum...	1·013	0·57 ,,	7·89 ,,	8·5 ,, ,,	Trace
Minimum ...	1·008	0·16 ,,	4·93 ,,	5·5 ,, ,,	,,
Mean ...	1·0082	0·35 ,,	6·34 ,,	6·2 ,, ,,	,,
Malt Vinegar:					
Maximum...	1·025	3·95 ,,	7·42 ,,	12 ,, ,,	0·74
Minimum ...	1·012	1·15 ,,	4·51 ,,	6 ,, ,,	0·25
Mean ...	1·019	1·8 ,,	5·52 ,,	7 ,, ,,	0·34
Cacao Vinegar:					
Maximum...	1·024	2·4 ,,	7·75 ,,	10 ,, ,,	0·65
Minimum ...	1·015	1·0 ,,	4·21 ,,	5 ,, ,,	0·21
Mean ...	1·018	1·7 ,,	6·21 ,,	7 ,, ,,	0·25

Cacao vinegar which has been well matured by keeping is very mellow and of a light colour, and is undoubtedly equal to most others on the market. Properly exploited it should become a considerable asset to the planter, and if sold at the price of some other vinegars would well-nigh pay the expenses of cultivation of an established estate.[1]

[1] See footnote, p. 216.—H. H. S.

CHAPTER VIII.

THE LAST WORD.

By the Editor.

As several years on an average have elapsed since the preceding essays were written, and at least twelve or thirteen years since Dr. Axel Preyer recorded on paper the results of his investigations, I was most anxious to hear what each of the authorities had to say at the present time on the progress made along the lines advocated by them. This was especially the case with Dr. Fickendey, as I had noticed that his name had been mentioned in the *Bulletin* of the Imperial Institute in a lengthy description of a process carried out under his directions, whereby the fermentation of the beans had been dispensed with, other means having been taken to kill the embryo without destroying the oxidizing enzymes. On this point Dr. Fickendey was good enough, at the end of March, 1913, to write as follows:—

With the fermentation of cacao there are two processes that should be kept strictly separate; on the one hand, the fermentation of the pulp, *i.e.*, the saccharine and the mucilaginous mass in which the beans are imbedded, and on the other the changes that the substances in the beans themselves undergo. This can be described as external and internal fermentation.

The juice of the pulp, according to my investigations, contains about 10 per cent. of sugar (dextrose and lævulose), 3 per cent. of mucin, and besides this, as much acid (chiefly malic acid) as corresponds to $\frac{1}{10}$ (1 in 10) normal solution. The specific gravity at 15° C. amounted to 1·06308, 100 c.cm. of juice contained 0·638 grm. of mineral ash, of which 0·192 grm. consisted of calcium carbonate, and 0·196 grm. magnesium carbonate. After hydrolysis of the mucilaginous substances a pentose and dextrose were proved to be present. No difference in the Criollo and Forastero varieties could be demonstrated as to the composition of the juice. The pulp is, therefore, a good nutritive medium for a large variety of micro-organisms, both yeasts and bacteria. The different methods of conducting fermentation are well enough known. The guiding principle is always to turn over the heaps the moment the temperature begins to fall, in order that the micro-organisms may be stimulated to renewed activity by the advent of oxygen. In the first place, the sugars are converted into alcohol, then oxidation fermentation sets in, acids, especially acetic acid, being formed. Under normal circumstances the acids are then for the greater part oxidized into water and carbonic acid. If wrongly conducted the process leads to the production of fermentation by-products (lactic acid fermentation, butyric acid fermentation), which have an unfavourable influence on the value of the product. A considerable variety of micro-organisms take part in the fermentation; both yeasts (mycoderma, torula, monilia, saccharomyces) and bacteria, of which the acetic acid bacillus plays a particularly important rôle. Preyer[1] isolated a yeast, *Saccharomyces theobromæ*, from fermenting cacao, and has recommended the use of the pure culture of this for the initiation of the fermentation. This idea has been repeatedly exploited. Not much success is, however, to be expected from the use of pure strains of yeasts. The first essential to success is lacking, that is, the possibility of sterilizing the culture medium, for with the death of the germs the destruction of the enzymes would be associated, whose action, as we shall see, is irreplaceable. Without sterilization, pure yeast cultures have but little prospect of competing with wild ones. It often takes some hours before the contents of the broken cacao pods reach the fermenting station, and, in the meantime, the wild flora, consisting of yeasts and bacteria, has already started the fermentation.

Now the processes taking place in the interior of the bean are only indirectly con-

[1] *Tropenpflanzer*, 1901, 5. Jahrgang, p. 151.

nected with fermentation. The principal changes in the bean, that are appreciable to the eye and taste after fermentation, consist in a brown colouration of the nibs and a softening or reduction of the bitter flavour. The object of fermentation is, in the main, to kill the germ in the bean in such a manner that the efficiency of the enzyme is in no way impaired. Behrens has already pointed this out,[1] and this statement is proved to be well founded, in the first place by the fact that the above-mentioned changes fail to occur when the enzymes are destroyed before fermentation. Thus, if fresh cacao beans are heated to 100° C., whilst they will still ferment, the brown colouration and softening of the bitter taste do not occur. A further proof is to be found in the fact that the changes essential to the preparation of cacao may take place without fermentation, if the germs in the beans are killed under conditions that leave the enzymes unimpaired. There are several ways of destroying the life of the bean without running the risk of destroying the enzyme. If there were any financial value in doing so, such methods could be used in the practical or commercial preparation of cacao. In every case the first process consists in the removal of the pulp. It is unnecessary to completely separate the pulp from the beans, in fact it suffices if one washes out the

[1] Lafar, "Handbuch der technischen Mykologie," Bd. i, p. 655.

dissolved substances (sugar and acid), which can be done by mechanical means without any difficulty.

The various methods consist of:—

(1) *Mechanical Means.* — The beans are crushed and then dried. A brown mass completely free from bitter taste would thus be obtained, but buyers are very unlikely to buy such a powder.

(2) *Chemical Means.*—For commercial purposes only non-poisonous and volatile chemical substances can be used here. Alcohol fulfils both these requirements. The beans are laid for ten minutes in 96 per cent. alcohol, and then kept for five to six days over alcohol. They are then placed for one minute in water, and afterwards dried. A large cacao manufacturer in Germany has expressed the following opinion about cacao prepared in this manner: "This alcohol treatment denotes a great advance in Cameroons cacao, as compared with beans prepared by the ordinary process."

(3) *Change of Temperature.*—The vitality of the cacao bean depends on its being kept within definite limits of temperature; overstepping these limits in either direction leads to the death of the bean—*i.e.*, of the germ. From a practical point of view it would appear that the easiest way to kill the germ is by heat. The protoplasm, the real life-bearing substance, is devitalized in the cacao bean at a temperature that lies below that which destroys the enzyme.

In the case of fermentation the devitalization is mainly brought about by the development of heat. It is thus possible to combine drying and devitalizing in one procedure if the drying be carried out at a definite temperature (about 50° to 60° C.); or, again, if it be deemed desirable to sun-dry the beans, this may be done after first subjecting them for one day to a temperature of 50° to 60° C. Laboratory experiments—which, however, one must own never represent a true imitation of what takes place on a wholesale or commercial basis—gave good results, provided only that fully ripe beans were used. Further attention must be called to the fact that the finer varieties, such as Criollo, more easily become brown and free from the bitter taste[1] than the commoner Forastero. Another method is the devitalization by cold. It is not necessary to actually freeze the beans; maintaining them for three hours at 1° C. is quite sufficient. On drying them after this, brown colouration and simultaneous loss of the bitter flavour take place on access of air. A manufacturer writes as follows about beans treated in this way: "The beans devitalized by freezing have the strongest flavour, and possess a full and pure cacao aroma, such as we have never yet met with in any other kind of bean."

[1] For one reason, because the bitter taste is not there to the degree that it is in the Forastero kinds.—H. H. S.

The Bulletin of the Imperial Institute (vol. x, No. 2, July, 1912) includes an interesting article on the preparation of West African cacao (pp. 239-247). On p. 243, when discussing certain experiments which have been carried out in that Colony in preparing beans for market without fermentation, the report tells us: "In preparing cacao beans for market, fermentation is usually resorted to, and for this purpose the beans and adherent pulp, after being removed from the pod, are placed in a vat or other receptacle where micro-organisms bring about fermentation, the temperature of the mass rising from 30° to 50° C. The germ of the bean is killed in this process, and at the same time the astringent matter in the fresh bean is destroyed to a great extent, and the colour changes from a purplish hue to a rich brown. The chief object of this process is to kill the bean without injuring the enzymes, probably chiefly oxidases, which are stated to be the real means of reducing the bitterness and altering the colour, for which reason the beans are frequently turned to keep the temperature below 60° C.

"Several new methods of bringing about these changes have been proposed. Dr. Fickendey, Victoria, Cameroons, has suggested that the beans should be subjected, after removal of the pulp, to changes of temperature, either by heating them to 50° or 60° C. (122° or 140° F.) for twenty-four hours, or by keeping them at a temperature of 0° to 1° C. (32° to 33·8° F.) for three hours. The cooling method was applied experimentally in the Cameroons, and the beans produced by this method were stated by a German firm of manufacturers to possess a good aroma and flavour."

And again on p. 247, in summing up the results of various experiments, and the reports of brokers and manufacturers on cacao prepared by the various methods, the Imperial Institute tells us: "It is clear from the foregoing statements that both brokers and manufacturers regard the fermented cacao (Nos. 1 and 2) as superior to the three unfermented samples (Nos. 3, 4, and 5). With reference to the latter, it will be noticed that the valuations of Nos. 3 and 4, treated by Fickendey's processes, are in all cases higher than those of No. 5,[1] which were merely washed and

[1] Sample	London Brokers' Valuation (Feb. 11, 1911)	Liverpool Brokers' Valuation (Feb. 15, 1911)	Manufacturers' Valuation (Feb. 15, 1911)
	Per cwt.	Per cwt.	Per cwt.
No. 1	About 54s. to 55s.	50s. to 51s.	52s. to 53s.
,, 2	,, 53s.	49s. ,, 50s.	52s. ,, 53s.
,, 3	,, 52s.	47s. ,, 48s.	48s.
,, 4	,, 53s.	46s. ,, 47s.	50s.
,, 5	,, 50s.	45s. ,, 46s.	46s. to 48s.

Values placed by the different centres will always vary, as the terms and conditions of sales are not the same.

dried. The *Bulletin* included a description of the samples, showing that Nos. 3 and 4 have undergone, to some extent, that change in colour and flavour which is usually regarded as resulting from fermentation, so that the results of these experiments tend to support Fickendey's contention that fermentation of cacao may be dispensed with, provided that other means are taken to kill the embryo without destroying the oxidizing enzymes which are believed to produce the changes in colour and flavour."

Brown colouration and loss of bitterness therefore bring about the changes in the beans. The bitter taste is due to the presence of tannic substances, and the brown colouration is due to a change in, viz., the oxidation of, these substances. If a cacao-bean whose enzymes are unimpaired be cut through, the exposed surface turns brown. This is a result generally met with in all fruits containing tannin, *e.g.*, apples, and is due to oxidation of the tannins. We should here mention the behaviour of the common sloe *(Prunus spinosa)*, which in many respects resembles cacao. The ordinary sloe has such an acrid bitter taste that it is unpalatable, but after a frost the cells of the fruit pulp die and the enzymes are then able to develop their activity. The result is that the acidity disappears and the fruit becomes palatable. In this case also, the loss of the acrid taste is accompanied by brown discolouration, and the cause of this change in colour is brought about by the oxidation of the tannic substances (possibly preceded by a splitting up of glucosides).

It has often been suggested that oxidases may play a part in the preparation of cacao. Indeed, it is easy to prove that such is the case. The oxidation of the tannin in other fruits containing that substance is also put down to oxidase. If fresh, decorticated cacao-beans are crushed in water, the watery extract gives a blue colour reaction with tincture of guaiacol, and a dark blue reaction with an aqueous solution of tetramethyl-paraphenylen-diamin hydrochloride. These reactions are best obtained by the capillary method of J. Gruess.[1]

The oxidase action may be demonstrated without the aid of foreign chemical substances. If cacao-beans be heated in water to 75° C. and then crushed, no change in colour and no reduction of the bitter taste is produced in the mass, whilst brown discolouration still occurs after heating at 70° C. for an hour. The browning of the beans heated to 70° C. can still be obtained if a small amount of aqueous extract of fresh cacao-beans be stirred into the mass. For comparison, another portion of the mass may be treated with a similar extract previously heated to 80° to 100° C.; in this

1 "Bericht der deutschen botanischen Gesellschaft," Bd. xxvi, p. 624.

case the brown colouration does not occur. If the paste of stewed or boiled (*gekochten*) beans mixed with the extract of fresh beans be placed in tubes having a small surface, the browning commences at the surface, and gradually passes to the deeper parts as the air gains access.

If the beans be boiled (*kocht*) in water the tannic substances go into solution. This solution also turns brown, owing to oxidation, if a small quantity of the above-mentioned extract be added to it. A purified solution of tannin (precipitation with lead acetate, filtering, breaking up of the lead compound by hydrogen sulphide) also turns brown if the extract of fresh beans be added, the colouration commencing on the surface. All these facts force one to the view that oxidase takes a part in the browning, *i.e.*, by bringing about the oxidation of the tannin in cacao-beans.[1]

About 50 grm. of decorticated beans devitalized by freezing were broken up and placed in a gas-tight flask. This was shaken several times, and the gases contained in it were examined. The result of the analysis was as follows:—

[1] The watery extract of boiled cacao-beans can be used very well on the other hand, to prove the presence of oxidase, a fact probably first pointed out by Gruess. This extract is, for instance, stained deep brown by the addition of Castilloa milk, which contains a powerful oxidase. In place of the watery extract, the alcoholic may also be used, but it must first be deprived of fats.

Carbonic acid, 4·5 per cent.
Oxygen, 12·8 per cent.
Nitrogen, 82·7 per cent.

A simple calculation shows that for every two unit-volumes of oxygen used up, one unit-volume of carbonic acid has been formed. Experiments conducted on parallel lines led to the same results. One may probably gather from this that oxidation is associated with a breaking up and giving off of carbon dioxide (*Kohlenstoffabspaltung*).

Whether the oxidation is preceded by a splitting off of glucosides has not been definitely determined. Lazarus certainly affirms that a glucoside (cacaonine) occurs in fresh beans, being composed of sugar, cacao-red and the alkaloids caffeine and theobromine.[1] Schweitzer[2] has confirmed this, and also isolated an enzyme capable of splitting glucoside. These experiments require repeating and checking, however.

The behaviour of the beans having white nibs differs from that of those with bluish-red cotyledons, in that the devitalizing temperature of the oxidase stands at about 5° to 10° C. higher. In other respects the conditions are the same. The tannin-containing cells of the white beans are just as much developed, as may be shown by treating sections with tannin

[1] Review, *Botanisches Centralblatt*, 1893, Bd. lvi, p. 296.

[2] *Pharmaceutisch Zeitung*, 1898, Bd. xliii, p. 381.

reagents. In the case of the bluish-red beans the tannin-containing cells can be recognized microscopically by the presence of the bluish-red colouring matter, which is also of a tannin nature.

A few words may be added with reference to the washing and drying processes. The washing of the beans after fermentation has been entirely given up in the Cameroons. The loss amounted to about 8 to 10 per cent. without adding to the price realized by the product.

The best method of drying is by the sun. Such a process works slowly, so that the air has time to penetrate into the bean and to complete the process of oxidation; and it further takes place at a temperature that in no way impairs the action of the enzymes—it is on this point that the greatest stress should be laid in connection with the various mechanical drying processes. If the enzymes are destroyed by using temperatures that are too high, it becomes impossible for the manufacturer later on to remedy any faults made by the planter. The drying method most commonly used is that of drying houses fitted with trays placed one over the other, *i.e.*, in tiers, through which currents of hot air pass. These buildings are a great advantage if the temperature is not allowed to rise too high, but if the heat is too great the cacao deteriorates. The introduction of fans obviates this evil. The acceleration of the currents of air, as by fans, would prevent excessive temperatures existing.

It is very doubtful whether, with the present class of manufactured cacao that is in demand it is worth the planter's while to improve the quality of their beans, provided that they can ship them even in quality, size, appearance and "break," and the following reasons can be advanced against incurring unnecessary expense to improve the class of bean shipped at present (provided always the bulk runs even as just mentioned):—

(1) The cacao-market has an increasing tendency to minimize the differences in price between the good and ordinary cacaos. Ten years ago the proportional value between the Cameroons and Caracas beans was as 100 to 240 approximately; now it stands at about 100 to 140. Even granted that the quality of Caracas cacao may have deteriorated somewhat, and that of the Cameroons cacao may have improved, the tendency to level down or up all kinds, already spoken of, is unmistakeable.

(2) There is no recognized general standard as to the quality of a cacao, and there is also no uniformity of opinion as to what constitutes an ideal bean as to quality. Since flavour is the main guide, the valuation of the same cacao may differ very markedly according to the different experts sampling it; on this account the broker who settles the price as a rule judges quite differently to the manufacturer.[1]

[1] Do we find this in London?—H. H. S.

Carelessly or insufficiently fermented beans often obtain a better price than those which have been properly cured.[1]

(3) The outer appearance of the bean seems to have at least as much to do with the price as the intrinsic quality.

For this reason the investigations relative to the fermentation of cacao and the experiments to improve the quality of the beans have been abandoned at the experimental station in Victoria, Cameroons, since 1909.[2]

At the same time, or soon after writing the foregoing remarks, Dr. Fickendey thus reviewed and discussed the situation generally, as it occurred to him after scanning the various essays which we had sent him. These did not include Dr. Sack's, as his essay was not received until some little time after I had written to Dr. Fickendey, in the Cameroons.

I have pleasure in acceding to the request of the Editor of *Tropical Life* to make a few remarks on the treatises in this book on cacao fermentation.

[1] Because being of a more "neutral" flavour it can be used in mixtures or "foundation" cacao, where a full flavoured bean would not do, as it would alter the taste.—H. H. S.

[2] Probably because that class of cacao, as shipped at present, is able to compete successfully with the other African kinds, or cacao from Bahia, San Domingo, &c., and this discourages any systematic efforts to improve the beans, especially as doing so would tend to reduce the weight, and increase the cost of production.—H. H. S.

Dr. Axel Preyer's work constitutes a first attempt to explain the entire process, its aim and import. Preyer considers enzymes derived from yeasts responsible for the changes occurring during the fermentation. Although I do not find this explanation to be correct, for I maintain that it is the enzymes of the beans themselves that cause the changes, his work is still of value, and it certainly gave the impetus to further investigations.

Preyer also succeeded in isolating a special variety of yeast, to which he has given the name of *Saccharomyces theobromæ*, which was always found to be present on fermenting cacao in Ceylon, and is claimed to produce a particularly high quality cacao. Experiments conducted with pure cultures of this yeast in Victoria (Cameroons) in 1900 did not yield satisfactory results however. This lack of success was perhaps due to the yeast having died during its transport from Ceylon to Victoria.

The fine work of Loew has only now become known to me. Loew regards the removal of the pulp as the main object of the fermentation or sweating process. With this I cannot agree; the loosening of the connection between the bean and its envelope, *i.e.*, between the cotyledons and the testa or shell, is also of no essential importance, for roasting in all cases easily separates the shell from the kernel. The essentially important changes occurring during fermentation may be considered as being the brown colouration and the reduction of the bitter taste of the nibs. I am pleased to find that Loew, in explaining this change, arrived in the main at the same conclusions that I did in my investigations undertaken a year later. There is one point in which Loew's results differ from mine. According to him the oxidase is insoluble, whilst I have regarded it as soluble. In my experiments I used an extract of fresh beans, which were crushed under water so as to delay oxidation. The filtrate was never clear, and it is therefore possible that the substance causing the cloudiness contained the oxidase. In order to clear up the divergence the following experiment was made. Fifteen beans were broken up in an atmosphere containing carbonic acid and then covered with boiled water. This was then filtered in a similar atmosphere. The filtrate was at first cloudy, but soon ran off clear. The clear, reddish-violet solution gave a marked oxidase reaction. Brought into contact with oxygen containing air it soon turned brown and became clouded, owing to precipitation of tannins. This brown solution showed a very much weaker reaction with oxidase reagents. If a few drops were allowed to fall on blotting-paper and a solution was added of, say, for instance, tetramethyl-paraphenylen-diamin-hydrochloride, the most marked blue reaction occurred in the centre, *i.e.*, where the precipitate had been mainly deposited. The deduction from this experiment would appear to be that the oxidase is soluble in water, but is carried down with the tannin precipitate and thus rendered insoluble.

As regards Dr. Schulte im Hofe's process, the last word has in my opinion not yet been spoken. The method is not new in itself, and has already been used for a long time in a good many cacao estate factories in completing the ripening process of the beans. It is more a question of the plant or machinery required. If it be possible to devise an apparatus which permits of the process being carried out cheaply and can be easily controlled, there is some prospect of the method being applied on a large scale.

The prize essays of Nicholls and Hudson offer a useful stimulus and contain new and interesting facts.

I cannot regard the proposal, that the small farmers should be forbidden to sell fresh cacao in order that thefts may thereby be avoided, as being of any practical value. In the Cameroons the tendency is, on the contrary, to encourage the natives to sell the fresh cacao so as to help exporters to obtain a better quality, as doing so enables the cacao to be treated in an expert manner by the European shippers. Thieving takes place all over the world, and the task of protecting himself against thefts devolves on the proprietor. Should special legislative enactments become necessary to prevent cacao thefts, it will surely be sufficient if the traffic in fresh cacao be controlled by demanding certificates of origin.[1]

The proportional weight of fresh to cured and dried cacao will vary considerably according to the variety of cacao and the country in which it is grown; also, Messrs. Mackinnon and Co. inform us, according to the machine used. This firm claims that its machines effectually dry the produce, cacao or coffee, with the minimum loss in weight. In the Cameroons the cacao produced is principally of the Forastero type, and in that case 100 parts of fresh beans yield 45 to 50 parts of dried cacao.

The best cacao is undoubtedly obtained by sun-drying. It will, however, be impossible, except in a few instances, to do without artificial drying plants.

Theoretically a plant constructed on the principle of bringing the produce into contact with opposing currents of air (*Gegenstrom*) should be the cheapest to work. The difficulty is, however, that the cacao dries very irregularly. The individual beans adhere to one another, and at the points of contact the

[1] I believe the German methods of handling and punishing the natives living under their authority are capable of rendering many laws to be unnecessary which we, in our own Colonies, have thought better to put into force.—H. H. S.

drying ceases or becomes delayed. It therefore becomes necessary to stir and turn the mass frequently, thereby interrupting the continuous working. So far as I can judge by experience, I consider a drying-house supplied with ventilators or fans and rows of trays the most practical method for carrying out the drying process.

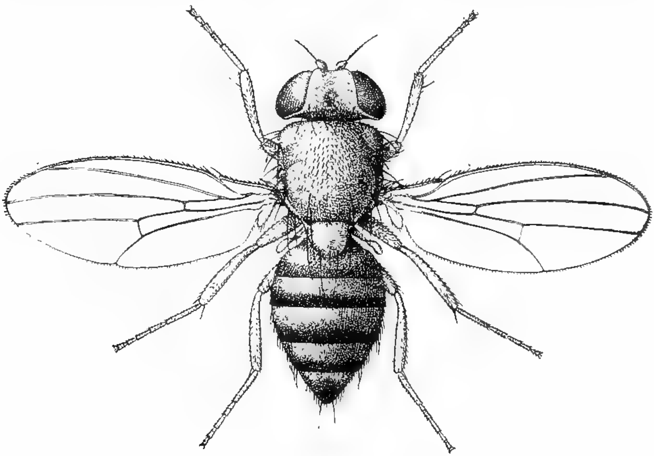
It is very doubtful whether the juice of the pulp can be utilized for the manufacture of vinegar, since, at least under the conditions prevailing in the Cameroons, a very large part of the juice runs off before the cacao reaches the fermenting boxes.

According to Nicholls the changes brought about in the interior of the bean are produced by enzymes formed on its exterior; in this view he coincides with Preyer. The statement can, however, hardly be substantiated.

The "cacao-fly" or some similar insect also occurs in the Cameroons, as it probably does in all tropical countries. It is always to be found on fermenting saccharine fruits. That it plays an important rôle in carrying the yeasts is a new and valuable observation for which we have to thank Nicholls.

Nicholls's proposal, that yeast should be added to the cacao from the first, seems worthy of consideration and of further investigation. Contrary to what Preyer aims at, he does not lay so much stress on using a pure culture (cultivated yeasts) as on increasing the total amount of yeast employed.. It would seem very probable that the quality of the cacao might be improved if an active fermentation could be induced from the first.

Dr. Schulte im Hofe, of Berlin, by the following remarks tends to show that he, whilst not disagreeing with Preyer and Nicholls, is



By courtesy of the "Bulletin of Entomological Research."

CACAO-FLY (*Drosophila melanogaster*), Mg. × 16; *see also* DR. NICHOLLS'S ESSAY.

more of accord with Dr. Fickendey, since he wrote thus:—

Dr. Preyer is of the opinion that the fermentation with yeast is the most important factor in the process of cacao fermentation, and maintains that the cleaner the yeast the better the quality of the beans. He considers that, for this work, the yeast *Saccharomyces theobromæ* to be the most suitable, and maintains that an acid fermentation would be harmful.

Dr. Nicholls likewise considers the fermentation with yeast the most important part of the process of cacao fermentation, but he also attaches importance to the penetration of the zymose formed by the yeast into the interior of the beans, which transforms the sugar contained therein into alcohol and carbonic acid. Nicholls certainly recognizes that in the process of fermentation the bitter substance is reduced, but considers this of secondary importance, and that it is more to the purpose to leave the removal of the bitter substances to the chocolate manufacturers.

In my work dealing with the removal of the bitter (astringent) substances, I consider this portion of the entire process to be the most important and critical for obtaining good cacao. The alcoholic and acetic acid fermentation is, in my opinion, of secondary importance. By means of this, the pulp should be removed by the cheapest and most simple manner, the life of the bean killed (which is done), and the bean itself is mildly acidulated. The acid effects (as also with tea) that the bean is subjected to in the process of oxidation which follows the fermentation causes it to better withstand the influence of harmful bacteria. The acid is further essential to obtain a cacao of the best possible quality.

Dr. Fickendey proves the presence of an enzyme which causes the oxidation, and likewise considers the killing of the bean, and the process of oxidation following thereon, as the most essential part of the fermentation. In order to accelerate the oxidation of the bitter (astringent) substances, Fickendey recommends that the beans should be treated after fermentation with a diluted solution of potash, in order to accelerate the oxidation by neutralizing the acid. Very bitter and sour beans are, as is well known, submitted to a similar process in chocolate manufactories.

Preyer and Nicholls therefore regard the most important period in the process as being when the beans are fermented with yeast, and attach no value to the conversion of the astringent substances contained in the beans. I myself, and after me, Fickendey, attach the chief importance to the conversion of the astringent substances. But whereas I regard it as necessary to submit the sour or acid-tasting beans to oxidation in order to obtain a good quality, Fickendey believes that better results can be obtained by the oxidation of the beans previously treated with potash in which the acid has been neutralized.

Dr. Oscar Loew confined his remarks to the prize essays of Mr. Hudson and Dr. Nicholls. This was due, I believe, to the fact that these notes were written in Munich on February 18, 1913, before the other essays had been translated and put into type. According to Dr. Loew, there can hardly exist any doubt that the fermentation of cacao was originally practised solely for the purpose of loosening the substances to be found between the pulp and the seed-coat. This leads to a ready removal of the attached pulp tissue, and thus a rapid drying process is insured, which is necessary in order to prevent the seeds becoming mouldy.

At the same time, however, changes in the cotyledons of the seed are produced during the fermentation, which finally lead to the development of the aroma. The chemical nature of this aroma has not yet been decided. It may be an ether-like compound or a ketone, or an aldehyde of the aromatic series, like *e.g.*, vanillin is. It would be an object of considerable interest to reveal the mother substance of the fine flavour peculiar to cacao.

So far the most important report on the subject, from a practical standpoint, is that of Mr. Hudson in the prize essay on the "Fermentation, Curing and By-products of Cacao." An experience of twenty years' cacao fermentation has been made careful use of and presented for our consideration. In regard to the aroma, this report contains a sentence of special importance, viz.: "*The higher the temperature attained and maintained for some days* *by primary natural fermentation, the better the class of cacao turned out.*"[1]

It seems to the writer that the effect of this temperature consists in promoting the action of a certain enzyme within the seed, splitting a glucoside in such a manner that afterwards, in drying and roasting, the development of a high-grade aroma is possible from one of the products thus broken up.

This is more probable than the formation of an ether-like compound by means of the alcohol produced by the yeast, since the fermenting liquid does not penetrate the seed.

As to how the fermentation should be started, the proposal of Dr. Nicholls to infect the pulped cacao with yeast and to add mineral nutrients in order to insure a rapid growth and multiplication of the yeast cells, is no doubt a good idea. In the opinion of the writer, the infection with a pure culture of *Saccharomyces ellipsoideus* would suit just as well as the infection with one of *S. theobromæ*. In fact the writer has discerned in Porto Rico only *S. ellipsoideus* and *S. apiculatus* in a lot of fermenting cacao beans.

Dr. Lucius Nicholls having read the translation of Dr. Schulte im Hofe's essay, wrote me that he could not altogether agree with his opinion, and then goes on to say :—

Oxidation of the interior of the bean naturally takes place, but the action is brought about by

[1] See p. 177.

oxidases, and these ferments are present in yeasts and other organisms and also in all seeds, for they produce changes which are necessary for germination. Apparently Dr. Schulte considers that all the oxidation takes place without any catalytic agent or ferment, but this is highly improbable, and his experiments certainly do not prove it. The same as with tobacco and tea, the fermentation is due to enzymes, either naturally present or due to organisms, and before one can test the changes occurring without the presence of these, they must be isolated from the rest of the constituents, and this is practically impossible without altering the cacao beyond all recognition.

Last, but by no means least, we come to Dr. Axel Preyer, whose work was carried on during the closing years of last century, and, as stated, published in *Der Tropenpflanzer* of April, 1901. Now, on April 7, 1913, or just twelve years later, Dr. Preyer writes from Venice, where he holds the position of German Consul, as follows:—

"It is with considerable pleasure that I accede to the request of the Editor of *Tropical Life*, Mr. H. Hamel Smith, to add a few words to my old essay on 'Cacao Fermentation.' Although, as I state in the concluding paragraph of this essay, which was published in *Der Tropenpflanzer*, No. 4, of April, 1901, I have, in the above communication, given some details regarding the causes of fermentation and the methods employed to induce fermentation in cacao, there still remains a difficult but important point to be solved, viz., the recognition of the chemical changes that take place during the fermentation and drying, and of the intermediary and final substances formed during the process. It would still be too risky, before even the composition of the fresh cacao bean in its various parts is fully known, to wish to advance chemical hypotheses about the processes and changes that take place during the process of fermentation; but it is very probable that, later on, the chemist will play an important part in the preparation of cacao on the estates.

"Although the above was written nearly thirteen years ago, I am afraid that I have not much to say now, as the *chemical side* of the problem, on which I touched towards the end of my essay, has so far not been elucidated by any new researches. This is, in my opinion, a pity, because in cacao (as well as in coffee) fermentation the chemical changes in the beans are certainly most important factors for those who are striving to improve the market quality of the produce and prices to be obtained by it, whilst ignorance of the nature of these changes makes further improvement of the planters' present methods difficult.

"Nevertheless, I would suggest that the question of cacao-yeast cultivation, which has been examined by several of the authors, be followed up most carefully. Probably the cacao-yeast of Ceylon would not thrive well in other tropical countries, if it met with other kinds of competing yeasts or bacilli, but I am sure that in every cacao-producing country *a* variety of yeast is to be found and isolated in pure cultures, which would facilitate the preparation of a first-class quality of cacao beans, provided the right methods of fermentation are followed, viz., tank arrangements, temperature, duration, access of air, and protection against bacilli infection. The resulting qualities of cacao may all be good, although in the same way as with the wine and beer fermentation in different countries of the world, differences of colour, flavour, &c., of the cacao of the East or West Indies, of the Cameroons, or Ecuador will always be noticeable. But, to the planter, the problem is limited to the question as to how he can best produce a good, high-priced cacao in an economical way, given the natural conditions of his country. Well, on this question my reply is—by using a good, pure culture of cacao-yeast, produced in the same country as where the cacao is grown, and in carefully giving this yeast the best conditions individually suited to it for fermentation."

I can only conclude by echoing Dr. Preyer's suggestion that the whole question of cacao (coffee, tea, tobacco, &c.) fermentation be carefully considered and followed up by experts and planters alike, and then put to practical tests until a certain method is evolved by which all planters at each centre can prepare their beans or other produce in such a way that it can be bulked and sold to type for shipment, no matter whether produced by a dozen large estates or a hundred small ones. This is a time of standardization, of big concerns and large orders; those planters, therefore, who want to secure the full value of their produce must give the buyers the type of cacao, or other produce that they, the buyers, want, and not what is easiest for the estates to to turn out.

Having done with these criticisms, I would like to call your attention to the following which appeared in the West Indian *Agricultural News* of March 15, 1913, p. 91. When speaking of the nature of cacao fermentation, we are told that recently communicated to the Chemical Society and published in their journal for November, 1912, is an important paper by Bainbridge and Davies (of Messrs. Rowntree and Co., Ltd.) entitled "The Essential Oil of Cacao."

Much of the information it contains is purely of scientific interest, but those matters dealt with which are likely to prove useful and interesting to the cacao grower have been abstracted as follows:—

The essential oil was obtained in the investigation by the distillation of cacao nibs. It possesses an intense odour of cacao, and the flavour was clearly perceptible in a dilution of 1 in 50 million parts of dilute syrup. The flavour is most nearly akin to that of coriander oil. It is pointed out that in the method of preparing cacao beans in the Tropics by fermentation and slow drying, a number of possible ethereal substances are added naturally to the crude oil. To explain this, a description is given of the different fermentation changes, as investigated by one of the authors in the West Indies.

The first runnings from the fermenting box contain alcohol, invert sugar and tartaric acid. Part of this liquor penetrates into the beans, but the shell membrane is fine enough to prevent the micro-organisms, which lead to the production of these substances, from percolating to the kernels.

During the first twenty-four hours of fermentation the temperature rises to 35° or 40° C., varying with the exact position of the box. Within forty-eight hours it rises to 40° to 45° C., and if the fermentation is continued for five or six days, the temperature will be found to rise to a maximum of 45° to 50° C. Higher temperatures are occasionally noted when the fermentation is continued for an exceptionally long period, for instance, ten to eleven days, as in Trinidad. In this case, however, the temperature will fall towards the close.

The bi-chemical nature of the different changes is explained as follows :—

(1) A large growth of *Saccharomycetes apiculatus* ("yeast") together with small quantities of *S. anomalus*, doubtless derived from the surface of the pod husks. This stage lasts about twelve hours.

(2) As in spontaneous wine fermentation, an enormous development of true *Saccharomycetes* occurs. If the temperature rises there will be no formation of new cells after the first forty-eight hours. The alcohol produced soon arrests the growth of *S. apiculatus* and "wild" yeasts. A quantity of alcoholic liquor drains away.

(3) Acetic acid fermentation occurs. This is caused by *Bacillus aceti* brought in great numbers by swarms of the "vinegar fly" (Drosophila). If the temperature does not rise above 50° C., the acetic bacteria continue to grow during the remainder of the fermentation.

(4) Finally, if the fermentation is prolonged beyond eight days, a growth of spore-bearing bacilli of the *Bacillus subtilis* type will take place.

In continuation the authors state: "It is obvious that a number of the products resulting from these complex fermentations will percolate into the bean, and of these the less volatile constituents will remain on the dry kernel. Consequently we shall expect to find that the true essential oil of cacao is accompanied by a certain number of esters and higher alcohols, analogous to those produced in other spontaneous fruit fermentations taking place at comparatively high temperatures in the presence of a free supply of air."

After describing the chemical and physical properties of the essential oil and other volatile products of cacao, the paper concludes with a summary, part of which is reproduced as follows :—

"(1) The aromatic principle of the cacao bean is an essential oil ; (2) two thousand kilos of cacao nibs (deprived of some cacao butter) gave a yield of 24 cc. of purified oil with a very powerful aroma and flavour of cacao ; (3) the oil was fractionally distilled three times and the third distillation yielded seven fractions ; (4) the early fractions were rich in esters, divided in all probability from the fermentation of the cacao bean ; (5) the middle fractions were rich in *d*-linalool, corresponding closely with coriandrol. The total linalool represents more than 50 per cent. of the cacao oil."

As the question of cacao oil is here introduced the following, taken from the *Journal of Chemical Technology* for December, may be of interest :—

"Duyck (*Ann. de Chim. Anal.*, November 17, 1912, p. 405). A summary of experiments on various methods for detecting adulteration in cacao butter. The official French method demands the determination of (*a*) the temperature of solution in absolute alcohol; (*b*) the saponification number; (*c*) the iodine value; (*d*) the volatile insoluble acids. The author also determines the acidity of the sample. In German tests the refractometer index, the melting point, and Bjorklund's test are also required. Robin detects coco-nut oil (5 per cent.) by finding the solubility in alcohol (55·5°) and comparing the co-efficient obtained with the saponification number. For pure cacao butter the constant lies between 7° and 8°, but is considerably decreased in presence of very small amounts of coco-nut oil (*Ann. de Chim. Anal.*, 1906, p. 454, 1907, pp. 14, 40, 87, 181). Coco-nut fat gives a figure of 15 to 18 (cc. N/10 NaOH for 5 grm.) for volatile soluble acids, considerably higher than that for cacao butter, and at the same time raises the saponification number and lowers the refractive index and the iodine figure. Bjorklund's ether solubility test is valuable for the detection of wax, margarine, and paraffin, especially when the melting-point also is taken of the fat which is deposited on cooling the solution to 0°. This melting-point should not exceed 30°. The acidity of commercial cacao butter, when not rancid, is not greater than 0·5 per cent., expressed as oleic acid. Cacao butter is also adulterated by the addition of fat from the pellicle and other waste parts of the plant. This fat is less aromatic than the true 'butter' and rapidly becomes rancid. It is hardly possible to detect this adulterant with certainty."

CHAPTER IX.

A FEW NOTES ON THE CURING AND FERMENTING OF TOBACCO.

By the Editor.

As the question of tobacco fermentation has been touched upon by Dr. Schulte and other writers, the following notes may be of use to those interested in tobacco production either as a main or a subsidiary crop, as well as to planters generally, to compare with the various processes involved in preparing their crops for market.

"There are many styles of houses used for tobacco, depending upon the method of curing." Thus reports Mr. J. N. Harper, M. Agr., Director of the Agricultural Experiment Station, Clemson College, S.C. "The flue-cured tobacco is cured in a house that can be made almost airtight, with a ventilator in the top which can be closed. The Virginia bright leaf is cured in this way. The White Burley is cured entirely without artificial heat, requiring from five to six weeks in its curing. Barns in which tobacco is air-cured should have lateral, horizontal ventilators rather than perpendicular ones, because the tobacco is not so liable to house-burn. The flue-cured tobacco requires only a few days for its curing. After tobacco has been thoroughly cured, it should be stripped and sorted into different grades, and after a certain time it should be put down in bulk for fermentation. Fermenting tobacco is an art, and the process is due to enzymes rather than to bacteria as was once thought. These enzymes are destroyed when the temperature of the tobacco is raised above 152° F. Before tobacco is placed in hogsheads it should be dried out so that it will contain about 11 per cent. moisture. Fermentation takes place more rapidly at a high temperature than at a low one. The stripping, grading and sorting should be done only by an expert. · The dark, heavy export tobaccos are cured in close barns by an open fire under the tobacco and require close attention during all of the stages of curing. It is possible to cure the tobacco a bright yellow or a dark mahogany by simply varying the temperature, the humidity of the atmosphere, and the length of time in curing."

Mr. Charles R. Jones warns us, in the article he contributed to the *Philippine Journal of Science*, Manila, P.I. (vol. viii, Section D., No. 1, February, 1913, p. 27), on the tobacco or cigarette beetle (*Lasioderma serricorne*, Fabr.), that with open mandalas, or fermenting piles (see illustration, fig. 1), where the beetles have free access to the leaves, they do incalculable harm, and it is at such times probably that this pest of all (tobacco) pests starts its campaign of mischief-making, which is estimated to annually cost Manila only from $3,000 to $6,500 (or £600 to £1,300) per factory for cigars actually destroyed in the factory alone.[1] For this reason I believe that it will be greatly to the interest of tobacco planters in all parts of the world to look into this matter of fermenting and otherwise curing their tobacco, and to see if it cannot be done in such a way as to effectually prevent the beetle obtaining access to the leaves. As the whole question of doing so is of such paramount importance to the success of the industry generally, I have dragged the matter into this book in a way I should not otherwise have done, simply because I feel that if the beetle is to be kept away from the tobacco at the start, new methods will have to be introduced to supersede the old ones, or if already introduced into some

[1] "This," Mr. Jones tells us elsewhere, "represents but a small fraction of the real loss, for these figures do not include the shipment of infested cigars, which gives a bad reputation to Manila cigars, and leads to a far greater loss to the factory than does any occasional waste in goods or damage due directly to the beetle. The Annual Report of the Bureau of Customs (Manila), during the fiscal year 1911, shows a decrease in the exportation to the United States, of tobacco and tobacco products, from pesos 4,023,404, in 1910, to pesos 1,483,544 in 1911. (peso = Mexican dollar, or about 2s.) The bulk of this decrease can undoubtedly be attributed directly to the cigarette beetle."

centres, that such improved methods must be adopted elsewhere.

Mr. Jones himself includes an illustration (see fig. 2) in his report showing how the tobacco can be fermented in closed receptacles, which, whilst keeping the beetle out, is said to give equally satisfactory results as regards the

[*Reproduced from the "Philippine Journal of Science."*]

FIG. 1.—Open mandalas (fermenting heaps) of tobacco.

quality of the tobacco as when the leaves are fermented in unprotected piles.

"The infestation of the tobacco by the cigarette beetle," he claims, "can be controlled to a certain extent by the use of a modern fermenting compartment. This can be so arranged as to prevent the beetles entering freely, and it will give just as satisfactory results as the open mandala." If, therefore, the root of the evil lies in the ability of the pest to obtain access to the fermenting piles, causing so much loss to the planters, I feel sure the question of improved fermenting, or sweating compartments for tobacco, will also receive the careful consideration of the planters and

Reproduced from the "Philippine Journal of Science."]

FIG. 2.—Closed Mandalas with Tobacco.

Government experts alike. "Forty-one per cent. of the annual factory loss due to insects," Mr. Jones tells us, in his concluding remarks, "would pay for the necessary chemicals and labour to combat the pest, and 13 per cent. for installing proper apparatus. There would thus still be a saving of 46 per cent. on this stock alone, and these figures do not take into account the direct loss due to this beetle outside the factories or the indirect loss of trade. At first the new and improved methods must be carried on by persons who realize the prime importance of accuracy and the necessity for keeping treated stock free from reinfestation; but in the course of time, as work progresses and the ordinary labourers become familiar with the ordinary operations, the cost of fermenting the tobacco by improved methods may be greatly reduced."

As regards drying and fermenting, reports Mr. N. C. Chudhury, Travelling Inspector of Agriculture for Behar and Orissa (India), the plants, immediately after being conveyed to the curing house, should be hung upon strings 6 in. apart, beneath the roof where it is well ventilated. They should remain in this state for about two months until thoroughly dry. Early in the rainy season the plants must be taken down, stripped and handled, when the three qualities, best, medium and worst leaves, should be separated, as they are stripped. Sixteen to twenty leaves may be tied together to make a bundle. These bundles are put into large heaps, 2 to 4 ft. square, 4 to 6 ft. high, and well pressed down for fermentation. A heap should not contain less than twelve maunds (maund = about 82 lb.) of dried leaves. The leaves must be transferred in order to avoid excessive heating, which can be ascertained by touching the tobacco, and so testing it by the hands, at one place and then another in the heap, at intervals of, say, three or four days until the desired colour and flavour is obtained. Excessive heating spoils the colour and the flavour.

In Behar the plants are carried to some grassy spot and laid out to catch the sun during the day and the dew at night, being turned daily. After a week or so, the plants are stacked together. After three or four days' heating the stack is broken and the plants are laid out on the ground where they are kept for two or three days. Then the plants are again stacked for four or five days. This process of heaping and spreading on the ground is repeated six or seven times until the leaves and stems are fully dried, when the curing is considered over. The plants are then carried home when the leaves are stripped and separated according to their grades. The former method of curing tobacco is recommended.

Of late there has been some demand for cigar and cigarette tobacco in India. It would not be feasible for the ordinary Indian raiyats to prepare these classes of tobacco. For the growers of this tobacco, I may point out that the cigarette tobacco should be completely dried very quickly, say within three days, for which artificial heat, gradually rising from 80° to 170° F., in a specially constructed room provided with ventilators, is necessary. A lower grade of this tobacco may be dried in the sun.

For the manufacture of cigarettes light yellow-coloured very thin leaves are wanted.

The process of fermentation for producing cigar tobacco is more difficult. Much care and skill is necessary to bring this work to a successful close. The desirable colour and aroma of the leaves depend entirely on this operation. After the leaves are dried in the shed they are put into bulk. The leaves should contain about 20 per cent. of moisture, so should be artificially moistened with a fine spray if too dry. On the other hand, 26 per cent. of moisture in the leaf is considered excessive. The temperature of the piles rises to about 126° F. within two days. Leaves should be rebulked in three or four days. The bulk should be watched closely during the fermentation. In the case of filler leaves the temperature must not be allowed to rise above 180° F. This maximum temperature is never desired. A temperature of 160° F. for the filler leaves and that of 120° F. for wrapper leaves are recommended by the tobacco experts of the United States. When this temperature is reached, the bulk should be broken down and rebuilt. The bottom and top leaves should now be placed in the middle. The temperature now rises more slowly. The next rebulking is necessary in seven or eight days. Altogether the piles are repacked from five to ten times until the temperature fails to rise. The temperature of the fermentation room should be maintained at 70° to 80° F. For the wrapper, light brown-coloured leaves and for the fillers deep brown-coloured leaves of good aroma and burning quality are in demand. The Sumatra variety of tobacco is the best for wrapper and the Havana for the filler. Among the country varieties, the Hingli tobacco of Nadia, which has thin leaves of mild flavour, may be suitable for ordinary cigarette tobacco.

I have quoted these remarks at length because I noticed that some little time back, Mr. Bernard Coventry, Agricultural Adviser to the Government of India, expressed the opinion that the comparatively slow expansion in the production of good tobacco in India was mainly due to two causes, viz., the degeneracy of the Indian plant, and the crude and primitive methods employed in curing the leaves. From what I know of Indian cigars, they are even more liable to be "pricked" by insects (which I take it is the same *Lasioderma serricorne* about which Mr. Charles Jones writes so ably) than Philippine cheroots or Cuban cigars. In the old days we have sent many a shipment of Trichinopoly cigars to the West Indies, with most unfortunate results, owing to their perforated state when landed or soon after. All this renders it extremely important to keep the insects away from the tobacco as much as possible, and above all when the leaves are being fermented and cured. For these reasons, therefore, I have included these remarks in order to call attention to the closed sweating or fermenting chambers of the Philippine Isles, in the hopes that by stimulating attention in that direction, tobacco producers, the same as cacao planters, will be encouraged to carry out individual investigations, with a view of discovering improved methods for fermenting their leaves, not only to enable the enzymes to improve the quality, but by keeping the beetles and other pests away, to increase the output of high-class tobacco from their estates.

INDEX.

Unless otherwise specified all processes, terms, &c., in the following Index only refer to Cacao and its preparation.

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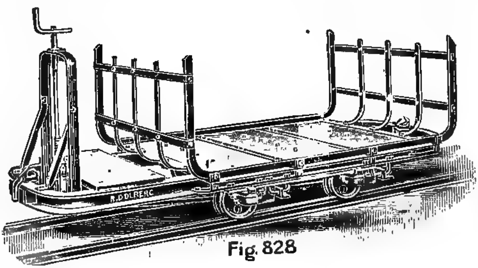

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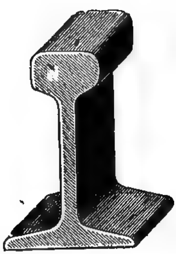

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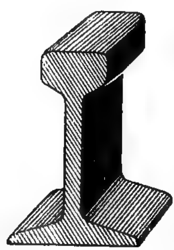

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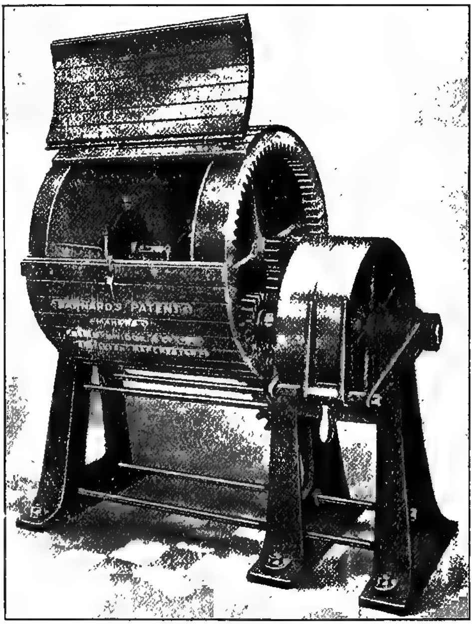

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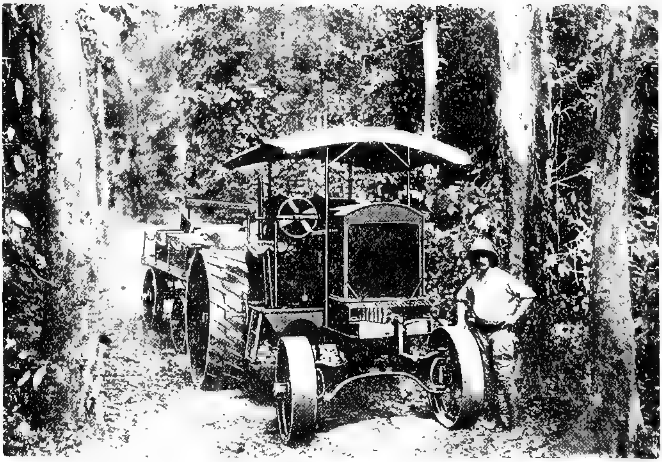

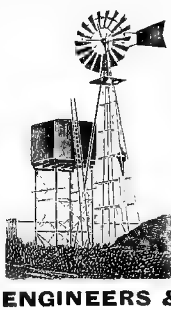

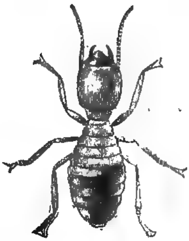

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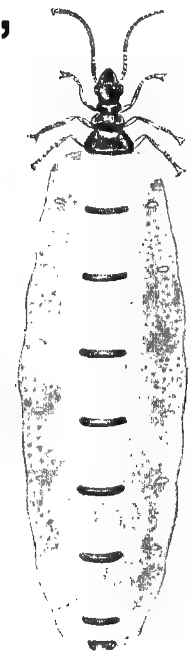

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