SUGAR MADE FROM MAIZE AND SORGHUM

Please
notice

E. J. Wickson.

SUGAR

MADE FROM

MAIZE AND SORGHUM.

A NEW DISCOVERY.

BY F. L. STEWART.

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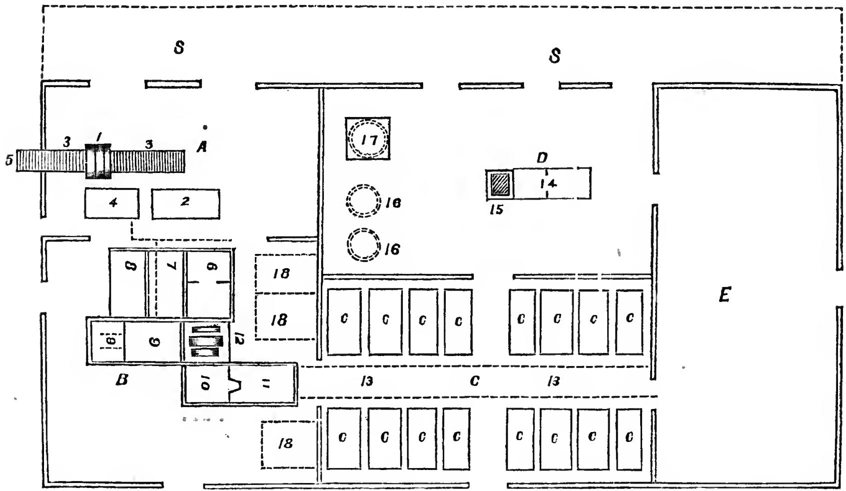
Plan of a Small Sugar Factory.
Maize or Sorghum,



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PREFACE.

The design of this work is plainly and briefly set forth in its title. The claims now made, a review of the facts upon which they are based, and some suggestions for the use of those who might desire to turn them to account, form the subject of a paper now about being published in the Annual Report of the Commissioner of Agriculture of the United States. But the necessity now existing for the immediate publication of a much fuller and more systematic treatise than the article above referred to, adapted not only to answer such reasonable inquiries as are constantly being made, but also to serve as a complete manual for practical use, has led to the preparation of this volume.

The subject itself has a claim upon the attention of the American people of no ordinary kind. The effect of the practical adoption of the truths herein set forth will be to revolutionize sugar production in this country, to enhance almost beyond estimate the value of Indian corn and sorghum, to carry the line of available sugar-producing territory from the Gulf coast to the 49th parallel, to save to the country the immense sum of about one hundred millions of dollars now annually expended for foreign sugars, and to assist, by the rise of a new and permanent industry, in the solution of a much vexed question, by giving remunerative labor on the corn lands of the West to a great number of our population now unemployed.

The alleged identity in all important particulars of crude saccharine juices, to which the author as well as others once gave credence, has proved to be an error. Whatever is valuable in the new process of making sugar from sorghum and maize, is the direct result of the removal of this old stumbling-block out of the way.

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Sugar made from Maize and Sorghum.

I.

INTRODUCTION.

Complex Nature of Saccharine Juices—Destructive Properties of Cane Sugar—Classification of Saccharine Plants—Maize and Sorghum as Sugar Plants—Peculiarities of their Juices—Errors Corrected—Inapplicability of Old Processes to Extraction of Sugar from Them—Necessity of New Modes of Treatment—Their Product—Cane Sugar—Spurious Corn Sugar—Sources of Sugar Production within the United States heretofore—Inadequacy of Them—The Sugar Cane in Louisiana—Causes of Deterioration.

The art of extracting sugar from the crude vegetable juices in which it exists must always vary in its processes and appliances with the nature of the associated substances in solution. This fact has sometimes been lost sight of. The large number, and often comparatively large amount of dissolved substances other than sugar found accompanying it, the instability of most of these substances and their complex chemical relations, together with a variety of other circumstances influencing the result, known only to the experienced manufacturer or chemist, combine to make what at first sight seems a matter of simple evaporation and crystallization a very intricate chemical problem.

For the reason that sugar is solely a product of nature, and that neither any "fortuitous concourse of atoms," nor any means within human reach, operating through any of the known laws of matter, have ever been able to produce it, the highest skill finds enough to do to separate it, unimpaired, from the combinations in which it is found. True sugar is radically distinct from all other saccharine substances as far as known in this particular. It is formed only in the living plant. Other kindred substances of a lower type, such as glucose and levulose, (grape and fruit sugar,) may easily be fabricated by familiar synthetic processes; but this is formed only through the mysterious operation of the vital principle upon lower grades of pre-existing matter in the same series. Its final separation in the pure crystalline form, from the association in which it is thus by nature found, is the result which every successive step in the treatment of raw material should contribute to secure. It is never found naturally in the pure state.

Hitherto the sugar supply of the world has been derived almost exclusively from two sources: the sugar cane, in the regions within the tropics, and the beet, within the temperate zone of Europe.

The sweet juices of most vegetables and nearly all fruits are due to the presence of saccharine substances entirely different in chemical properties, constitution and use from true sugar, and these should never be confounded with it.

Plants containing a sweet juice may be divided, generally, according to their composition, into three classes, viz:

1. Those like the sugar cane and the beet, which, when their juices are mature, contain, in association with other substances, true, crystallizable sugar only.

2. Those, like most fruits, such as the apple and the grape, which, whatever their composition otherwise, contain no true sugar, but only glucose, levulose, &c.

3. To these must now be added a third class, heretofore not generally recognized as distinct, *which contain in their best condition both true sugar and glucose*, but the latter uniformly in comparatively small quantity.

The representatives of this class are maize and sorghum.

I propose to show in the following pages that the last-mentioned plants have a legitimate claim to be ranked with the best sugar-producing species now known. In proof of this, and in the face of natural obstacles to a practical realization hitherto of the value of these plants in this particular, which none so well know the magnitude of as those who have fully encountered them, it can now be shown that the current opinion as to the uncrystallizable character of the sugar of the juices of these plants is not founded on fact.

This opinion is based upon the very unsafe ground that, because sugar has not been practically obtained from these sources hitherto, they do not contain it; for it can now be clearly shown that chemical analysis invariably reveals the fact that not only are the juices of maize and sorghum, grown in the United States, as rich, if not richer, in sugars, than any other plants that can be grown in temperate latitudes, but that, when in the proper condition, nine-tenths of their saccharine matter is crystallizable sugar of the true cane type.

I am certain that there should now be no controversy on this point.

Taking this for granted at present, it is plain that the obstacles to the extraction of the sugar from these plants does not consist in any deficiency of true sugar itself, because they contain it in larger quantity than any other sugar-producing plants except the cane of the tropics; nor does it consist in the presence in them of a larger proportion of impurities or substances other than sugar, because they are less by at least one-half in either of them than in beet. The impediments to crystallization, therefore, must be in some peculiarity apparently of the composition of these juices themselves, and this is now found to be the fact.

Accordingly, I find, as might have been anticipated, that neither the processes adapted to the extraction of sugar from the southern cane, nor the much more elaborate methods of the beet-sugar manufacturers in Europe, are appropriate for the successful extraction of sugar from these plants, which in this case *involves entirely new conditions*, and requires radical changes in the modes of chemical treatment.

The obstacles to the crystallization of the sugar of this class of saccharine juices have now been finally overcome by the use of the means which it is the object of this publication in the plainest manner to describe. A new field of manufacture, practically almost limitless in its range, is thus opened up. The class of plants from which these new sugars will be produced are annuals of a comparatively short period, of wonderfully luxuriant growth, simple in all their requirements as to soil and culture, and capable of being grown over a geographical area beyond all comparison greater than that of the southern cane and the beet combined, not only within the United States but throughout the world.

The force of these natural advantages will be found to be greatly augmented by the circumstance that the departures from the old processes of manufacture now necessary to be adopted are all in the direction of greater simplicity, cheapness, and ease of management in accomplishing the result—the reverse of what the more complex nature of these juices would seem to indicate.

It will be found, for example, that the cost of the manufacture of corn or sorghum sugar in this country can easily be reduced to less than one-half the cost of the beet-sugar manufacture in Europe—*the carbonatation process and the use of animal charcoal being entirely dispensed with, and the use of the vacuum-pan made unnecessary.*

It is important in this connection that there should be no misapprehension as to the nature and quality of the sugars now furnished from these plants.

Although chemistry recognizes a distinct class of substances to which the general name of sugar is given, there is but one body in nature, recognized in the commercial world, to which the appellation of crystallized sugar can properly and honestly be applied. It is exclusively a natural product. It must pre-exist in the living plant. It cannot be counterfeited or made. In its association with other bodies in the original sources from which it is obtained, its presence is oftentimes indicated only by the nicest chemical tests. To break the alliance subsisting between it and the substances often in great number found along with it, and to separate the sugar without destroying it, is, in many cases, one of the most difficult problems in organic chemistry. And it becomes a *new* problem, involving new modes of treatment, every time that a crude saccharine substance is brought under examination of a different organization from others, which are well understood. Sugar, as it exists in the tropical cane, in the maple of our forests, in the beet, in sorghum, and in maize, is, in its purified form, precisely the same substance. In saccharine value no other substance can at all compare with it. No other possesses the same crystalline form, the sweetening power, or the same chemical constitution and adaptation to the uses of man as an article of food.

This distinction is necessary to be made here at the outset, because Indian corn has recently obtained some celebrity as a sugar plant in its capacity to furnish from the starch of its grain, by a well-known transformation, the miserable "STARCH SUGAR," to which by an amazing stretch of courtesy the name of "Corn Sugar" has been applied. The misnomer should deceive no one. This spurious sugar is manufactured largely for the uses of the brewer and distiller, and for the fabrication with other substances of cheap table syrups; but, in its isolated form, it lacks all the essential qualities of true sugar except sweetness, and that in so much lower degree as to reduce its commercial value to about one-third that of common sugar, and incapacitate it from serving any of its ordinary uses.

The natural sources within the territory of the United States which have heretofore contributed to the supply of sugar have always been extremely limited, but never so much so as at present. The product of the maple tree of our forests as compared with the demand is utterly insignificant, and although it is possible that production from the tropical cane in Louisiana in certain districts and at a few other favorable points may be extended in the future so as to utilize to the utmost all available resources and restore it to a condition of comparative prosperity, still it must be admitted upon all hands that we cannot in coming years reasonably look to that source to supply more than a small fraction of the sugar annually consumed in the United States.

The decline of this industry of the South during the decade preceding the late civil war was due to natural causes affecting the growth and development of the sugar cane itself. After years of careful experiment it became plainly evident that the transplantation of an exclusively tropical plant into a narrow fringe of extra-tropical territory along our gulf coast, where alone the climate will permit it to grow at all, was in violation of a law of the life of the plant, the ultimate result of which was disease and decay.

It was of no permanent avail that Government aid was invoked, and freely given, to encourage production. Cuttings of new and undegenerated varieties were introduced from distant quarters of the globe, protective duties upon foreign sugars were imposed, and nothing was left undone to foster an industry which, where it was temporarily successful, so abundantly rewarded capital and skill.

Never was the ingenuity of the American mind more conspicuously displayed or more enthusiastically bestowed than in the attempt to supplement by human intervention and assiduity the lack of the needed qualities in the sun and air of Louisiana.

Apparatus of rare workmanship and enormous cost was employed in the manufacture of the sugar, and not without reward, for, in quality, the sugar of New Orleans soon enjoyed a marked pre-eminence; but nothing could countervail a climatic defect, by which the frost of a single night would wither the hopes of the planter for a whole season, or arrest the deterioration of his best imported canes.

Contrary to a widespread belief, the civil war was not the immediate cause of the prostration of this industry, although it precipitated it; and now, notwithstanding so many years have elapsed since its close, during which the stimulus of high prices has been constant, the business has not revived, and every year the disparity between the demand and the supply from this source has been becoming greater.

Nature has plainly set barriers to the geographical range of the plant, beyond which it cannot be grown with success. It is only within the tropics that the regions are found from which the markets of the world are now supplied from this cane, or can be expected to be with any regularity in the future. There is no apparent reason, however, why the former yield of sugar from the Louisiana cane may not be again equaled or even increased within certain climatic limits. Damage by frost before or during the rolling season has become so frequent of late as often to leave the crop entirely worthless for the extraction of sugar by the means now used. The partial fermentation which ensues converts a portion of the sugar into the uncrystallizable form, which prevents the crystallization of the remainder. If, as some experiments show, the loss in this way is not more than 2 or 3 per cent., analogy would lead to the inference that the same process which now extracts the sugar of maize and sorghum, in the presence of a like amount of uncrystallizable sugar, would prove a remedy for the effects of such a disaster, if seasonably applied. Some tests to be made this season will determine this point.

II.

MAIZE.

Origin and Early History of Maize—Evidences of its Existence in America from Pre-historic Times—Uses of the Immature Plant by the North American Indians—Its Saccharine Value Recognized—Maize Among the Aztecs—Mexican Sugar—More Recent Experiments in the United States—Their Character—Biot's Analysis in France—Erroneous Theories—Unsatisfactory Results—Obstacles to Success Defined and Causes of Failure.—New Researches Made Necessary.

The discovery of maize, regarded as to its influence upon the welfare of the human race, was the most important event directly following the discovery of the New World. The uses of Indian corn are found to be so numerous, its products are so multiform, its productiveness and vigor are so wonderful in this its original home, as to give it deservedly the very foremost rank among agricultural plants. The peculiar summer climate of North America —almost tropical in its temperature—seems especially adapted to the growth and health of the plant.

Nothing illustrates more forcibly the inadequacy of the means used two or three hundred years ago to fix and transmit exact knowledge than the uncertainty which existed in the minds of the early botanists as to the origin of Indian corn. It was not until De Candolle within the last half century had authoritatively established its birthplace in the New World that the truth was at last acknowledged.

The American origin of maize, independent of the direct testimony of the early discoverers to the fact, is proved by the absence of any description of the plant by the old writers as existing anywhere in the Old World previous to the conquest of Mexico.

Cortez brought back with him on his first return to the court of Charles V some ears of Indian corn. The plant had acquired a great variety of uses among the Aztecs when the Spaniards first entered their country, and it was assigned a prominent place in their sacred calendar. The ancient Peruvians left artistic representations of the plant executed with exquisite fidelity in gold; and it was cultivated in the gardens of the Incas. An ear of corn was found in the envelope of a mummy from Peru, formerly exhibited in Peale's museum, which must have been deposited where it was found before the time of Pizarro.

Its existence in North America at the earliest period of which we have any traces is no less unmistakable. Among the Iroquois, the names of all the summer months were derived from the different phases characteristic of the growing maize throughout the season. The grain (yellow, blue, and red) was found everywhere by the first explorers along the whole eastern coast. Pointing to a still earlier date are the charred remains of corn-ears found imbedded in the mounds of the West, an example of which exists in specimen No. 21,044 among the Archæological Collections of the Smithsonian Institution in Washington, recently disinterred from a mound in Utah.

But still more conclusive as to the extensive cultivation of the plant here at a period far antedating all European knowledge of it, was the discovery made many years ago of a remarkable deposit of charred Indian corn beneath the alluvion of the Ohio Valley, at a point about twenty miles below Wheeling. Dr. Johnson, of Louisville, describing it, says: "The stratum is generally eight to ten inches thick and five to six feet below the surface, and contains nothing but corn grains closely impacted together with black dust." He expresses the opinion that "if all the corn raised in the Ohio Valley and all its tributaries above this point were collected together, it would not amount to one-tenth of this deposition." (*Atwood's Southern Almanac*, 1851–'2, p. 30.)

The superiority of American corn passes unchallenged in the great grain marts of the world, and but for the fact that the means of transportation cannot keep pace with those of production, there would scarcely be a limit to the profitable growing of the grain for foreign export.

But it is only of very late years that any practical advantage has been taken of the fact that the *immature grain*, especially of some varieties of sweet corn, when properly cured and dried, possesses qualities singularly different from those of the grain when ripe, and eminently befitting it for becoming a highly valuable and acceptable article of food all over the world. This use of it is yet in its infancy; but this desiccated corn will evidently soon be made the basis of a greater variety of light, nutritious and palatable food preparations than the ripened grain is capable of. The ancient inhabitants of this country used it very generally in this way—the Aztecs and the southern nations particularly being skilled in various methods of utilizing the plant of which we are now in ignorance.

But in nothing is the defectiveness of our knowledge as to its economy and uses so palpably evinced as in our lack of appreciation of its saccharine value. This quality of the juice of the green plant was early noticed. Captain John Smith, in a narrative which he has left of his visit to Virginia nearly three centuries ago, gives an exceedingly interesting description of the natural productions of the country at that day, and especially of Indian corn, and remarks: "The stalke being yet greene hath a sweet iuice in it, somewhat like a sugar cane, which is the cause that when they gather their corne greene they sucke the stalkes; for as we gather greene pease, so do they their corne, being greene, which excelleth their olde."*

It is not probable that these rude Virginia savages, living, as Smith expresses it, "from hand to mouth," ever advanced beyond the primitive practice of peeling and chewing the stems to extract their sweets, just as all other savages have done from time immemorial in places where the sugar cane abounds; but the remarkable people who inhabited the Mexican plateau, and who were as far in advance of their northern neighbors in the useful arts of life as they were in civil affairs and military skill, if we may believe the old historians, were versed not only in the preparation of a

* True Travels, Adventures and Observations of Captaine Iohn Smith. Account of 6th Voyage, A. D. 1606. London ed., A. D. 1629.

multitude of articles of food produced from both the ripe and the unripe corn, but also had acquired the art of extracting a species of sugar from the juice of the living stems.

It was this three-fold use of the plant, together with its wonderful productiveness, which excited the astonishment of the early discoverers, and which led the native races themselves everywhere throughout the continent from Hudson's Bay to Patagonia to venerate it as the crowning gift of the Great Spirit.

It is certain that in Mexico some sugar had been made from it at the time of the landing of Cortez, but the old chroniclers of the Conquest drew their pictures with a free hand, and it is extremely improbable that, as a regular production, it had attained to any very considerable importance. This appears from several circumstances, among which is the fact that maize sugar had no such prominent place, at least, in the vast enumeration of articles statedly provided for the cuisine of the Aztec monarchs, which it certainly would have had if it had ranked as a staple of the country.

The nature of the juice of maize is such that it yields with comparative facility by ordinary treatment a small proportion—some 2 or 3 per cent.—of its sugar. We may, therefore, fairly infer that, as in the case of some experiments reported to have been made in this country, a short time before the introduction of the Chinese cane, sugar was not obtained from it in remunerative quantity; and there is no evidence to show that sugar-making, as it existed among the Aztecs, can ever be claimed as one of the "lost arts." *

Yet these statements are not merely mythical, and in their relation to other facts have certainly some practical significance.

At this time, with a peculiar force, the inquiry comes up for answer: Has Indian corn any definite, practical value as a sugar-producing plant?

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* Prescott extols the noble growth and saccharine qualities of maize in those equinoctial regions, and refers to sugar made from it. (*Conquest of Mexico*, rev. ed., 12mo, 1874, vol. 1, p. 139.)

Carta del Lic Znazo, M. S.; Oviedo Hist. Natural de las Indias, cap. 4, Ap. Barcia, tom 1.

Hernandez, Hist. Plant., lib. 6, cap. 44, 45 are the authorities which he recites.

No sufficient reply has ever been made to this question.

It has long been known that the negroes in some of our Southern States have occasionally produced a very harsh-flavored, treacle-like syrup from the stems of green corn by cutting them in small pieces, boiling them and expressing and evaporating the juice.

The only experiments ever made in the United States to extract sugar from corn, of which there is any record, were made by a few persons—mostly farmers—in different parts of the country, principally during the years 1842 and 1843, an account of which appears in the reports of Hon. Henry L. Ellsworth, Commissioner of Patents at that time.

These experiments, unfortunately. were of such a desultory character as to determine nothing expert except the inappropriateness of the means used to secure the desired end. No trustworthy examination of the juice was made to determine its nature ; and, as might have been anticipated, the mode of treatment followed was based upon errors which a little rigid investigation would have corrected.

It may be of use to point out what some of these were, just here, to prevent the possible revival of them.

1. Reasoning from a false analogy, it was inferred that in order to secure the presence of the largest amount of sugar in the juice it was necessary that the ear should not be allowed to form. The experiments in this country evidently followed in the path of some undertaken by M. Pallas in France and Algiers in the year 1839. By him the plausible theory was broached that the grain is nourished at the expense of the sugar in the stem, and, as a consequence, that the ears should be removed as fast as they form.

Against this was the unanswerable testimony of Biot, the father of the optical method of analyzing saccharine juices, and the only person who seems to have made a competent chemical test of the juice of maize, who found 13 per cent. of sugar in the well-developed plant, and discovered that the quantity of sugar in it was diminished, instead of increased, by the treatment recommended by Pallas; and further, that the pulling off of the ear wounds the growing stem, greatly impairing its health and productive power. This mutilation of the plant needed to be constantly repeated to contract its almost ungovernable tendency to throw out fresh ears and to form its grain, requiring great additional labor and expense. It was also found that, as a further effect of this treatment, additional substances injurious to the sugar were formed, as well as an actual diminution in the quantity of the sugar itself.

2. Therefore, as a means of obviating these evils, the sowing of corn broadcast or planting so thickly as to prevent entirely the formation of the ear, was strongly recommended. But this simply perpetuated the mischief at a less expense. Slender woody stems and an impoverished juice were the unsatisfactory results.

3. A kindred error gained currency in the statement that the best period for working up the juice is soon after the formation of the silk, or during the early part of the flowering period. As the result of this, some of the experiments were made entirely valueless.

4. Another mistake was the supposed applicability to corn-juice of the processes employed for the extraction of sugar from the Louisiana cane. Adherence to this resulted in the crystallization of only a meager proportion of the contained sugar and often none.

Mr. M. Adams, of Monroe county, New York, in an account furnished by him to the New York State Agricultural Society, of a practical attempt to produce sugar from corn by the method employed upon the southern sugar-cane, evinces very unusual discrimination in his sense of the difficulties in the way, and concludes with the statement that to secure success there will be needed—

1. Something more effectual than lime water for classification.

2. Some means to make the crystallization of the sugar more sure and perfect.

3. A definite point of concentration for the finished syrup.

4. A more perfect means of drainage for the sugar.

5. The means of removing the harsh, natural flavor of the plant.

In consequence of these difficulties, and the absence of any means then discovered of obviating them, the experiments were discontinued; and the subject seems to have attracted no further attention.

A casual observation, made some years ago, very strongly impressed me with a belief that naturally the corn-plant possesses, at a certain period, a far higher saccharine value than has been conceded to it generally, but time and opportunity were wanting to give the matter proper attention.

Believing it to merit at least a thorough examination, about two years ago, however, I undertook some researches which have been conducted with patience and care up to the present time. And sufficient results have now been reached to furnish a decided and intelligent answer as to the practical value of Indian corn for sugar production.

III.

RESULT OF INVESTIGATION.

Similarity in Chemical Constitution of the Juice of Maize and Sorghum—Important Discoveries—New Process Devised Which is Applicable to Both Plants—Significance of These Facts—Present Capacity of the United States for Sugar Production from these Sources—Adaptation to Present Wants—Why Their Value Was Not Heretofore Recognized.

In the course of these investigations it was very soon discovered that the juice of maize, in certain important particulars, bears a strong resemblance to that of another notable plant now domesticated in this country, the value of which has been much debated and the peculiarities of which have hitherto been but very imperfectly understood—the Chinese sugar millet or sorghum. Although these plants are strongly contrasted in some respects, it was discovered that they are so intimately related in chemical constitution as to entitle them not only to be ranked together, but to separate them by a wide interval from all other known sugar plants. Natives of opposite hemispheres, they seem to have been brought together here to fulfill a common destiny.

New and interesting peculiarities presented themselves in the juices of these plants, foreshadowing the necessity of new modes of treatment, and it was at once perceived that but little practical benefit would result from an investigation, however wide in its range or important in its disclosures, unless a process could be devised capable of the extraction of the sugar as uniformly and certainly as it is now obtained by the special processes adapted to them, under favorable circumstances, from the beet and the southern cane.

This has now been done.

It may now be confidently affirmed that not only maize in the green state, but also the Chinese and African canes, are beyond comparison superior to any other plants that can be successfully grown in the United States for sugar production, either as to certainty of results, abundant and regular yield, ease of culture or cheapness and facility of manufacture.

It is difficult to express in few words the importance of this statement. It will readily be seen that the natural resources of the United States for sugar production from these plants are practically limitless, if the facts here assumed prove to be well established.

The area of land annually planted in Indian corn, of late years, in the United States averages 45,000,000 acres, as shown by the reports to the Department of Agriculture at Washington.

It is demonstrated that if the average sugar-producing capacity of either sorghum or Indian corn per acre of ground be taken at one-third less than the experiments of the past year show it to be clearly equal to, if the crop be grown and worked up with ordinary skill and care, it would require less than the one-fiftieth part, or one acre in fifty of the area annually devoted to the Indian corn crop in the United States, to support a growth for sugar of either sorghum or maize that would be fully adequate to supply the whole immense home demand for sugars—an amount now equal in value annually to more than one hundred million dollars.

It can now be shown that we have the resources at perfect command, if rightly utilized, not only to save to the country the vast sum which we are paying in gold every year for foreign sugar, but that within a very few years hence we shall be able to send to other markets a surplus of our crop, which will take equal rank with our exports of flour and corn.

To accomplish this it is not necessary that any delay should be incurred, or that any preparation should be made involving changes in the modes of agricultural labor to which our people have become accustomed. Nor have we to spend time in experimental culture of plants new to us, or to our climate and soil. To insure success, we need not invoke the presence of any other agencies than those which the Creator has so lavishly and so opportunely laid to our hand.

The failure to recognize the true value of these plants heretofore is surprising, but it is not at all unparalleled. Some of the grandest industrial movements of the present century were not even foreshadowed during the last. It is no disparagement to us that through the swift strides which our country has taken during the past fifty years in some fields of material progress we have overstepped in our haste some mines of wealth which the surface concealed. The truth is, that the corn plant of America, in common with many others, of our indigenous productions was not appreciated at the time of its discovery. It was recognized, indeed, as an invaluable acquisition by the early colonists, and perhaps some proper estimate of its value would have been reached in the old countries if the dazzling splendor of the riches brought home by the Spanish adventurers had not blinded the eyes of all Europe to all discoveries but those of silver and gold. In the enthusiasm of the time the old dream of the alchemists seemed at last to find a realization in the teeming wealth of the mines of the New World, and men were well content to accept as the power to bring it forth the steel of the Conquistador instead of the philosopher's stone.

A full century later it was the fashionable hobby of European writers, like the Abbe Raynal, to assume the essential inferiority of the productions of the Western Continent as compared with those of the East—a mistake which the Old World has learned to correct. This whimsey imposed itself upon the fancy of no less a naturalist than Buffon. It repressed investigation, and threw into discredit knowledge which a later age turned to profit by estimating at its proper worth; and it must be remembered that it was not until another century had rolled by that modern chemistry and the systematic interrogation of nature took its rise.

It may be said, too, that our forefathers in this hemisphere had no immediate wants with which the almost unbounded resources of the country did not supply without calling forth much technical skill; and prior to the year 1850 no crisis in the commercial history of the nation had stimulated research toward the discovery of an adequate native source of supply, such as gave life to the beet-sugar industry in France.

Still, it is not a little remarkable that half the value of this plant in American agriculture has for these three hundred years been practically ignored. Scarcely less so is the fact that a plant so rich in sugar as sorghum cane is now shown to be, should have been grown for almost a quarter of a century in this country and in Asia from time immemorial, without any adequate realization of its value.

IV.

SORGHUM.

Historical Sketch of the Plant—Period of its Introduction into France and the United States—Sorghum of China—South African Varieties—Specific Characters—Results of Acclimation—Prominent Varieties now in Cultivation—Asiatic and African Races—New Varieties—Early Amber Cane—New Hybrid—New Chinese Varieties.

The unsatisfactory experiments made with Indian corn, as already mentioned, had scarcely passed out of notice when the Chinese cane was introduced into the United States. In the year 1851 the French consul-general in China forwarded to Paris from that country the seeds of this plant, from which were derived the first specimens grown in France and in this country of the variety known as the Chinese cane or Asiatic black sorghum.

Very successful experiments were made in France in the manufacture of alcohol from the juice of the plant, by M. Vilmorin and others, previous to its introduction into this country, and attention was immediately attracted to it as a source for the production of sugar; but the same difficulties were encountered there in the attempted accomplishment of that object that were afterwards met with in the United States, which no means then known were successful in removing, although there, as here, competent scientific investigation had determined the existence of a great preponderance of true cane sugar in the properly matured juice.

It was not until the year 1855 that the plant was grown in the United States. The seed was imported from France during the previous year. The success which attended the first attempts to make a somewhat palatable, crude table syrup from it, at a very small cost, awakened immediate attention, and when public curiosity was at its height Mr. Leonard Wray arrived in this country, bringing with him the seed of more than a dozen varieties of South African sorghum or imphee.* These he found growing in the country of the Zulu Caffers, near Cape Natal, in the year 1851, or simultaneously with introduction of the Chinese sorghum into France. The first samples of sugar and alcohol produced from these African canes were made by him and exhibited at the Paris Exposition of 1856.

It can scarcely now be doubted that the Chinese and Caffrarian plants, although widely separated geographically when found, are all referable to a single original species. The points of difference between them are not of such a kind or importance as to entitle them to be regarded as specifically distinct. On the supposition that they had a common origin, there is nothing improbable in believing that through Egypt the original plant may readily have found its way to the extremity of either of the connected continents, where they now grow.

Through natural influences tending to the destruction of the weaker and less strongly marked varieties, and the selection of such as have proved to be the most valuable for their saccharine qualities in this climate, the original number of Wray's imphees has now been reduced to less than one-half. Those now remaining may be regarded as very distinctly marked sub-varieties, their relationship to each other, as indicated by the qualities of their juice,

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* See note, Appendix D.

general aspect and facility of hybridization is evidently much more intimate than to the Chinese cane. Accordingly, while the latter may now be readily recognized by all the most prominent characteristics that it exhibited when first grown here, the imphee group which we retain exhibits varieties which have lost some of their peculiarities and acquired others, through the influence of climate and accidental hybridization. Only the most strongly marked sorts survive, and they possess characters which within certain limits may be considered permanent.

These are now the so-called "*Liberian*" cane, the most robust and strong-growing sort now in cultivation and the latest ripening, adapted to strong soils, and characterized by its short, very stout, close-jointed stem, its small, compact panicle and diminutive reddish-yellow seeds.

White imphee, related more closely than any other to the Liberian, as indicated by its general habit, mild-flavored juice, and long period of growth, but of smaller size, and remarkable especially for its heavy, open-topped, greenish-white panicles when mature.

Red imphee, the very opposite of both the above in general aspect, tall, long-jointed, early ripening, and noted especially for its highly acidulous juice and its beautiful, wide-spreading, rust-colored panicle when the seeds are ripe.

Black imphee, an early, not very productive variety, with a short stem and rather small and close panicle of a brilliant glossy black color—that of the glumes—which entirely inclose the seed. The juice of this sort possesses very strongly the peculiar flavor generally characterizing more or less all the imphee race.

Purple imphee, (otherwise known as Oomseeana, Otaheitan, &c.) This tall, reed-like cane, with its trim, spear-shaped head, is the most remarkable of its race in being in some of its modified forms almost the only sort from which any sugar has heretofore been made. There is every reason to believe that in its latest and most highly improved form we may recognize it in the now justly celebrated "*Early Amber*" *cane of Minnesota.*

The Chinese cane contrasts strongly with almost every one of the imphees in certain special peculiarities, but these differences are only those of race, and are far outnumbered and outweighed by striking features of similarity.

None of the African canes excel this variety in hardihood or richness of juice, and none perhaps equal it in productiveness. It might fairly be regarded as the type of the species from which all the other varieties by easy gradations of change might readily have been derived.

I have succeeded in establishing the existence of only one new and permanent variety produced by the intermixture of the original Chinese cane with an imphee. This is a cross, originating in Western Pennsylvania, between the former and the red imphee, (*Schlagoova* of Wray.) For future identification a specimen seed-head of this new hybrid was deposited in the colleetion of the Commissioner of Agriculture at Washington during the past year. It possesses the productiveness and saccharine richness of the Chinese sorghum and the early maturity of the red imphee, ripening its seed shortly after the Minnesota amber. Naturally it produces no sugar, but when properly treated its juice yields an amount of it not excelled by any other cane. This hybrid has been in existence for two or three years, and its character may be considered fixed. It originated simply from the planting of the two sorts, from which it is derived, in close proximity to each other for several successive years. As an example of a permanent consolidation of some of the best qualities of the varieties from which it sprung and of the suppression of some of these in each that we would most desire to see eliminated, it affords evidence that we have it in our power by skillful and judicious hybridizing to produce new varieties of these plants much superior to any at present known. Great good would, no doubt, result from future experiments in this direction, if they are conducted with sagacity and care.

It is a mistake to suppose that the Chinese cane grown here is the only variety grown in its original home. A tendency similar to that manifested by the canes of South Africa to divergence within certain limits, and the formation of distinct sub-varieties, is also exhibited by the Asiatic sorghum. With the object of determining this point, I made an examination of the immense seed collection forwarded by the Chinese Government to the late Centennial Exhibition at Philadelphia, and discovered the existence of four distinct sorts of sorghum, of all of which, through the kindness of the commissioner in charge, I obtained specimens for planting and experiment. Confirmatory of all previous accounts from that country, the statement was made that these plants are grown in China almost exclusively for the grain, which is ground and made into bread.

The seeds of these specimens grew well and ripened early last year, and although nothing can be affirmed positively as to their comparative saccharine value, some of them are new to this country, and they will be subjected to careful experiment this season, (1878.)

There is nothing in the past history of any variety of these plants that leads to the conclusion that they had ever been utilized for the extraction of their sugar in the countries from which they originally came.

V.

MAIZE AND SORGHUM AS SUGAR PLANTS.

Value of Sorghum and Maize as Sugar Plants—Nature of the New Investigations Made—Errors Corrected—Hitherto Discordant Statements Reconcilable—Newly Established Facts—Comparison with the Sugar Beet in France—Adaptation of Maize and Sorghum to the Climate of the United States—Value of American Corn—Overproduction—Relief for Unproductive Labor—New Use for Unemployed Machinery—Choice of Varieties in the Use of Corn and Cane—Brief Period of Growth Comparatively—Greater Climatic Range—Causes of Failure of Beet-growing in the United States—Effects of Moisture—Soils—Manures—Greater Simplicity and Much-diminished Expense of the New Process—Improvement of the Soil—Yield of Corn and Sorghum in Sugar—Gross Yield of Maize and the Beet in France—Conclusions.

I now propose to relate more particularly the conclusions upon which the foregoing statements of the value of maize and sorghum as sugar-producing plants are based.

To do this fairly, and with the conciseness which is here necessary, a comparison will be made, in all important points, between these plants, respectively, and the beet and the southern cane. From this the reader will be able to decide intelligently as to all points of practical value.

The facts adduced as to maize and sorghum are derived from a great number of analyses and practical experiments, a condensed account of which will be found in the Appendix.

The chemical investigations were conducted with care and after the most approved methods now in use. For the quantitative determination of the sugars, Fehling's standard cupric solution was generally employed. The plants, chemically tested, were used when freshly cut from the ground, unless it is otherwise indicated, and they were taken at all periods of their growth from the time when sugar began to be developed in the juice until it ceased to yield it in remunerative quantities. Many varieties of both species were tested. The action of manures upon the juice of the growing plants, the effect of differences of soil and climate, the influence of diverse modes of planting and culture, the comparative yield under the various modes of treatment, estimates of the value of some of our most prominent varieties of corn, grown for sugar alone, as compared with the same when grown so as to utilize the plant not only for the extraction of the sugar but also for the preservation in the best condition at the same time of the unmature grain, and of other residual products, have all received more or less careful consideration. But the most prominent attention was bestowed upon the characteristics of the juice itself in order to secure the separation of the sugar.

This investigation was entered upon with the determination not to permit any preconceived opinions, either of myself or others, to influence its course; and, as a result, many of those opinions were shown to rest on very insufficient grounds. But it is especially gratifying to me now to say that how much soever the published statements of some eminent chemists are apparently at variance with each other as to the composition of the juice of sorghum, no well-established fact is necessarily discordant with what is now known. The truth, so far as it is clearly ascertained, harmonizes all the facts.

Notwithstanding the great diversity prevailing among different varieties of the same species, in some respects, the most remarkable uniformity was found to exist in the chemical constitution of the juice at the same stage of growth of the plant.

The results of the experiments, so far as they relate to maize, were announced for the first time in the Philadelphia *Public Ledger*, of December 1st, 1876, and specimens of the sugar made from maize during the autumn of that year were displayed at the Centennial Exhibition toward its close.

During the past year (1877) the best results of the previous season were fully confirmed; the process was fully perfected, and its applicability to the extraction and crystallization of the sugar of the Chinese and African varieties of sorghum was fully established. In fact, the facility with which sorghum juice crystallizes under this treatment, is as remarkable as its obstinate refusal to do so under any other.

The success of the beet-sugar manufacture in Europe, the attempts which have been made to establish it here, and the circumstance that the beet is the only plant grown in temperate latitudes from which, hitherto, sugar has ever been obtained in any adequate quantity, have given it special prominence, and it is with that manufacture, perfected as it has been in its processes and appliances, that we must now make the closest comparison. And that it may be made with the utmost fairness, we assume as true, what has by no means been proved, by the experience of those who have fostered the beet-sugar industry here, that it is capable of being carried on in the United States as successfully as it is in France and Germany.

But it is now well known that the beet-sugar manufacturer, at the very initial point of his work here, encounters the discouraging obstacle hitherto insurmountable, of not being able to secure cheap labor for the growing of the raw material. Independent of the great expensiveness of the machinery and of the processes employed, and the high degree of skill required, it is necessary that radical changes should be made in the means and methods of agricultural labor now existing and established in this country, together with the great loss of time necessary to make such changes.

On the other hand, the cultivation of Indian corn and its now fully acclimatized relative, sorghum, is reduced here at present almost to a science. It may be said that we have scarcely anything new or valuable now to learn in regard to the growth of either of them. By means of labor-saving implements and skill in the use of them here, if anywhere, the cost of growing them has been reduced to the lowest attainable minimum. No American who visited the Centennial Exhibition at Philadelphia and compared the maize of the valley of the Nile, of the plains of Hungary, of Portugal, Italy or France, with the product of the valley of the Kansas, or of the prairies of Iowa or Illinois, but must have felt that, in all that pertains to the production of this grandest of the cereals, we are unrivaled by all the world.

But our very success is our peril. The over-production of corn has become almost the bane of our western agriculture. The ease with which maize is grown has a fascination for the farmer on the prairies which it is difficult to resist; so great, indeed, that oftentimes to him ruinously glutted markets and lack of transportation do not have their proper effect in preventing a continued repetition of the evil. The statistics at Washington abundantly show that, in the case of this crop, unrequited labor almost invariably follows in years of largely increased yield.

It is just here that this new industry comes in to give immediate relief to unremunerative labor by turning a part of the overflowing stream of production into a new channel, thus utilizing our greatest waste of labor to supply our greatest want.

It is from the uprising of such an industry as this that the highest benefits resulting from a division of labor among our people can be realized. It may be established without a jar in the routine of agricultural work, or any inroad upon established usage. The redundant population of the cities will flow out to meet the demand thus newly created for laborers, and the solution of a much vexed question now of national importance may thus, almost insensibly, be reached.

If sorghum be grown in preference to Indian corn, as will often be the case, we have the advantage at the start that it has been long enough in the country to make us familiar with all its requirements as to soil, climate, and cultivation. It is scarcely to be regretted that its full value has not heretofore been realized, for it is not probable that the attempt to supplement a defective knowledge of the means required for the defecation of the juice of the plant by mechanical devices of such rare ingenuity for open-air evaporation as now exist, would have been made to the same extent as now. This concentration of inventive talent upon a single point—although it was not the most important one—led to the use, if not the discovery, of some principles in the evaporation of saccharine juices which have been overlooked. To have learned thoroughly the fact that rapid evaporation, at the atmospheric pressure, of thin films of liquids containing sugar, may be made to equal the results of boiling in a vacuum, is worth all the past twenty years of baffled expectation.

All over our land there is a large amount of capital invested in sugar apparatus, now almost idle, the outcome of the early interest taken in Chinese cane. Most of this, although undervalued in many quarters as slight and insignificant, is just what is needed at the start in this industry; and it is widely distributed over the country and in intelligent hands. Serving a present purpose, it will lead inevitably to the rapid introduction of more perfect machinery, and to all the advantages resulting from concentrated capital and skill.

These considerations, together with the fact that the crystallization of the sugar from these juices is now reduced to an absolute certainty, have their value more than doubly enhanced by the circumstance that, from the very outset, our choice as to the source of production lies between maize and a still richer saccharine plant, of similar requirements as to soil, climate and general modes of treatment, but sufficiently diverse to enable us to use the one to supplement the other under a variety of circumstances, when either could not be used so well alone; both capable of having their sugar extracted by the same process, and thus giving us *a combination of advantages such as belong to no single sugar plant.*

There are also a large number of well-established and clearly-marked varieties of each, giving us a much wider range of subordinate qualities to adapt them to meet diverse local peculiarities of climate than are secured by any existing varieties of the beet; and the probability of still further improvement in this direction may be safely predicted.

It will be observed* that the period of growth of either plant when used for this purpose, and the time while they occupy the ground, is *less by one-half* than is required by the beet; and consequently the profits of a second crop of another kind the same season is easily procurable from the same ground when it is well cared for, and is to be credited to these plants as against the beet.

The expense of preparing the ground and planting the seed is about equal for all these plants, and they have thus a great advantage over the tropical cane.

The climatic range of these saccharine cereals on this continent is vastly greater than that of the beet. It is also worthy of notice that a broad area of territory within which it would be possible to grow the beet toward the South affords plants with a juice too weak to be profitable and too liable to fermentation for the establishment of factories there; a temperature as high as 60° F. during the working season being fatal to this pursuit with existing processes. The latitude of 45° N. is the limit in France. No such extreme delicacy of organization characterizes maize or sorghum, and their juices are almost equally strong under the summer sun of either Texas or Maine.

Deficiency of moisture during our early summer—a very common occurrence—almost ruins the beet crop for sugar; and it is partly the cause of its deficient yield here. But maize can mature its juice in a season of early summer drought by being planted as late as July in the latitude of Pittsburgh. The beet, on the contrary, requires the whole season to ripen.

In point of adaptation to the rich, deep, natural soils of our western prairies and the alluvions of our rivers, no plant grown either for sugar or grain, perhaps, ranks equal to Indian corn. Sorghum thrives equally as well upon them, if they are not defi-

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* See Appendix A.

cient in drainage; but heretofore beet-growing upon the prairies has met with but little success. Among the causes of failure, the preponderance of nitric salts in the juice, derived from the soil, is assigned as the first.

All sugar plants suffer from the effects of manures abounding in nitrogen, directly applied; but the presence of certain mineral salts in constant quantity, generally, for each species, show that they require a soil rich in all the ordinary elements of plant growth. Normally, the azotized substances in all three of the above are not far from equal. But the presence in the beet of a great amount of mineral salts, which cannot be eliminated in the processes of manufacture, destroys utterly the value of the molasses for ordinary use. Indian corn, for a similar reason, does not afford as palatable a syrup as sorghum. The latter, in this respect, is capable of taking, when the syrup is purified, a front rank among all plants of its class, and in the quantity of crystallized sugar which it produces it stands next to the southern cane. It has been the aim to limit the amount of molasses (drainage) from either plant, by the new process, almost entirely to the glucose originally in the juice; and this has been so nearly realized in the case of sorghum as to enable us to extract 10 pounds of crystallized sugar from 13¼ pounds of very dense syrup, a result which, in the practical manufacture of sugar from other sources, is almost unparalleled. But it is in the vastly diminished cost of the production of well crystallized sugar from these plants by the means now discovered, as compared with that from the beet, that the most marked disparity exists. In sugar-producing capacity the Chinese cane is in advance of Indian corn, in the proportion of 14 to 12 or 7 to 6, but the greater value of the grain of corn (well dried sweet corn being worth about $20 per barrel of 300 pounds) as compared with the grain of sorghum, fully compensates for the deficiency of sugar.

The almost absolute certainty of realizing a large return from both the dried sweet corn and the sugar in our long summers is a strong argument in its favor. In this case, of course, only a large stemmed and large eared variety of sweet corn should be grown.

The amount of molasses (as drainage) finally resulting from either is small, but greater in the case of maize, while that from sorghum is comparatively fine flavored and freer from mineral salts.

The greatly diminished cost of growing these plants, as compared with the beet, arises from the peculiar adaptation to them of our soil and climate, the use of our greatly improved agricultural implements, and the substitution largely of animal instead of human labor. But the disparity in cost becomes the widest when the processes of manufacture are contrasted. Some appreciation of this will be realized when it is stated that the three chief items of expenditure in the beet-sugar processes, viz: *boneblack filtration*, *carbonatation*, and *vacuum apparatus*, are, in this process, entirely thrown out; the first two as entirely useless and the last as unnecessary. In the largest maize and sorghum sugar factories a preference may perhaps be given to vacuum finishers, but in operations of less magnitude the comparatively simple and equally effective and rapid system of final evaporation of syrup in thin films and at a low temperature will prevail.

Not the least of the advantages which will result from the new sugar industry in the United States will be in the improvement of the soil. Some of the rich soils of the West have borne successive crops of corn for more than twenty years, in which cases, generally, the grain was marketed and the soil has been depleted of its most valuable mineral constituents. Even on these soils the effects of such a system are now becoming apparent. But if sugar is made, and the soft grain in the dried state only is sent abroad, but little will be necessary to be returned to any soil, already in good condition, to maintain its fertility for this crop. The elements of sugar being derived from the air and water only, it abstracts from the soil nothing of consequence, if the trash be carefully returned, while the ashes from the furnaces and all residual chemical products will, if properly applied, constantly supply more of the salts, &c., than the unmature grain takes away. But with somewhat less profit, the soft corn and the seed of sorghum may be fed on the ground, and a constant accession of the elements of fertility may thus be secured to the soil. Besides, the thorough tillage which the business demands will go far to inaugurate a rational system of farming, where it is lacking, increase the value of land, and cheapen production.

The maximum crop of sugar beets that can ordinarily be grown upon an acre of ground is found to be such as to allow the rows in which they are planted to be one foot ten inches apart, and the plants one foot six inches apart in the rows, thus producing over 21,000 beets to the acre. It is not profitable to grow beets for this purpose of very large size. They ordinarily weigh from one to three pounds each. It is not possible, as yet, to determine the maximum product of corn or cane attainable. I do not think that the largest yield yet reported has reached that limit, nor perhaps can the mode of planting be indicated by which it can be secured. My own experience, however, would show, perhaps, as the most advisable, the adoption of a rule to plant in rows three feet apart, the hills at intervals of twenty inches apart, so as to admit of cross cultivation once or twice in the season by an implement drawn by horses, passed between two or three of the cross-rows at once. The rows, both ways, should be laid out with accuracy; the number of plants in the hill to number from two to four; the weight of trimmed canes to the hill two to eight pounds.

The stems of "evergreen corn" in Pennsylvania will average one pound each, varying from twelve ounces to forty-eight ounces each. Single, trimmed stems of Kansas corn have equaled six pounds each, but the juice of this giant growth is more impure than that of one of inferior size; but an average of three pounds of stem to the hill will yield 21,700 pounds to the acre of trimmed stems, giving 180 gallons of dense syrup, or 1,800 pounds of crystallized sugar, and 44 gallons of syrup of drainage, (molasses.)

If a growth of four pounds to the hill is secured, (an average easily attained upon good soil with good culture,) 2,250 pounds of sugar and 55 gallons of molasses will be obtained from 225 gallons of dense syrup.

From experiments made the past season I conclude that an attainable limit is 3,000 pounds of sugar and 66 gallons of molasses from an acre of land which would readily yield 100 bushels of ripened corn, and which if planted in sugar beets would yield about the same amount of sugar in France.

If sweet corn (evergreen) be grown for the grain and sugar combined, a reduction of one-third will have to be made in the yield of sugar in each of the above estimates respectively. The yield of sorghum in sugar will be about one-seventh greater than corn in each of the above instances.

From 100 to 350 gallons of syrup per acre have been produced from this plant in this country, and a yield of 300 gallons of syrup, so dense as to seem an almost solid mass of sugar when granulated, can be secured from an acre of land by sufficiently close and regular planting, good cultivation and a thoroughly prepared soil. Two gallons of such syrup per square rod of ground should in all cases be aimed at as an average attainment. Of course, while the means taken to grow a crop of corn or cane vary as widely as they have done hitherto, often without any regard to system or economical management, the average production will fall far below what it ought to reach.

While the maximum yield of the beet has reached in Europe 5,000 pounds, the average per acre in France has dropped to 1,071 pounds. The lowest remunerative yield of sorghum—100 gallons of syrup—will produce the same amount.

When it is considered that not a pound of sugar is wasted from the juice obtained at the mill, that the softer substance of the stalk, either of corn or cane, yields its juice in much larger proportion than that of the southern sugar cane, that the juice itself is from 10 to 50 per cent. stronger in sugar than that of the beet ordinarily, and that the product of green fodder from maize in countries less favorable to its growth than our own has reached maxima much exceeding those upon which the above estimates are based, they will be acknowledged as fairly representing the capacities of these plants.

In France, the home of the beet-sugar industry, extensive experiments have been made for the purpose of ascertaining the largest attainable yield of various plants for green fodder for stock; the process of *ensilege* or fermentation in pits being adopted for curing it. In the maize-growing departments of that country, twenty-six to thirty-five tons of green maize fodder per acre is estimated as the *average* yield. But far greater yields are announced there in different quarters, as the results by higher culture. Upon a schistose, sandy soil in the department of Finisterre, limed and enriched with barn-yard manure and superphosphates, 44.61 tons (89,220 pounds) in one case, and 66.91 tons (133,820 pounds) in another, of the Caragua or giant maize, have already been produced there per acre.

M. Le Conteaux* in the journal *Pratique d'Agriculture* summarizes the comparative maximum yields of maize and the sugar beet, as fodder plants, as follows: Caragua maize, 66.96 tons; sugar beets, 35.68 tons. Thus in the gross yield, for the same purposes, *maize leads the sugar beet by almost one-half.* One third being deducted for weight of blades, unmature ears, &c., there will be left a weight of 44 tons or 88,000 pounds of trimmed stems per acre, equivalent to the enormous amount of 8,800 pounds of sugar, if the juice be of the average quality. *One-half* this yield is much beyond the *maximum* which has been assumed for Indian corn here. It is asserted that 40 tons per acre of Chinese cane have been grown in the United States.

VI.

SYSTEM OF MANUFACTURE.

Preparatory Work—Selection of Seed—Extension of Sugar Season by a Proper Choice of Varieties—Prominent Large Stemmed Varieties of Corn and Sorghum—Modes of Hastening Germination—Preparation of the Soil—Fall Plowing—Clovering—Drainage—Fertilizers—Influence of Ammonia—Effects of Certain Mineral Salts on Crystallization—Effects of Moderate Stimulation by Use of Ammoniacal Manures—Gypsum.

In the following pages I design to embody for general use the details of the system of manufacture. Its practicability has now been fully tested, and no part of it is recommended for general

* Report, Dept. Ag. of U. S. for 1875, p. 404.

adoption which my own experience has not sanctioned the use of, not only as eminently practical, but in its principal new feature, the defecation of the juice, as the sole discovered means by which the same ends can be attained. Its application is not limited to any special variety of either corn or sorghum, or by any varied conditions of climate or soil within the United States as far as already known.

By this means, the common yellow corn yields its sugar as readily and abundantly as the "sweet" corn of the gardens, and the refractory Chinese sorghum, hitherto held to be inferior to the imphees, and useless except for syrup, now seems to be unequaled by any sugar-producing plant in the world except the tropical cane.

But it must be borne in mind that strict adherence to a well-defined system is essential to success. At the outset every available means within reach should be resorted to, to increase the productiveness and improve the quality of the saccharine plant itself.

Care should be exercised in the selection of the seed and in the choice of such varieties of maize or sorghum as will best serve the purpose of the planter. If he selects corn, and has facilities for drying the unmature grain or otherwise preserving it for table use, he will choose one of the large-stemmed, later ripening varieties of sweet corn—preferably "Stowell's evergreen." If he designs to feed the soft corn to stock, he may take either the "evergreen" corn or any of the large sorts of common yellow or white field corn; and either by successive plantings at intervals, or by the selection of varieties of longer or shorter periods of growth, he may extend the time for the working up of corn, in proper condition, from the 10th of August until the 1st of November, in the latitude of the Middle States. The seed of "Stowell's evergreen corn," grown for the two-fold purpose above mentioned, should always be taken from the upper and best-developed ear on the stalk. The stems should be stout and well developed, and produce not fewer than two large ears each.

There are tall and stately races of maize which now attain to unequaled perfection in the middle belt of the United States, especially on the rich river alluvions and prairie soils of the central States. To these correspond certain varieties of sorghum, of which the Chinese cane, and the "Liberian" and "Oomseeana" are conspicuous representatives. Some individual specimens of these are occasionally found to mature their seed much earlier than others. If such are strong-stemmed, and when tested prove to be rich in sugar, their seed should be reserved for future planting, but strength of stem and richness of juice should never be sacrificed to secure early maturity. Ordinarily, the largest and heaviest seeds produce the strongest and healthiest plants. The earliest ripened and best-developed seeds on a given panicle of sorghum are generally found on its summit and upper half.

Germination may be hastened by steeping the seed just previous to planting. All sorghum growers are familiar with the fact that by pouring hot water upon the seed contained in a sieve or coarse sack so as to permit of its draining off immediately, and setting it aside in a warm place for from twelve to twenty-four hours, and then planting in well-prepared ground, its growth will be hastened by several days' time; and there is great advantage in doing this, if, for any reason, the planting has been unduly delayed; but, where early spring planting is practical, which seems to be the most congenial to the natural habit of the plant, this course is harmful, as it is also during a very wet season, causing the seed to rot.

As a rule, select the best developed seed, from the best specimens of the best varieties, and plant early.

Fall plowing, or plowing during the frequently mild weather of our winter months, is a suitable and often a necessary preparation to early planting, and the work being done during a season of comparative leisure, it has the additional advantage of securing the aid of the pulverizing and aerating power of the frost upon the soil. The light, spongy texture of land, so essential to the rapid growth of vegetation in early spring, and which on stiff clayey soils particularly is so difficult to attain, is simply an example of the effect produced by allying ourselves with the favoring powers of nature instead of running counter to them.

The adequate preparation of the soil need scarcely be insisted upon, and the mode of planting and cultivation best adapted to both corn and cane are so well known as to require but little discussion. In all cases, however, this part of the work should be of the most thorough character. The soil itself should be naturally rich in all the elements of plant growth. In point of adaptation the preference between different classes of soils will be in favor of a light, deep, mellow, calcareous loam; and the more nearly all natural soils designed for sugar culture are brought up artificially to that character the better. Heavy clay lands, especially those that have been run down by injudicious cropping, can be restored and put in condition more quickly by seeding down to clover—plastering heavily in the early spring and turning under the green crop. New lands from which a crop or two of grain have been taken are in a favorable condition.

The drainage of sugar lands should always be as perfect as possible to prevent absorption by the roots of solutions of certain salts in undue quantity, or their decay by constant contact with the stagnant water of the sub-soil.

The qualities of the soil best adapted to sugar production from these plants are not essentially different from those commonly considered necessary to produce a good crop of corn, except that thorough drainage be secured and the application of ammoniacal manures restricted.

The presence in sufficient quantity of potash, lime, gypsum, and the phosphates is indispensable; and the continual restoration of these substances, in some form, to the soil as fertilizers cannot be too strongly insisted upon. Lime should be applied by sowing it upon the clover or other green crop turned under in the fall; in which case any animal manures that are to be used must be applied in the spring. Decomposed begasse and straw, barn-yard manure thoroughly rotted and used in moderate quantity, guano used as a top dressing, bone dust, ashes, are all appropriate as fertilizers, when well incorporated with the soil.

For a long time the idea has been prevalent that all mineral salts, either existing in or added to the soil, except in very meager quantity, are injurious to the sugar. This is true only in certain exceptional cases, and it is possible to be much too fastidious and parsimonious in the application of fertilizers to sugar lands. With the soil well drained and in good physical condition, and the plant liberally supplied with all that it needs, it is rare that it takes up a large excess of any substance deleterious to the sugar. The best results with Chinese cane the past season were from a well drained limestone soil enriched with thoroughly decomposed animal manure. It is true that in this case a larger proportion of azotized products existed in the juice than would probably have been found in cane yielding a half crop on unenriched land, and any injurious effects that might otherwise have been produced are prevented by the new process of defecation. The influence, however, of the ammoniac salts, in undue quantity, in forming a large proportion of the nitrogenous compounds in the juice and of some salts of potash in hindering crystallization are chiefly to be guarded against.

It has been proved that while a few salts do hinder crystallization, the much larger proportion of those introduced during the growth of the plant are either neutral in their effect or promotive of the crystallization of the sugar.*

It is certain that judicious manuring, or, in other words, keeping up the fertility of a naturally rich soil by the supply of what will compensate for the annual waste, is quite as necessary as in any other agricultural operations. In fact, the *stimulating* influence of fertilizers containing nitrogen, if they are not applied in excessive quantity, promotes early growth, increases the size of the

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* A. Marschall has studied the subject of the influence of different salts on the crystallization of sugar, and classifies them as follows:

1. Salts favoring crystallization: Sodic sulphate, nitrate, acetate butyrate, valerate and malate, potassic aspartate, magnesic nitrate, sulphate and chloride, calcic nitrate and chloride.

2. Indifferent salts, (without influence:) Sodic carbonate, oxalate, citrate and aspartate, potassic sulphate, nitrate and chloride, calcic hydrate.

3. Salts preventing crystallization, and consequently favoring the formation of molasses: Potassic carbonate, acetate, citrate and butyrate.

Magnesic sulphate promotes the crystallization of 10 times, magnesic chloride of 17 times, calcic chloride of 7½ times its weight of sugar.—*American Chemist*, ii, 406.

stems and very markedly increases the quantity of the juice, without affecting the sugar. Even if the percentage of sugar in the juice of canes from lands so fertilized rates somewhat lower than in those of a less thrifty growth, the yield of the latter in sugar is so much less on account of the smaller size of the stems, the smaller percentage of juice which they contain and the greater resistance which they present, on account of their woodiness, to the expression of the juice by the mill, as to present the most marked contrast. To obtain the largest quantity of sugar at the least cost should be the main object of the planter in all cases. A large growth of well-developed canes follows the application in moderate quantity of nitrogenous manures of whatever kind. Upon a decomposed clover sod either corn or cane produces heavy crops, an effect no doubt due largely to the nitrogen supplied. According to Professor Voelcker, the roots alone of an acre of clover contain as much ammonia as 800 pounds of guano. The effect of the cow-pea (also a nitrogen-storing plant) when plowed in as green manure on the sugar lands of Louisiana, is similar to that of clover at the North.

One of the most efficient of all fertilizers that can be applied to sorghum is gypsum—plaster of paris. Many years ago very remarkable effects resulting from its use were detailed by Mr. Harris, of the *Genessee Farmer* and published in the *American Agriculturist*, (vol. 21, p. 361,) in which it was shown that the yield of cane on land heavily plastered was increased above that on unmanured land about five-fold. It was also shown that superphosphate of lime, containing 50 per cent. of sulphate of lime, (plaster,) applied in larger quantity, produced an effect second only to that of plaster itself, indicating that it was due almost solely to the plaster contained. These experiments have not since been repeated with the same care; but enough is known to prove that the application of gypsum may be made in the highest degree beneficial in increasing the yield. Its effect is most manifest upon soils not rich in vegetable matter, especially upon clay lands. Also, on account of its difficult solubility, the results of its use are most marked in wet seasons.

VII.

SYSTEM OF MANUFACTURE.

Yield of Cane and Corn—Proper Distribution so as to Secure a Uniform Yield—Preparation for Planting—Combined Effect of Clover and Gypsum—Early Cultivation—Influence of Lime Soils—Advantages of a Combined Crop—Harvesting—Proper Period for Cutting—Preparation of Dried Sweet Corn—Evil Effects of the Storing of Cane or Corn—Conversion of Sugar—Stripping—Protection from Sudden Frost.

The proper distribution of the plants on a given surface, so as to obtain the largest possible amount of sugar-producing material, well developed and properly matured stems, that the land is capable of, should be the primary object of the planter. The additional labor and expense required to enable the land to produce two gallons of dense, crystallizing syrup from each square rod above what is necessary to produce one gallon on the same surface, is really so inconsiderable as to be a matter of astonishment to those who for the first time make the experiment. Yet the difference in the yield in the two cases amounts to more than half a ton of sugar per acre.

In planting, it is well to retain the general features of the common method, but to lessen the distance between the hills so as to increase the "stand" of corn or cane to the utmost extent consistent with healthy growth and development. As already suggested, the rows (running north and south) may be three feet apart, (or 3½ feet in rich soils,) the hills 20 inches apart, each containing from three to five plants. Thus, from three to five pounds of stripped stems may readily be grown to the hill. If the main and cross rows are first laid out with accuracy by means of a marker, making a shallow furrow, cross cultivation by means of an implement passing between two or three of the rows at once is always practicable, and the work is done easier and better than when drill planting is practiced.

It is scarcely necessary to say that before marking out the ground for planting the soil should be most thoroughly pulverized. Given a clover sod of the previous year, turned under when in full growth, and previously heavily plastered, thoroughly decomposed and lightly replowed and well harrowed just before planting, and we have a seed-bed for cane or corn upon which, with due care in the after cultivation, will spring a crop of either of these plants, which for luxuriance, stateliness and value is unapproached by any other rapid vegetable growth of a temperate clime.

It is a common mistake to plant too deeply—half an inch of earth over the seed is always enough, if the soil is moist and in good condition.

The ground should be stirred as soon as the plants are well up, by working close to the hills on all sides with the cultivator and the hand-hoe. Horse-hoes and cultivators should be provided with a shield of sheet-iron at the side to prevent the loose earth from being thrown on the plants. In regard to sorghum culture, no fact is more fully established than that the early stirring of the soil around the young plants, commencing even before they can be clearly distinguishable in the row, is in the highest degree conducive to the vigor and early maturity of the cane. A limed or naturally calcareous soil, which has a peculiar quickening power upon all cultivated crops, efficient drainage, and a warm, sunny exposure, are all auxiliary to the same result. The continued cultivation of cane, however, after it has attained a height of two or three feet, retards development by destroying the roots, which by that time extend a net-work of fibers through every part of the soil.

It will generally be found most advisable in sugar production to grow a crop both of corn and cane, for the reason that corn comes to maturity for this purpose generally a month earlier than cane, because the same system of working is adapted to both, and that by combining the two, the working season may be extended so as to cover at least three months. The proper period for cutting corn for the production of sugar, when it is a double or triple eared variety, is when the silk of the upper ear has become dead, and the second ear is in the early roasting-ear state. The first ear will have slightly passed that condition and will have begun to harden somewhat. There is little difference, however, in the yield or the saccharine value of the plant from the time the first ear has its grain fully developed until the last ear has begun to harden—a period of about two weeks.

In order, however, to save the grain in its best condition for curing, the first ears should be removed at the proper time, leaving the rest to come into condition before cutting and blading the stalk. "Evergreen sugar corn," besides some other prominent advantages, continues in season about three weeks. In the latitude of Philadelphia and St. Louis, the grinding season will begin regularly the first week in August.

One month later, or from the 1st to the 10th of September, the early amber cane and the new Chinese hybrid will be in condition, if planted early in May. The imphee or Caffer canes may be worked up from the time the flower has made its appearance until the seed is ripe; the Chinese variety from the time the glumes or external seed envelopes begin to darken in color until the seed is perfectly ripe. On account of the slower development of the large-stemmed imphees, the Chinese cane will generally be ready first.

In the case of corn, the ears may be removed a week before the stems are cut, without detriment to the sugar. When the grain of sugar corn is to be dried for market, no time must be lost until it is properly cured. After being boiled or steamed for about five minutes, it should be removed from the cob by cutting instruments, operated by machinery, and then dried as rapidly as possible in shallow trays or pans, placed over flues, or steam heated, or heated on perforated plates, and constantly stirred. In from four to six hours it will be thoroughly dried, if the temperature is maintained at, but not allowed to exceed, the highest point at which the grain remains uncolored by the heat. If the operation is properly managed, the dried corn should be as free from color as when cut from the cob. In the retail markets this corn bears about the same price as brown sugar. As a secondary product, its manufacture would be profitable at less than half that rate. It should be packed in barrels, when dry, and the barrels headed up.

This grain is nearly equal to green corn, fresh from the field, and in its nutritive properties and capacity to fill a place otherwise unoccupied as an article of diet, it is a most important product. In its nature and uses it is very different from the ripened grain. This difference is so great that it may be said that we are thus enabled practically to produce at will two different varieties of grain from the same plant. The popular demand for dried sweet corn, both in our own country and in Europe, will always render its production a valuable adjunct to sugar manufacture from maize. (See analysis, &c., Appendix.)

I must refer here to an error into which operators are likely to fall, which has been in accordance with the general practice of sorghum-growers hitherto, but which cannot be too strongly condemned. There is now the most certain evidence to show that a profound modification of the juices of these plants, setting in at the base of the stem and gradually progressing upward, *begins to take place within a very few hours after they have been cut from the ground.* The storing of cane for considerable periods before it is to be worked up has been a common practice heretofore, but the transformation and loss of a part and finally of the whole of the crystallizable sugar is the uniform result. Therefore, it must be insisted upon as a general rule that both corn and cane should be worked up within, at most, from twenty-four to forty-eight hours from the time of their being cut in the field. In other words, the successive operations of beading, topping, cutting, removal from the field, extraction of the juice, defecation, evaporation and crystallization should follow each other without any loss of time. The contact of the freshly-expressed juice, in the unsophisticated state, with the air is extremely injurious if prolonged for more than an hour or two. There is no point in all these successive stages of work at which it will be safe to suspend it or to take rest until the defecated syrup has reached a density of 25° to 30° Beaumé.

Store room, therefore, need be provided for only such an amount of canes as can be worked up in a single day. The crushing mill should have sufficient capacity to extract with ease the juice of a considerably greater amount of corn or cane than has been apportioned regularly to one day's work.

The stripping off of the blades of either cane or corn should be performed immediately before the cutting and grinding of the stems. The ears of corn may be removed, however, several days previous to the time of cutting down the stalks without damage to the juice, if the blades are left on. The stripping of cane is sometimes entirely dispensed with; this neglect, however, is somewhat wasteful, and has nothing to recommend it except the saving of the labor necessary in the operation of stripping itself. The latter is very much lessened by striking off the blades of the standing cane with a staff or flat, sword-shaped wooden implement. The value of the fodder saved and the loss of juice prevented by stripping will, no doubt in most cases, more than compensate for the expense of doing it. Still, it does not appear that the quality of the juice is perceptibly impaired by passing the blades (which are then almost sapless) through the mill along with the stems. The evil is in the absorbing of a portion of the juice by the comparatively dry mass of blades.

It sometimes happens that the later-planted corn or late maturing canes are exposed to sudden danger from an early frost. The effect of a heavy frost upon a standing crop of sorghum cane is more damaging to its juice than to that of corn similarly exposed. But in both a peculiar process of decomposition speedily sets in and crystallization is made impossible. As a partial prevention of the evil the standing cane should be immediately cut down without loss of time, and in this case the blades should not be stripped off, as they serve to protect the cane in the windrow from sun and cold and undue evaporation. The mode of protecting cane by windrowing consists simply in depositing it lengthwise in a long, narrow, compact row, the butts resting on the ground, and each successive bundle of canes overlapping the preceding one, and inclined backward upon it, so as to leave only the tops exposed throughout the whole length of the row. But in the manufacture of sugar from these plants no dependence is to be placed upon this or any other arrangement for their preservation beyond two or three days after the stems are cut down. By this method protection from frost is in a great measure secured, but not from the destructive power of the atmosphere commencing at the base of the cut stem. So insidious is the influence by which the conversion of the crystallizable sugar takes place as it extends from joint to joint, that it is not manifest in any change in the appearance or flavor of the juice or of the syrup made from it, and it is only when the attempt is made to crystallize the sugar, or when the proper chemical tests are applied, that we realize what has occurred.

VIII.

SUGAR MACHINERY.

Inapplicability of the System of Maceration and Percolation for Extraction of these Juices—Loss from Inefficiency of Mills—Capacity of Mills, how Increased--Results of Repressing of Corn and Sorghum—Practical Suggestions—Expression of the Juice—Arrangement of Tanks—Evaporating Apparatus—Forms of Finishing Pan—Stirring Instrument—The Cooler—Crystallizing Boxes—Adaptation of Existing Machinery—Future Requirements—Importance of the Chemical Treatment.

For the extraction of the juice of the southern sugar cane, no other means yet devised at all compares in practical efficiency with the well known iron crushing mill. The vegetable structure of both maize and sorghum is so nearly similar to that of the sugar cane as to suggest the use, as applied to them, of the same mechanical means for the same general purpose.

Yet the inefficiency of the mills in sugar manufacture from cane, the world over, has ever been a cause of complaint, and has really been a source of great loss.

Since the introduction of sorghum into the United States, lighter forms of crushing mills—those adapted to steam power differing in nothing except size from the southern plantation mill—have everywhere come into general use.

In the manufacture of sugar from cane the chipping of the stem into fine fragments, and the subsequent extraction of the saccharine matter by maceration and percolation, has been experimented upon, but independently of the mechanical difficulties that present themselves to the success of this method there are objections of a far more formidable kind to it, as applied to maize and sorghum, in the inability of the more complex and delicately organized juices of these plants to withstand the effects of such treatment. (See Appendix B.)

It would seem, however, that the softer texture of the stem of sorghum, and especially of corn, should enable us to reduce the waste of the juice in milling to a small amount. The fresh, undried stems of corn or sorghum contain about 85 per cent. of their weight of saccharine juice. The ordinary crushing mills extract but 50 to 60 per cent. of the weight of the stalk. Most of the lighter class of mills do not average more than 50 per cent. A perfect machine would produce 85 per cent. If in practice but 50 pounds in 100 are obtained, 35 pounds, or more than 41 per cent. of the whole amount of juice originally contained in the stalk, is discharged with the begasse.

We have thus revealed the astonishing fact that about five-twelfths of the crude material is thus utterly wasted at the outset, in consequence of the imperfect means ordinarily used in attempting to extract it. It is true that the best mills may be abused by grinding at too high a rate of speed, yet this is very commonly done. Good results are obtained by mill rolls, which develop a surface of four to five yards in length per minute, so that a roll of two feet diameter should make but from two to two and one-half revolutions per minute in order to extract the largest amount of juice from a given weight of canes. Any increase in the capacity of the mill that is required may easily be obtained by increasing the length of the rolls and not their velocity. In the case of common mills of small power, a largely increased yield of juice will follow the *repressing* of either corn or cane. If the loss of time incurred in this be urged as an objection, it may be replied that there is no waste of material in sugar manufacture that is justifiable if it can be prevented, and that there is none so utterly inexcusable as that caused by a failure to extract all the juice practically separable, after a previous expenditure of time and labor in producing the crop, which is just as great when the canes are half extracted of their juice as when they are wholly so. The difference between the product of an efficient and an inefficient mill may thus be almost equal to the difference between a half and a full crop.

As has already been said, the successful working of the new process can be tested by using apparatus already at hand in most parts of the country, or at least by the addition to the common machinery of perhaps one or two inexpensive parts. It will not be necessary, therefore, to occupy the reader's time with a description of the construction, mode of using, or comparative merits or defects of sugar machinery now in use. It is taken for granted that the present owners of such machinery, or those who may supply themselves to make the experiment with such apparatus as is now furnished by any of the prominent manufacturers, will have the good sense to adapt the machinery they use, as far as possible, to the requirements of this process, as hereinafter described, instead of giving the precedence to certain special uses under the old methods which the machinery may perhaps have been particularly designed to serve. If the operator will dismiss from his mind, for the time being, all preconceived opinions and theories of working which he finds to be at variance with the simple routine here prescribed, and especially with the chemical treatment of the juice, much time and useless labor will be saved. On the other hand, so much is already known as to the practical management of the common forms of sugar mills and evaporators, that, until apparatus adapted to the demands of a large and permanent business shall be called into existence, little need be said of them in detail. Equally out of place at present would be specifications of suggested but not yet perfected mechanical improvements, to which peculiarities in the chemical treatment have given rise.

In the arrangement of the works, the mill should be placed upon a sufficient elevation to allow the juice to flow from it by a pipe into the defecating tanks, hereafter described, and from them into the evaporating apparatus as required. A strainer of wire gauze should be placed at the outlet of the receiving tank at the mill to arrest any of the coarser impurities, such as fragments of cane, pith, &c., that may be floating in the juice.

Two heating tanks of equal capacity—100 gallons or more each—to be used alternately, are to be so placed as to receive the juice as it flows from the mill, and at such an elevation as to empty readily into a broad, cooling tank, which supplies the evaporator directly.

The tank last named may be made entirely of two-inch plank, closely jointed—15 to 20 inches in depth, and of a capacity equal to that of the two heating tanks combined. The latter may be entirely of metal, (copper preferred,) or they may have bottoms of sheet-copper or tinned-iron and upright wooden sides, and placed over the flue of a separate furnace in small works, or they may be heated by a steam coil or jacket—which is preferable—in order that the ebullition of the juice may be immediately checked when the scum has perfectly formed on the surface. If they are to be heated over an open fire, there should be an arrangement for throwing off the heat into another flue, by means of a damper, when the proper temperature has been reached. It is convenient to have these heaters each large enough to contain as much juice as is received from the mill in one hour.

The evaporator may be of any required capacity—preferably with a sheet-copper bottom, tinned-iron will answer—and of any of the best forms now in use in the sorghum-syrup manufacture, provided that its construction admits of a continued descent or flow from one compartment to another of a thin sheet of juice over a large, heated, evaporating surface, with convenient arrangements for the removal of the scum which forms immediately after the juice enters it. It is rarely the case that the form of the evaporator will admit of the syrup being reduced in it to the finishing point. Instead of attempting to do this, it is much better to have a small furnace detached, over which a plain, flat copper or perfectly smooth and clean iron pan is placed, or it may be so constructed as to be heated by a steam jacket. If heated over a flue, the most convenient finisher, perhaps, is a tilt pan. A suitable size is three or four feet in length and breadth, and eight to ten inches in height, the sides vertical, and the bottom perfectly smooth and flat. It should be placed upon a flue or arch, the diameter of which externally is a little less on all sides than that of the pan, if the walls of the furnace are not very thick. From the middle of one of the sides of this finisher extends a broad beak or lip, inclined gradually upward from the bottom of the pan, and projecting a foot beyond the furnace wall. From the corners of the side to which the beak is attached project two short iron pins or gudgeons, forming the extremities of the axis of the pan, upon which it turns. These enter sockets or staples securely imbedded in the furnace wall itself or in timbers placed directly outside of it. To a ring on the middle of the side opposite to that from which the beak projects a short chain is fastened, and secured at its other extremity to the short arm of a lever, pivoted to the head of an upright post, set in the ground, a few inches in the rear of the pan. By bearing upon the long arm of the lever, at any time, the whole contents of the pan may be instantly dumped into a cooler, placed below the projecting beak. A damper should be so arranged as to throw the heat at any time into a lower flue, particularly when the pan is tilted.

If steam is used to heat the finishing pan, the use of the tilting apparatus may be dispensed with, but in this case the heat should be applied by means of a steam space or jacket underneath, and not by a coil, to prevent inconvenience by the adhesion of the dense heated syrup to the pipes. In connection with this vessel a sharp-edged, wooden scraper should be used, consisting simply of a board of hard wood, four or five inches in width, and of a length slightly less than the width of the pan, pierced with holes of half an inch or an inch in diameter, and attached by its middle to a handle of three or four feet in length, set at right angles to it. This instrument is to be moved back and forth over the whole bottom of the pan during the last two or three minutes of the concentration of the syrup.

The cooler into which the finishing pan discharges may be simply a close jointed, wooden tank, broad and flat, and capable of containing the successive batches of crystallizing syrup produced during half a day's or a day's boiling. Two of these boxes should be provided, to be used alternately. These, as they are filled, are to be emptied into the crystallizing vessels, which may be of any convenient size and shape, in which provision for drainage is secured. They are placed in a close apartment near by, the temperature of which is kept up to about 80° to 90° Fahrenheit.

For experimental purposes, tubs or half barrels, with movable plugs in the bottom, with false bottoms of slats fitted inside, covered with coarse sacking, may be used as crystallizing vessels; but of a better form, and scarcely more expensive, are wooden boxes of about five feet in length by three in width, the bottoms formed of two planes inclined six inches, their intersection forming a groove in the middle. In this groove are twelve or fifteen holes of an inch in diameter to permit the syrup to flow out, but temporarily closed with plugs abruptly pointed, and projecting inside two or three inches. The depth is nine inches at the sides and sixteen inches at the center. These vessels may be made of boards one inch thick, cemented at the joints with white lead, or litharge and glycerine cement, and burned out with a hot iron inside, so as to form a sloping cavity, surrounding the openings, for drainage. These vessels when filled to within three inches of the top will hold about 75 gallons of syrup for granulation. They should be supported upon open timbers, above gutters connected with a cistern on a lower level, to receive the molasses as it drips from the sugar. This form of crystallizing box originated with Dutrone la Couture,* one of the most eminent names connected with sugar manufacture from the southern cane during the last century, and it may still be recommended for this purpose as combining almost every possible advantage in crystallizing and draining with the requisite strength, at least when natural drainage is relied upon for purging the sugar. The number of these boxes, or of some suitable substitute for them, that will be required will, of course, depend upon the amount of work to be done.

It is convenient to have the cooler mounted upon a small truck, to run from one side of the finisher into the crystallizing room, where it is to be emptied.

The simple apparatus above described, together with a Beaumé's syrup hydrometer and a pair of good thermometers—one of which is kept immersed in the tank into which the heaters discharge—is all that is *indispensable* for the production of a good quality of sugar from these plants by this process. Most of the machinery that is required is already in use or has been employed within the past few years in every State in the Union. The requirements of capital working on the large scale will necessitate ere long the introduction of the most perfect and permanent forms that can be adapted to the purpose; but the essential features of the work on every scale of magnitude will remain the same; for it must be borne in mind that it is upon the peculiar *chemical treatment* of the juice that success almost entirely depends.

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* Quoted by McCulloh, report, p. 286. *Precis sur la Canne*, p. 184, Paris, 1790.

IX.

CRYSTALLIZATION.

Obstacles to Crystallization—Nature of the Difficulties to be Overcome—Inapplicability of Old Processes—General Features of New Process—Means Employed—Chemical Reactions—Process of Manufacture—Use of the Heating Tanks—First Stage of Process—Second Stage—Action of "Solution B"—Characteristics of Purified Juice—Finishing.

It now only remains to particularize the different steps in the system to be pursued and to explain as briefly as possible the principles upon which they are founded.

The whole subject of the extraction of sugar from these sources is fraught with interest at every point of view. Especially is this so when we come to regard closely the peculiarities of these juices themselves. At the first view it might seem that the art of extracting sugar from liquids so rich in it as these have now proved to be ought not to be a matter of much difficulty in practice; but its apparent simplicity disappears when it is found that these two saccharine liquids constitute a *distinct class by themselves*, and that they contain, intimately associated with the sugar, a variety of other substances of very different chemical properties and relations, some of them among the most unstable of all organic bodies. Most of these substances, incapable of crystallization themselves, prevent by their presence the sugar from assuming the crystalline form, the only form in which it can be obtained pure. In order that we may produce sugar, therefore, it is necessary first either to remove these extraneous substances from the saccharine solution, or by some chemical agency so to change their form and characteristics that although present in the solution they will present no barrier to the crystallization of the associated sugar. In this case it has been necessary to employ media operating in both these ways.

But the means used for these purposes must be well chosen. They must be adequate. They must be of such a kind as to be adapted to common use on the large scale; the defecating agents must be perfectly harmless if added inadvertently in excess to the juice, and must leave no harmful compounds in any product which is afterwards to be used as an article of diet; they must be sufficiently convenient in form and low in price, and they must not exert any prejudicial influence upon the sugar itself.

In a problem of this kind nothing good can be accomplished at hap-hazard. A strict adherence to system is necessary to practical success; but it must be a system in which the means employed are commensurate with clearly defined ends.

Lack of information of an exact kind upon some of the most important points has led some persons, whom a little investigation would have taught better, to adopt expensive and in this case useless methods of treating sorghum, borrowed from the beet and cane-sugar manufacture of France and Louisiana, which in the end they have been compelled to abandon after much disappointment and loss. It is fortunate that at this time not only that both corn and sorghum are adapted to a single general mode of treatment, but that the peculiarities of no known varieties of either are sufficiently marked to require any considerable deviation from an established routine; provided that such due care be taken to prevent deterioration of the juice as has already been shown to be necessary.

The complete defecation of the juice as now accomplished by this process consists of two stages. The first is preparatory and secures what has long been a *desideratum* in the clarification of juices containing both glucose and sugar, the important auxiliary aid of lime in excess, to the fullest extent of its action, with heat, in removing certain substances from the solution, without any injury to the sugar. The second leaves it free from the special hindrances to crystallization, and the reaction of the chemical substances previously introduced upon the impurities and upon each other is such that the final purification is complete.*

The series of chemical changes produced in the juice follow the addition to it at proper times and in graduated quantities of two standard solutions, which for brevity I shall designate respectively

* The facts connected with the discovery upon which this process is based, the reader will find detailed in Appendix B.

as solutions *A* and *B*. Solution A consists principally of a concentrated liquid saccharate of lime. It is of standard strength and produces uniform results. In cases in which it cannot be produced, milk of lime may be used in its place, but with the disadvantage that the strength of the mixture is extremely variable, the lime being chiefly suspended in water instead of dissolved. In the preparation of it, lime of the best quality should be used, carefully slaked and washed afterwards with a large volume of boiling water to remove any potash that it may contain, lime itself being but slightly soluble in hot wåter. After slaking the lime, pour hot water upon it in a capacious vessel; stir it thoroughly and allow the lime to subside. The water must then be poured off; the coarser particles of the sediment containing sand and other impurities will subside first and occupy the bottom of the vessel. The fine sediment only should be used, mixed with water, to bring it to about the consistence of cream.

Taking the capacity of the heating tanks to be 100 gallons each between the level of a mark made on the side six inches from the top and the level of the exit-cock near the bottom, we begin by filling one of the tanks up to the mark, and then turn the flow of juice from the supply pipe into the other; 100 gallons is a convenient measure of juice, and can be reduced to the proper density on an evaporator and finisher of moderate capacity in one hour. Heat should be applied rapidly as soon as the juice begins to enter the tank, and when it has been filled up to the mark, and the temperature of the liquid has risen to about 180° F., or a point hardly endurable by the hand immersed in it, add to it about five pints of strong milk of lime if the juice is that of corn, or seven pints if it is sorghum. Stir it thoroughly; bring up the heat to the boiling point and shut it off, and remove quickly with a large skimmer the blanket of scum formed.

Allow the liquid to rest a few minutes to permit the suspended flocculencies to subside somewhat; without waiting, however, for this to be accomplished perfectly, commence to draw off by means of a siphon or swing-pipe the upper portion of the liquid into the tank below, and finally the lower stratum down to the muddy sediment, which may then be swept out by a stroke or two of a coarse broom, through a large pipe or gate at the bottom, into a long bag strainer.

The tank is then to be refilled as before, while its companion is being exhausted. At this stage of the process the juice is strongly alkaline, and of a light wine color.

A thermometer is kept immersed in the tank supplied by the heaters, and as soon as the temperature of the liquid has fallen to about 150° F., five pints of the solution *B* are to be poured into it if it contains the contents of one of the heaters, or in that proportion.

The peculiar chemical reactions induced in these juices at this stage of the process may briefly be described as follows: Previous to the addition of *solution B* to the juice the latter had received the full benefit of the action of heat and lime both separate and combined. Some pernicious substances are thus separated in the insoluble form, the removal of which could not be effected by lime in smaller doses or readily by other means. But new compounds are, at the same time, formed in the liquid, or are in process of formation, which would exert a still more injurious effect upon the sugar through the associated glucose than the bodies which they supplant. The introduction of *solution B* at this point arrests this action, and its effects are manifested—

1. In the preservation of both sugar and glucose from decomposition, and from the production of a dark red coloring matter which is the visible evidence of such decomposition. The benefit of this action will perhaps be better appreciated from the fact that by it *bone-black filtration is entirely dispensed with.*

2. The neutralization of the excess of lime is accomplished far more perfectly than by the use of carbonic acid and much more easily and cheaply. Hence, independent of its inappropriateness otherwise as applied to these juices, *carbonatation* is dropped, which, as is well known, is so essential a part of the beet-sugar processes, and which has heretofore been found to be necessary in all processes, whenever a large excess of lime is used.

3. The separation in an insoluble form of a previously dissolved

and pernicious nitrogenous body associated with a peculiar fatty substance. These separate in curdy flocks, forming a broken, greasy pellicle upon the boiling liquid. Without following out these changes further, at present, it may be said that the removal of these substances takes away the last hindrances to crystallization.

After the separation of the characteristic scum, which forms almost as soon as the juice, treated as already described, is admitted into the evaporator, a great change is seen to have taken place. The liquid is then brilliantly transparent and of the lightest golden color. Except to take away the thin curdy pellicle, which will still continue to be thrown off to some extent, no special care need be taken in the evaporation, other than that it be conducted as rapidly as possible from a shallow bed of juice.

All the characteristics of the juice, when purified as above indicated, should be retained by the syrup to the close of the evaporation. And if from any cause the color deepens perceptibly, and the syrup loses its *distinctly acid* character, more of *solution B* must be added to it while the evaporation is going on, until the former indications are restored.

After the juice has reached the condition of a not very dense syrup (a point indicated by a boiling temperature of about 225° F.) it is ready to be received into the finisher, as above described. This syrup will then be of the brightest golden hue, if it is from sorghum, and perfectly clear. If from maize, the color will generally be somewhat deeper, with sometimes a faint pinkish tinge.

In the case of sorghum, the syrup should be concentrated in a few minutes to a point at which it suddenly becomes clouded or opalescent, and scarcely flows upon the surface of a ladle dipped into it and immediately held up in the air. It boils without foam, except at the last, and during the final stage of concentration, for two or three minutes; it should be constantly stirred with the perforated scraper already described, moving the latter slowly back and forth over the entire bottom of the pan.

Corn syrup must not be boiled to quite so great a density, but it may without detriment be reduced to as low a point as is indicated by a temperature, while boiling, of 236° to 239° F.

The cooler should be capacious enough to contain the successive "skippings" of several hours' work. The type of crystallization setting in will be improved and the process will ensue more rapidly if a very small quantity of well crystallized sugar be mixed with the syrup as it cools. Therefore, when the cooler and crystallizing vessels are emptied each time to be refilled, it is advisable to allow some sugar to remain adherent to the bottom and sides to form nuclei for the following batch, and it is well to stir into the first batch made each season an ounce or two of well-crystallized sugar; but this need not be repeated.

The cooler, when charged, is to be run into the crystallizing-room, and its contents dipped out into the proper vessels, either of the form above described or some convenient substitute for them.

X.

DRAINAGE OF THE SUGAR.

Crystallization of Maize Sugar—Treatment of Drainage Syrups—Crystallization of Sorghum Sugar—Special Treatment—Drainage by Pressure—Drainage Sacks—Recrystallization of Fine-Grained Sugar—Mode of Producing either Coarse or Fine Grained Sugar from Sorghum.

The first crystallization of corn syrup will have become perfected in from two to ten days. From this time forward it may be treated precisely as the sugar of the southern cane. It may be left to purge itself by natural drainage from the vessels in which it has granulated, or the molasses may be removed by inclosing the mush sugar in close muslin or linen sacks and applying a screw or hydraulic press, or preferably and much the most expeditiously, by means of a centrifugal machine, such as those now used in the refineries and in beet-sugar works.

The syrup of drainage should be reboiled in the finisher, or in the evaporator and finisher combined, and treated at the close just as the original syrup, except that the finishing temperature should reach 240° F.; the stirring operation in the finisher should be commenced sooner than before, and previous to boiling it the second time about one-fourth of its volume of water should be mixed with it, to which a little of *solution B* has been added. The quantity of the latter needed will vary with the quality of the syrup, but about a pint of the solution to each ten gallons of the undiluted molasses will generally be sufficient.

The product of the first crystallization from corn should be about 6¾ pounds of sugar from a gallon of syrup weighing 13¼ pounds; product of second crystallization, 3¼ pounds; total, 10 pounds. About a pound and a half of uncrystallized sugar remains in the molasses of the second crystallization, which may be fed to stock or otherwise utilized, but the mineral salts still remaining render it of no value as an article of human food.

Sorghum should be reduced at first to such a density by evaporation that after a lapse of from twenty-four to forty-eight hours, when kept in a warm place, it will become an almost solid mass of sugar. It requires, then, a special mode of treatment, the crystals being small and held together by a comparatively small quantity of molasses. When in this condition, the mass should be thrown into a large tub or mixing vessel, and a small quantity (about one-eighth or tenth of its bulk) of a fair, thin syrup of a density of about 30° Beaumé when cold, previously prepared from sorghum juice, should be poured upon it and thoroughly incorporated with it by means of a wooden stirrer.*

This will bring it to a more plastic or semi-fluid state, if the room in which the operation is performed has been kept heated. This syrup dilutes the uncrystallized sugar sufficiently to render it mobile, and does not dissolve the cane sugar already granulated.

The mass may then be drained in a centrifugal, the inner drum of which is very closely but minutely perforated, and running at the highest rate of speed—a drum of two feet in diameter making not less than 1,400 revolutions per minute.

Another method of drainage is similar to that employed in some sugar-beet factories, to extract the juice from the pulp of the beet,

* An iron mixing-mill constructed somewhat like the feed-hopper of a centrifugal sugar-drainer, with a revolving shaft in its center, set with long, projecting teeth, may be employed in regular work.

and also to separate the saccharine matter left in the scums. A number of linen or coarse and strong muslin sacks are provided, of any convenient size ; but their length should be about two and one-half times their width—say 20 by 50 inches. Each sack must be about one-third filled with the sugary mass, then folded once on itself across the middle, and flattened by placing it upon a table, upon a sheet-iron plate with rounded corners, a little larger on every side than the flattened half of the sack and its contents, the loose half being folded under.

The open end of the sack may be folded, before being turned under, if necessary. The plate and sack and its contents are then to be placed within a frame upon the bed of a powerful screw press, and a series of such sacks and interposed plates, laid neatly one upon another—the butts of the sacks alternately being turned in opposite directions—are subjected to pressure, gradually applied at first to avoid rupture of the sacks, and afterwards with sufficient power to remove all the molasses and leave the sugar nearly dry.

This fine-grained sugar is then to be transferred, without further drying, to a heating vessel, and about one-tenth of its weight of pure water mixed with it. Here it is to be heated very gradually, with frequent stirring, so as to diffuse the heat through the mass, and when it has partially remelted, and is in the half-liquified state, it is to be poured finally into the crystallizing boxes, in a room heated to about 90° F., where it will form a solid mass of crystals, as soon as it becomes cooled down to the temperature of the room. The result is a very coarse-grained, beautiful sugar, of a high grade. If properly prepared it will be almost white, and the immediate yield is almost double that which may be secured in any other way without reboiling.

The sugar prepared from sorghum in such a way has the additional advantages, that it is not contaminated with the secondary products usually formed by reboiling, the final crystallization is attended by no risk from want of experience or skill on the part of the workmen, the work is easily and cheaply done, and with due care the product should rank nearly or quite equal to vacuum sugar. The very small quantity of syrup left in contact with the crystals, at the proper temperature, will drain off from the crystallizers, and it being almost free from glucose will crystallize gradually if exposed in broad trays, at the temperature of the room.

If the production of sugar of a softer and more open grain is desired, it can readily be accomplished by a mode of treatment of the prepared mass, almost identical with the "stirring off" process adopted by maple-sugar producers; but as to color and grain, with much better results. After the reheated sugar mixture, as above mentioned, has been poured into the crystallizing boxes, instead of being allowed to remain at rest, it should be stirred with a broad, oar-shaped, wooden instrument, without interruption, until it is cool, and the sugar has become dry; but this course should never be followed when sugar of a large, bold grain is desired.

These last-mentioned modes of crystallization and drainage are better adapted to sorghum than to Indian corn, and hence I recommend for the treatment of corn syrup, in crystallization, the method previously given as the best. Sorghum may be similarly treated with good results, and dried in a centrifugal.

XI.

SUGAR FACTORIES.

System of Work—Advantages of Division of Labor—Point at which this Process may be Suspended—Central Factory System—Associated Interests of the Planter and Manufacturer—Benefits of the System—Plantation System—How the Small Factories may be made Auxiliary to the Central Works—Present Wants and Opportunities—Utilization of Existing Machinery—Home Manufacture—Plan of a Small Sugar Factory—Explanation of the Diagram—Arrangement of Small Works.

In all cases where the extraction of sugar from these juices is the object, the general system as above given should be adhered to. It will readily be seen that it is adapted to operations of any degree of magnitude.

It has already been shown that the storing of the canes is always attended with loss, and that after the canes have been cut, immediately the work of manufacture must begin, and progress without interruption until a defecated syrup of 30° to 35° Beaumé has been produced. This makes it necessary that the whole series of operations up to the point when crystallization commences in the syrup, at least, should be conducted at one establishment and in close succession. An economical division of labor under which alone the highest degree of success can be attained will separate, in a great measure, the agricultural operations necessary to the production of the ripened canes ready for the mill from the manufacturing process.

This can be effected in two ways, either of which may be followed with perfect success. These are—

1. The central factory system; and
2. The plantation system.

By the concentration of all the machinery, capital, and skilled labor at one point, advantageously located within each sugar-growing district, many advantages are gained, and they will be found perhaps to be most fully secured by the central factory system. The central factory will bear a similar relation to the wants and interests of the sugar planter that the district flouring mill does to those of the wheat grower, with this difference only, that the interests of the farmer and manufacturer in the former case are more closely allied than in the latter, because the perishable nature of the raw material, its bulk and weight, prevent it from becoming an article of ordinary commercial traffic like grain. In consequence, the local producer and the manufacturer are permanently associated together in the strongest possible union of interests. The work of the one is the exact complement of that of the other. Each is enabled to do in the *best* manner what neither could do so well, if at all alone. By previous contract, the factory owner will pay the producer as much for his cane on its delivery as the latter could sell his sugar for after deducting the actual cost which, with his limited time and facilities, he would incur in the manufacture.

Among the benefits of such a division of labor and responsibility will be the rapidly increasing production and value of the lands in the neighborhood of the central works, greater uniformity and value of the crude material on account of the greater care and more exact system used in producing it, adequate remuneration to all employed in both branches of the work, certain and steady employment at fixed prices during the entire season, the smaller cost proportionately of the machinery to the amount of land in cultivation, and an aggregate production for the whole country immensely greater than by any system which casts the burden of the whole work upon a single individual. At such an establishment it is expected that the entire process of sugar extraction would begin and end; that the highest grades of sugar would be produced there, and a stability secured for the business in all its branches which cannot be attained by unsupported individual efforts.

At every such large factory ample means must be provided for reducing to syrup, at least, the juice of the fresh canes as fast as they are received, the uniformity in the supply being maintained from early in August until late in November, in the middle latitudes of the United States, by the reception, by previous contract, at the works, of maize and the earliest and last ripening varieties of sorghum in succession, throughout the season. The canes will be paid for by the ton, as received, and the responsibility of the producer will end when they are delivered in proper condition. At the close of the milling season the work at the factory will consist in the drainage and preparation for the market of the sugar, the reworking and recrystallization of drainage syrups, and the proper utilization of all secondary products. This work will consume profitably the whole of the winter months.

2. The plantation system will differ from the above chiefly in the much more restricted range of its work. Smaller factories conveniently located will take off the crop of the surrounding region as rapidly as it comes in season, and reduce it to a perfectly clarified syrup of a given density. This syrup properly stored will then be in a regularly merchantable condition, ready for market a few hours after leaving the evaporators, and commanding at the large central factory or refinery a price proportionate to its quality. The value of a barrel of syrup according to an exist-

ing standard may be determined with as much accuracy as that of a bushel of wheat, by the use of the copper test in a simplified form, a means which can easily be placed within reach of seller and buyer alike.

Just at the present time, however, there is a large class of persons in our country having lands well adapted to sugar-growing, and possessed of sufficient energy and intelligence, whose means or opportunities do not permit them to engage largely in this pursuit, but who would be glad to have it within their power to work up, during this season or the next, the crop of corn or cane which they grow upon their own lands; and it is just this class of persons, farmers of moderate means, desirous of assisting in an important work, and of enhancing their own comfort, profit, and independence, by whom the initiatory steps will be taken in this pursuit. Thousands of sets of small, cheap apparatus, formerly used in the manufacture of crude sorghum syrup, are now scattered over the whole country, in the possession of persons of this class. With but slight modification this machinery can now be utilized largely during the next year or two in the production of crude maize and sorghum sugars. The process is sufficiently simple, as above defined, to make this quite practicable without expense.

The growth of this new branch of industry will soon give rise to large establishments; but from the circumstance that the means are already provided for success in this stage of the work, the value to the country from the time gained and the money saved by putting them to immediate use will be immeasurable.

It was only after many years of trial of mills propelled by animal power and of inexpensive apparatus, that the sugar industry of Louisiana ever attained to any prominence; and, notwithstanding the most elaborate and expensive machinery has of late years been in use there, small planters still adhere to the simpler appliances, and with a marked degree of success and profit. Here, also, as there, large works will not interfere in the least with those conducted on a very moderate scale, if the latter be managed with skill and prudence. The one will be auxiliary to the other. On account of the expense and risk of transporting large quantities of the canes from different parts of an extended area of country beyond a very moderate distance, the establishment of small factories to reduce the crop to crystallizable syrup, or at most to sugar of the first crystallization, is highly to be commended.

The question is asked, How can the planter work up to advantage a crop of from ten to twenty acres of cane or corn on his own land and under his own care, conducting the whole series of operations, beginning with the working of the soil and the planting of the seed and ending with the production of a good article of crude yellow sugar?

The importance of this question in this connection demands an answer in more explicit terms than is found in the general outline already given. In the accompanying diagram the essential features of a sugar factory to answer such a purpose are sketched. It is most convenient in such case to have the whole work done under one roof or within a single building. When the location admits of it, the general arrangement here given will be found to be very advantageous. But, whatever be the shape or size of the building, it is necessary that the space inside should be divided off into four separate compartments, and these should be contiguous to each other in the following order: The mill-room (A;) the evaporating room (B;) the crystallizing room (C;) and the drying-room (D.) (See diagram.)

The first two of these may be open sheds simply, but the last two should be tightly closed in and provided with the means of keeping up the temperature within them to 80° F. whenever necessary. In addition to these there should be space for the storage of the products of the factory.

The mill (a) may be propelled by steam, water or animal power, and in any case should be placed upon a strong platform of plank supported by stout timbers. If horses are used to propel it, they work on the ground floor below; the swape is a straight beam, secured in a horizontal position, at a height suitable for easy draught, to a vertical wooden shaft of ten or twelve inches in diameter, which is strongly coupled to the shaft of the driving-roll. Mills with either horizontal or vertical rolls may be used in this manner.

The convenience of this arrangement is obvious. The horses work to good advantage, the vicinity of the mill is clear of all incumbrance, the loss by waste, dirt, damage to machinery, &c., is much diminished. The horizontal mills should be furnished with aprons for carrying forward the cane and removing the trash. There is room at one side and sufficient elevation to allow the trash to be dumped over the platform outside the building either into wagons or carts to convey it to a barnyard for conversion into manure, or it may be utilized by burning it in the furnaces close alongside. It is convenient to have the mill-room at the base of a slight declivity or platform of rising ground, so that its floor will be on a level with the ground at the side where the cane is received to be passed through the mill.

The supply of cane or corn to the mill should be continuous. As already indicated, it should be conveyed to the mill as soon as it is cut down in the field, so that only a few hours may intervene until it is worked up. Store room need only be provided for as much as can be passed through the mill in 24 hours. The mill, horses, cane, and all the machinery should be under roof, that there need be no interruption of the work.

From the tank (4) at the mill sufficient fall for the juice is secured. It is received first into the heating tanks (6) by a pipe (p p,) and thence by its downward flow successively into the defecating tank (7,) the supply tank (8,) the evaporator (9,) the finisher (10,) and the cooler (11.) Thence the cooler containing the granulating syrup is conveyed along a tramway into the crystallizing-room (C) adjoining, and the crystallizing boxes (c c c) are filled in succession from it. Centrifugals for drying the sugar (16 16) or the press (17) are located in the adjoining room, (D.) Brick-lined and cemented cisterns, (18 18 18,) excavated beneath the floor of the evaporating-room, receive through pipes or troughs the syrup of drainage from the crystallizing vessels, the centrifugals, or the press.

In the draining-room (D) sufficient space (14, 15) may be provided for the cutting from the cob by machinery, and the drying of the grain of unripe sugar corn.

The water supply for the works should be abundant, and if an engine is used to propel the crushing-mill the boilers should be sufficiently large to supply steam for evaporative or heating purposes.

Ordinary good judgment on the part of the operator, attention to details, a knowledge of the main principles involved, and a degree of practical skill, easily acquired, are all that are necessary to give to this new business a rapid and permanent success.

XII.

UTILIZATION OF SECONDARY PRODUCTS.

Importance of the Subject—Reworking of Scums and Drainage Syrups—Important Rule—Value of Green Cobs—Test to be Made of Preserving Them for Winter Forage by "*Ensilage*"—Unfinished Experiments.

The proper utilization of the various secondary products arising from this industry is a subject of great importance. The maize-sugar manufacture in particular, in its relation to the feeding of farm stock in a systematic way, demands special attention. In these pages but one mode of utilizing the grain of green corn is indicated, but a wide field is opened for investigation to determine what other and perhaps more valuable forms it may be made in skillful hands to assume.

In this manufacture nothing whatever should be wasted. The scums and precipitates, the washings of the sacks and of the tanks and vessels used, should be exhausted of the sugar which they contain, by reboiling and skimming, or straining and condensation to syrup for crystallization; the same precautions being taken to secure perfect defecation that are necessary in the treatment of the impure juice. The rule always adopted in all well-regulated sugar-works should be enforced here. No inferior saccharine solution should be brought in contact with another of a higher grade.

The careful farmer will appreciate the importance of preserving in the best condition the tops, blades, cane seed, &c., which have been removed in the field. The ashes of the furnaces, precipitates, &c., are best utilized as manures. The cobs from which sweet corn is cut for drying are as saccharine as the stalks and much more nutritive. The process of "*ensilage*," or burial in pits, the French method of curing green forage for winter use, suggests itself as important in this connection. Experiments designed to determine fully its value, will be made during the present season. The cobs of green corn from which the grain has been cut retain the "pips," or most nutritive portion of the imbedded grain, which increase very largely their value as feed for cattle or hogs. As compared with the cob of the unripened corn, that of the mature ear is almost valueless.

The attention of the reader is directed to paper (C) in the Appendix, containing information and suggestions of value as to the utilization of various secondary products of maize and sorghum, which may be made auxiliary to the sugar manufacture in the majority of cases to a very large extent. Experiments now in progress, the results of which cannot be communicated before the close of this season, seem to indicate that there is no portion of the fabric of these most remarkable plants which does not appeal to our intelligence as contributing to supply some important want of our modern civilization.

APPENDIX.

APPENDIX A.

COMPARISON OF SUGAR PLANTS.

1.—BOTANICAL RELATIONSHIP.

Sorghum, maize, and the tropical sugar-cane are closely related. They are all simply gigantic grasses, with a solid pith, as distinguished from those which are reed-like or hollow. The pith is charged at a certain period of their growth with a rich saccharine juice, differing in its nature and properties with the species from which it is obtained and perfectly characteristic of each. There are numerous well-defined varieties of each species.

The beet is remarkable as being a member of a peculiar order of plants, to which belong such alkaline sea-side plants as the samphire, (*salicornia*,) saltwort, (*salsola*,) and obione. Of the same natural family is the common wormseed (*ambrina anthelmintica.*) It is probable that its saccharine character has been developed largely by cultivation. Of the many varieties of the beet only the white-fleshed kinds, especially that known as the Silesian, are adapted to the production of sugar.

2.—PERIOD OF GROWTH.

Sorghum.—Annual, at least in temperate latitudes. The length of its period of growth differs with the variety, varying from three to five months.

Maize.—Annual; ripening its seed in from three to five months in North America.

Sugar-Cane.—Perennial from the root-stalk in the tropics; flowering in from twelve to twenty months. In Louisiana it never matures its seed.

Beet.—Biennial, ripening its seed the second year from the planting, but maturing its juice in the root during the first season. The time required for this purpose is about eight months from the time of sowing the seed.

3.—Propagation.

Sorghum.—Propagated from seeds planted in early spring. Much labor and expense is thus saved, which in Louisiana is expended in the cultivation and care of the "seed cane" or cuttings of sugar-cane.

Maize.—Annually, during summer, from the seed. Enjoys equal advantages with sorghum in this respect.

Sugar-Cane.—Propagated always in the sugar district of our Gulf States, and ordinarily in the tropics, from cuttings of the stem, (joints.) In Louisiana, on account of constant deterioration, it is necessary to replant from cuttings at least every third or fourth year. One-fourth of the whole breadth of land devoted to sugar-culture being employed constantly in the propagation of the joints from which the cane crop on the other three-fourths is grown.

Beet.—By seeds, annually; but unlike maize or sorghum, no seed is grown from the crop which produces sugar. The expense, however, of growing beets for seed is trifling to that incurred for the propagation of the sugar-cane.

4.—Ratooning, or Tillering.

Sorghum.—The crop of sorghum is capable generally of large increase each season by side shoots arising from the root. It cannot be propagated from cuttings of the stem; but when the stems are cut down they ratoon like sugar-cane. Mr. Leonard Wray has stated that in South Africa he grew ratoons of neeazana, or white imphee, six feet in height, within two months after the first cutting, sometimes as many as fifteen stems tillering out from one root. These ripened their seed. This mode of increase is precisely analogous to the tillering of our winter wheat when it has been cut down by the frost; but unlike wheat, and like the sugar-cane, sorghum in some climates produces an increased second crop of matured stems from the same roots which supported a previously ripened crop.

Maize.—This mode of increase is not at all characteristic of maize.

Sugar-cane.—Ratoons regularly as above described.

Beet.—Cannot be multiplied or propagated in any way analogous to this.

5.—Climate.

Sorghum.—The climate of the whole territory of the United States south of Alaska, where the soil is not barren and the moisture is sufficient during the summer months, is adapted in various degrees to its growth. Early maturing varieties are adapted to northern localities.

Maize.—A little more sensitive to cold than sorghum, but all over North America, where sorghum will thrive, it may be grown, especially as it matures its juice within a shorter period.

Sugar-cane.—Limited to a very narrow belt of country bordering upon the Mexican Gulf. A tropical climate only is well adapted to its production.

Beet.—May be grown for sugar in the latitude of the Middle and Northern States generally, but not at the South. It will yield sugar remuneratively only in localities where the summer rainfall is well distributed throughout the season and equal to that of spring, and where the natural peculiarities of soil are not unfavorable.

6.—Soil.

Sorghum.—The most suitable soil, deep, rich, well-drained calcareous.

Maize.—The richest and deepest natural soils, moderately enriched; not so sensitive to excess of moisture in the soil as sorghum.

Sugar-cane.—A rich, deep, moist loam the best. First crop off new lands poor in sugar.

Beet.—Similar requirements to the above as to depth and high fertility, but it is much more sensitive as a sugar plant; and our best "corn lands" and natural soils, the alluvions and prairies, have proved unfavorable to it.

7.—MANURES.

All these plants yield juices less rich in sugar, and containing more impurities—especially substances containing nitrogen—when supplied very liberally during the period of their most rapid growth with animal manures. As a stimulant to early growth a limited amount of well-pulverized animal manure, such as guano, is of advantage. Lime, gypsum, and the superphosphates may be used always with profit, and often to immense advantage.

8.—CHEMICAL COMPOSITION—THE STEM.

	Sorghum, (average.)	*Maize*, (average.)
Sugar	12.0	10.8
Woody fiber, mucilaginous, resinous, and albuminous matter and salts	12.5	10.1
Water	75.5	79.1
	100.0	100.0

	Sugar-Cane.			*Sugar Beet.*
	AVEQUIN, LA.		Stenhouse.	Payen, France.
	Tahiti cane.	Ribbon cane.		
Sugar	14.28	13.39	18.02	10.50
Woody fiber, mucilaginous, resinous, and albuminous matter and salts	9.64	9.88	10.91	6.00
Water	76.08	76.73	71.04	83.50
	100.00	100.00	100.00	100.00

CHEMICAL COMPOSITION—THE JUICE.

	Sorghum, (average)	*Maize,* (average.)
Sugar	13.5	12.0
Organic matter and salts	1.7	1.6
Water	84.8	86.4
	100.0	100.0

	Sugar-Cane.		*Sugar Beet.*
	Avequin, La.	Evans.	Payen.
Sugar	15.78	18.2	10.66
Organic matter and salts	0.38	0.8	4.57
Water	83.84	81.0	84.77
	100.00	100.0	100.00

APPENDIX B.

The chemical composition of these plants and of their juices I have made a subject of special investigation, a brief abstract of which is given in the foregoing comparative statement, (A.) The information thus gained, outside of its *chief value in outlining a special mode of treatment for the extraction of the sugar*, possesses additional interest in its bearing upon other important questions. One of these is whether a more *exhaustive method of extracting the juice can profitably be employed* to take the place of the ordinary cane mills. The very great loss sustained in the expression of only the larger part of the juice of the Southern cane has led to the suggestion of a method of cutting the stem of that plant into thin slices, and exhausting the sugar by prolonged maceration and washing with hot water and subsequent hydrostatic pressure.

The inapplicability of the latter method to the extraction of the sugar of Chinese cane (and of maize as well) is decisively shown if we consider the amount of soluble substances other than sugars contained in the stem, as compared with the amount of the same substances found in the juice when expressed by a sugar mill.

A perfectly ripe stem of Chinese cane (containing more undissolved matter than if it had been taken at an earlier period) had the following composition :

Water	per cent.	65.80
Sugar (crystallizable)	"	11.25
Sugar (glucose)	"	0.75
Gum	"	3.31
Pectin	"	0.60
Starch	"	7.15
Albumenoids	"	2.60
Cellulose	"	7.32
Oil	"	0.02(?)
Silica, lime, potash, soda, peroxydes of iron and manganese, chlorine, phosphoric acid, sulphuric acid, &c	"	1.20

I have found that by washing the rasped or thinly-sliced cane repeatedly with *cold* water it is capable of extracting 4.5 per cent. of albumenoids, gum and pectin, while but 2.4 per cent. of other substances than sugar are found in the juice as it leaves the mill. But if *hot-water* maceration be employed to dissolve out the sugar, an additional amount of pernicious substances escape with it—notably a large proportion of starch in the gelatinous state, or *amidin*. It will also be observed that the combined weights of all the substances in the stem capable of being removed along with the sugar by acidulated or alkalized water considerably exceed the whole of the crystallizable sugar.

On the other hand, the softer cellular structure of these plants, as compared with the southern cane, facilitates very much the action of the mill and increases the yield of juice proportionably. While from 50 to 60 per cent. only of the juice of Louisiana cane is obtained ordinarily, by this means from 80 to 85 per cent. from maize, and from 75 to 80 per cent. from sorghum (Chinese) may readily be obtained, as recent experiments abundantly show. When light mills are used repressing may sometimes be necessary.

The following results of analyses made during the past season are of interest chiefly as showing the relative proportions of the sugars in these plants, at different times, during the period when the extraction of sugar is profitable :

Juice of Maize.

Varieties.	Stage of growth.	Specific gravity.	Per cent. of crystallizable sugar.	Per cent. of uncrystallizable sugar.
Penna. yellow......	Silk appearing, early flower........................	1.044	6.98	1.92
" "	In early " roasting ear "..	1.053	9.34	1.63
"Pop" corn (large)	In early flower..............	1.044	7.25	1.65
"Stowell's evergreen"............	Grain in "early milk"...	1.060	11.34	1.56
Eight-rowed yellow	" " " " ...	1.060	11.42	1.65
Kansas yellow......	Grain hardening.....	1.051	9.86	1.04
" "	Stored 2 weeks. Two lower joints..........	1.062	10.48	2.52
" "	Stored 2 weeks. Middle and upper joints..	1.071	9.80	5.20

Juice of Sorghum.

Varieties.	Stage of growth.	Specific gravity.	Per cent. of crystallizable sugar.	Per cent. of uncrystallizable sugar.
Chinese (regular)...	Flowers just expanding...	1.042	6.72	2.18
" "	In flower a few days. Butt joints..	1.060	11.30	1.60
" "	In flower a few days. Top joints..	1.053	9.75	1.25
" " ...	Seed ripening..................	1.058	11.52	1.18
" "	Seed quite ripe. Upper and middle joints.	1.063	12.72	0.78
" "	Seed quite ripe. Lower joints.	1.055	10.57	0.93
" " ...	Mixed juice, ripe and unripe	1.060	11.34	1.56
Red imphee	Seed in early milk	1.053	9.92	0.98
"	Seed ripe......................	1.060	11.92	0.98
Black imphee........	Coming in flower..........	1.053	9.98	0.92
White imphee........	Not yet out in flower.......	1.059	10.90	1.90
" "	Flower just expanded.....	1.057	10.30	2.20
" "	Seed nearly ripe	1.060	10.66	2.24
Chinese.............	Cut and stored 3 weeks. Lower joints.	1.082	14.97	3.53
Chinese.............	Cut and stored 3 weeks. Upper and middle joints.	1.082	16.19	2.31

The principal causes of failure in all the attempts heretofore made to produce sugar from sorghum, and which would prove almost equally formidable in the case of maize, are chiefly two, viz: First, the presence in the juice, when in the best condition, of an almost constant quantity of glucose; and, second, the uniform presence of peculiar protein and amylaceous (starchy) compounds which distinguish these from other sugar-producing plants. Consequently, the extraction of the sugar from them is a problem involving entirely new conditions.

It was found that the existence of these bodies in the juice presented an almost insuperable barrier to the modes of treatment adapted to the cane of the South and to all the processes so successful, and at the same time so tedious and expensive, which are employed in Europe in the extraction of sugar from the beet. By the common treatment with lime the destruction of the glucose and the speedy reduction of a large part of the cane sugar to the condition of a permanently liquid sugar, the darkening of the syrup, and the incapacity of the remaining sugar to crystallize, was the inevitable result. On the contrary, if no lime was employed no defecation was possible, and the juice retained within itself the active elements of its own destruction. Thus, constantly placed between Scylla and Charybdis, the practical operator was left without resource.

It has commonly been supposed that maize contains no grape sugar. The prevalent opinion in regard to sorghum has been that it contains it in very considerable quantity. Both these opinions are now shown to be incorrect. But that they both contain uncrystallizable sugar largely—even in larger proportion than that which is crystallizable if not taken fresh from the field—is proved by every analysis made of canes in that condition. Deterioration commences within a few hours after they are cut from the ground. And to this fact almost solely are attributable all the hitherto discordant results of chemical analysis. Plants were used which, although bearing no external evidence of it, were really, as to the sugars, in various stages of decomposition.

But the utter failure hitherto to extract sugar in remunerative quantities from these plants has not been due primarily to such deterioration. Canes taken in the freshest possible condition have proved just as refractory by the common modes of treatment as if crystallizable sugar had no part in their composition. The failure has been due to a cause for which no remedy was provided.

I have discovered, in its application to these juices, a most remarkable property in the dioxide of sulphur. which has been heretofore unused and unknown, namely, that of protecting as by an impenetrable shield the sugars of both kinds in the solution against the action of forces by which the other deleterious substances are either neutralized or destroyed. It has its use pre-eminently as applied to natural juices containing a proportion of grape sugar. The juices of maize and sorghum are the principal examples of this kind, and there are always other substances combined with the sugars which give to the solution a peculiar character. One of these is a complex and powerfully destructive body in its effect upon the associated substances, and especially the sugars. This body, as well as gum, is found in these juices in comparatively large quantity, and, although there is a variety of others more or less harmful, none are to be compared with it in their power to hinder crystallization or activity in producing decomposition. This body, by the means here employed, is broken up, and as was before observed, with it is removed the last and the most important barrier to the crystallization of the sugar. It is worthy of remark that the *solution B*, into the composition of which the dioxide of sulphur* enters, not only removes the hindering cause to crystallization—the body in question—but it makes it easy to secure the *full effect* of the action of *lime* and of *heat* in defecation, an object otherwise unattainable. Lime, to be really useful, must be added in large excess; but heretofore in clarifying saccharine juices by the use of a large excess of lime, the method has been to mix enough of it with the juice to form a lime compound with a large part or the whole of the sugar, and afterward to neutralize or remove the lime by carbonic acid, assisted by filtration through boneblack. This method is inefficient as applied to these juices, because of its bad effect upon the uncrystallizable sugar, and because there are very harmful impurities which still remain dissolved in the saccharine liquid after the lime has been removed by precipitation by carbonic acid and filtration through boneblack, or neutralized by any known chemical agent suitable for that purpose. But such a method, even if it were at all appropriate to be used in this case, would be objectionable on account of its heavy cost.

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* The use of this agent in any form in which it can be produced—solid, liquid or gaseous—or as it may be produced from its salts, the sulphites, and applied to sugar manufacture from these juices in such a way as to obtain its proper action, is fully secured to me by letters-patent of the United States. Sulphurous oxide has had its uses for other purposes than those for which I now employ it, but that they have no practical value in this connection the results of the last twenty-five years fully show.

Heat, to be efficacious for any other purpose than simple evaporation, must be applied to the juice when it is in a fit condition to receive it. In the ordinary process of making sorghum syrup it is either a powerful agent in the destruction of the sugar, or at best it is shorn of half its useful effect. The manufacturers of such syrups find no advantage in the use of lime in any considerable proportion, and generally confine themselves to the action of heat alone as a purifying agent. But the action of heat under such circumstances is confined to the coagulation of only a small portion of albuminous matter, and a boiling heat has no further beneficial effect in separating the pernicious, dissolved substances. On the contrary, they become permanently incorporated with the syrup, and their subsequent separation is an impossibility without destroying the sugar.

The efficiency of this process consists in the power which we possess, by means of it, of guarding against these evils and of producing thorough purification.

Appendix C.

SECONDARY PRODUCTS.

Products of the Begasse.

1.—*The Fiber.*

The begasse as it leaves the mill (after repressing) contains cellulose, a considerable proportion of starch and cerosie, oil, coloring matter, a minute quantity of silicia, and about one-seventh of the juice at first contained in the stem, holding in solution, besides cane sugar, some glucose, and a variable quantity of gum, albumenoids, pectin, and soluble salts.

The use to which the begasse is perhaps most readily applicable consists in its capacity as a manure to restore to the land most of the substances necessary to the growth of future crops, which year by year are continually removed with the cane. Its decomposition is most rapidly promoted by spreading it out in a cattle-yard during the fall and winter, where it may be mixed with animal manure, and subjected to the trampling of the animals.

As fuel, also, it answers a good purpose in the evaporating furnaces, where special provision is made for burning it; but in a country such as ours, where fuel is generally so abundant and cheap, and when it is generally known that the material itself is much more valuable for other important purposes, such uses of it will no doubt ere long be discontinued on the score of economy.

The fiber of sorghum possesses in a pre-eminent degree the properties of toughness and strength. It has already been used for the manufacture of paper. The important preparation which it receives by the powerful mechanical action of the mill, the condition of extreme subdivision to which it is reduced, particularly after being twice rolled, and the facility with which by a proper process of exhaustion other valuable products, amply compensating for the work, may be separated from the purified fiber, are considerations demanding attention. Not less than 8 to 9 per cent. of the original weight of the stem (2,000 to 3,500 pounds per acre) is pure cellular fiber. It will be readily comprehended that at the ordinary price of paper stock of the same quality, the value of this material will soon be appreciated, and in view of our heavy importations of paper-making substances its home manufacture will soon become very important. The fiber from corn begasse may be employed in a similar manner.

No directions can be given as to the best method, in its details, of utilizing these substances until certain tests now being made shall be concluded; but the results will be published as early as practicable.

2.—*Coloring Matter.*

It has been known for some years past that the Chinese produce in fabrics of silk and wool a beautiful red color, which is derived from the seeds of sorghum. Experiments made, both in this country and in Europe likewise, show that the same dye may be obtained from the crushed canes. For this purpose they must be sheltered from the rains after they are received from the mill, and thrown in close piles until fermentation sets in. Afterward the heaps must be opened and stirred frequently to prevent heating, which would destroy the coloring matter. When their color has changed to a deep red or reddish brown, they are then cut up, washed, and dried. A weak lye of caustic potash or soda may be used to extract the color from them. By neutralizing this alkaline solution with a weak solution of oil of vitriol the color falls in the form of red flakes, which are easily soluble in alcohol, alkalies, and diluted acids.*

Mr. Henry Erni, formerly chemist in the National Agricultural Department, contributes the following information, derived from experiments conducted by himself; † up to this time, however, the matter seems to have attracted no attention:

"The simplest solvent is alcohol, (very expensive at present.) Dilute acids were resorted to with very good success, and at an expense and trouble scarcely worth mentioning. The seeds were boiled in vinegar, or in water to which oil of vitriol had been added before heating, until the mixture tasted as acid as vinegar. Other acids, such as tartaric, oxalic, &c., can be used, but are more expensive. When the liquid assumes a red, or rather an intense orange color, it is ready for use. The articles to be colored are at first brought into the hot solution, and agitated until the color no longer increases. They are at once removed and dipped into a weak solution of salt of tin, (chloride of tin,) obtained by dissolving tin in hydrochloric acid. They are then exposed to the air for a short time and washed.

"Cotton and silk may thus be colored red. Wool turns to a beautiful purple, and an almost unlimited variety of colors and shades may be obtained by substituting for salts of tin other mordants. All the various shades of red, purple, orange, gray, &c.,

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* A. Winters, in Liebeg's Jaresbericht, 1859, p. 754, quoted by Wetherill, Ag. Rep. 1862, p. 535.

† Rep. Dept. Ag., 1864, p. 532.

are thus produced from the same bath, the cloths being afterward drawn through solutions of proto-chloride of tin, bichromate of potash, sulphate of copper, ammonia, lime-water, subnitrate of bismuth, &c. Yellow is produced by adding to the seed sufficient nitric acid to form a thick mushy mass. Too much acid will make a straw color.

"The dye turns solid by standing, and may thus be stored. To dye silk or wool yellow the solid dye is dissolved in boiling water, the goods dipped into it and afterwards washed.

"Cotton has the least attraction for sorghum dyes, while the wool receives the brightest colors. The same dye is developed in the stalks."

The extraction of the coloring matter, if properly conducted, may be accomplished without injury to the fiber of the begasse, and the coloring matter so obtained may be augmented largely by the exhaustion of the seed hulls, (glumes,) from which water, especially if acidulated or alkalized, extracts it very readily.

3.—*Cerosie.*

Every one has noticed the peculiar plum-like bloom covering the stems of ripened sorghum. It is found on their surface in such condition as to be scraped off in considerable amount, with a knife, in the form of a white powder. More careful examination reveals its presence in the hard exterior layers outside the pith. It covers the stem at the joints, especially beneath the sheathing bases of the leaves. It is found most abundantly in ripe cane. This substance seems to be identical with cerosie, or the peculiar vegetable wax found on the exterior of the southern sugar-cane. It is hard, dry, and pulverizable, somewhat resembling spermaceti, or white wax, in appearance when pure, but its melting point is much higher, (about 194° F.*) The only experiments yet made upon it seem to have been those conducted in Algeria shortly after sorghum was first introduced there from France.† By scraping the stems of a lot of ripe canes with a knife it was estimated that 108 kilogrammes 400 grammes of the substance could be collected to the hectare, (or about 110 pounds per acre.)

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* Goessmann. † Hardy.

Cerosie should be of equal value to white wax or solid paraffine. A prominent purpose which it seems designed to serve in the economy of the plant is to form, with the silicious coating and the close exterior layers of cells of the stem, a barrier to the evaporation of the matured juices. Goessmann estimates the quantity at 0.50 per cent. of the stalk, which would be 180 to 240 pounds per acre.

It is said that the scum from the juice of the sugar-cane in Louisiana contains, when dried, 50 per cent. of this substance, and if it is found to a similar extent in that of sorghum its extraction by the use of a suitable solvent would be a source of considerable profit. But much the larger proportion of it is left in the begasse, and when the latter is employed for paper stock its extraction is a necessity.

It may be manufactured into candles, or in solution in benzine it may be employed to render wooden tanks impervious to fluids; in short, to serve all the useful purposes of paraffine. Its melting point being higher it may be used sometimes to advantage where the latter is inapplicable.

This substance should not be confounded with a fatty substance which exists in less quantity in corn and cane stems, and which is separable in a somewhat similar way. This oily matter contains in a large degree the peculiar odor and flavor of the plant from which it is derived. The juice contains it; but it separates entirely by the action of *solution B*, which breaks up the combination in which it occurs.

4.—*Alcohol.*

The production of alcohol, largely as a secondary product, does not enter into the plan of a sugar factory. The expensiveness of the apparatus required, the extensive scale upon which the work must be carried on as a distinct department, taken in connection with the very serious impediments thrown in its way by the operation of our revenue laws, are most serious objections. Besides, its profitable manufacture in connection with sugar works is presumptive evidence of an entirely unnecessary condition of things existing there.

It presupposes in such an establishment the regular conversion of sugar in large amount into uncrystallizable material, and its comparative worthlessness for other use.

As an economical source for the manufacture of commercial alcohol, as compared with grain, these juices present great advantages. Each ton of sugar which they contain is equivalent to 173.2 gallons of 90 per cent. alcohol, (specific gravity 0.8228.) But their capacity to produce alcohol can never be brought into competition with their capacity to produce sugar under any ordinary circumstances.

5.—*Vinegar.*

The manufacture of vinegar from weak, purified saccharine juices is profitable in certain localities and to a certain extent. The space and vessels required, the bulkiness of the product, the limited demand for it, and the existence of other sources from which it may be profitably derived, will always limit its production from this source.

The addition of yeast seems necessary to produce the regular alcoholic and acetic fermentation in these juices, and, to prepare them for this purpose, they should simply be limed to produce slight alkalinity, heated to boiling, and the clear liquid diluted to about 4° Beaumé's hydrometer. The fermentation may be conducted in casks somewhat more than half filled with the liquid; a cupful of fresh yeast must be added to each cask, and the liquid exposed to the air, the temperature at the first not being below 65° F.

Analysis of Dried Sugar-corn.

Samples taken of the immature grain of Stowell's evergreen sugar-corn, prepared August, 1877, from it when in proper edible condition, by boiling the corn in the ear for about five minutes, cutting it from the cob with a sharp knife and drying it as rapidly as possible upon metallic plates at a regulated temperature, (about 225° F.) For the purpose of comparison, I append also a recent analysis of the mature grain of Pennsylvania yellow corn, made by Dr. Wm. McMurtrie, chemist of the Department of Agriculture, and published in the annual report for 1873, (p. 178.)

	Dried Sugar-corn, (green.)	Penna. Yellow, (mature.)
Moisture	7.12 . .	8.87
Oil	4.20 . .	5.17
Sugar	3.52 . .	1.10
Gum	42.52 . .	1.23
Starch	35.50 . .	70.66
*Albumenoids and gluten	3.02 . .	9.92
Cellulose	2.62 . .	1.72
Ash	1.50 . .	1.33
	100.00	100.00

It will be seen that the proportion of these substances in the dried sugar-corn is not quite equal to one-third of that contained in the ripened yellow corn ; but this difference is due chiefly to the loss of gluten (diastase) occasioned by the cutting off of the germinal point of the grain of the green corn—nearly one-third of its substance—in the usual process employed in preparing it for drying. This circumstance, taken in connection with the fact that the cob of the green corn is exceeding rich in saccharine matter, gum, &c., indicates the very high value of the cob with the adherent portion of the grain for stock-feeding purposes. The pith of the green cob is large, solid, and rich in sugar and gum. I regret that I am not prepared at this time to furnish an analysis of the cob in this condition.

The fatty matter or oil in the dried sugar-corn is about equal to that in matured specimens of corn generally, especially the white varieties, although it is less than in the yellow corn, with which it is here more directly compared. The saccharine matter is much greater than in the latter, and by the application of the proper chemical tests, it is to be found almost entirely crystallizable sugar. The sugar of the grain of ripened corn is generally glucose.

The most marked peculiarity of the desiccated sugar-corn is the very large proportion of gummy matter which it contains (gum and dextrine) as compared with that of true starch.

* For convenience the azotized substances are here classed together.

Taken altogether, this substance as an article of human food exhibits peculiarities not found in any other grain, and properly prepared it is light, rich, nutritive and easily digested.

Appendix D.

It is by no means certain that all the different kinds of sorghum existent in Asia and Southern Africa have been introduced into this country or Europe. As already mentioned, some of the sorts exhibited in the Chinese Department at the Centennial Exhibition at Philadelphia in 1876, seem to be new.

The Caffrarian varieties brought over by Mr. Leonard Wray in 1857, have encountered influences here which have resulted in great changes in their appearance and saccharine properties. These, as well as the Chinese varieties, have heretofore commonly been classed as one species. English botanists, however, who have studied the flora of the Cape Colony, within recent years, enumerate two native species. It would be interesting to know what are their characteristics and whether we have representatives of both here. Harvey's large work gives merely the generic characters but does not describe the species.

"*Sorghum.*—Spikelets at the end of the twigs of a branching panicle—either female, male or neuter—dissimilar. Outer glumes 2; in the fertile and male spikelets coriaceous, hardening with scarcely obvious immersed nerves; in the neuter spikelets membraneous, nerved. Flowering glumes thinly membraneous, ciliate, the lower neuter, the upper fertile, with a short, twisted awn, or awnless. Palea small, narrow scales fimbricate. Seed thick, short, hard, closely wrapped in the hardened glume and palea." Nees l. c., p. 85.

"Tall, strong, broad-leaved grasses with villous or pubescent glumes, grain used as food in India." Two Cape species.

"The Genera of South African plants, arranged according to the natural system, by William Henry Harvey, F. R. S., &c., edited by Dr. J. D. Hooker. Cape Town and London, 1868, p. 442."

Appendix E.

The Copper Test—*Fehling's Solution.*—This method depends upon the property possessed by grape or fruit sugar—but not by cane sugar—of reducing to the state of suboxide the hydrated protoxide of copper when the latter is presented to it in an alkaline solution, and the temperature of the mixture is elevated to the boiling point. The quantity of the oxide of copper reduced is proportional to the quantity of grape sugar in the solution, but uniform results are not obtained except in a nicely-regulated alkaline solution. *Fehling's solution* is of this character, and is not liable to decomposition at ordinary temperatures. It may be prepared as follows:

40 grammes of sulphate of copper, 160 grammes of neutral tartrate of potash (or 200 grammes of tartrate of soda) are dissolved and added to 700–800 c. c. (cubic centimeters—grammes) of caustic soda, specific gravity 1.12. This dilute with water to 1154.5 cubic centimeters. Of this solution

$$\text{I cubic centimeter} = \begin{cases} 0.0050 \text{ grape sugar} \\ 0.0045 \text{ cane sugar} \end{cases}$$

or grains instead of grammes—and then 1 grain=0.0050 grape sugar, without further change of calculation. And

$$\left.\begin{array}{l} \text{100 parts of grape sugar} \\ \text{95 parts of cane ``} \end{array}\right\} = \begin{array}{l} \text{220.5 CuO or} \\ \text{198C2 O*} \end{array}$$

Fresenius, in his late able treatise upon Quantitative Chemical Analysis, gives very minute directions for the successful application of this test, which, somewhat condensed, I insert below. It will be observed that sorghum juice, being a mixed solution of sugars, must be subjected to two experiments; one portion of a given sample to determine the per cent. of grape sugar, and another to determine that of cane sugar by reducing the latter to the

* Dr. Ure.

condition of grape sugar, and applying the same test. By subtracting the quantity of grape sugar indicated by the first experiment from that indicated by the second, we obtain the quantity of grape sugar into which the cane sugar was converted, and thence by a simple calculation the cane sugar itself, from the data given above.

The cane juice to be tested should be a clear solution, prepared by precipitating with subacetate of lead, and filtering through bone-black as before recommended, or by treating about 15 c. c.* of the crude boiling juice with a few drops of milk of lime, filtering through animal charcoal, washing the precipitate thoroughly on the filter, adding the washings to the filtrate, and diluting it to 15 or 20 times its original volume. Add 12 drops of dilute sulphuric acid (SO_3 HOx5 water) and boil the mixture from 1 to 2 hours, adding water as it evaporates. This operation is best conducted in a steam-bath. Neutralize the free acid by means of a dilute solution of carbonate of soda.

The sugar solution must be *highly dilute*, containing only one-half, or, at most, 1 per cent. of sugar. If in a first experiment the sugar solution is too concentrated, dilute it with a definite quantity of water and repeat the experiment.

The copper solution prepared, as directed by Fresenius, gives very accurate results.† "Dissolve exactly 34.632 grammes of pure crystallized sulphate of copper, completely freed from adhering moisture by pulverizing and pressing between sheets of blotting paper, in about 200 c. c. of water. Dissolve in another vessel 173 grammes of perfectly pure crystallized tartrate of soda and potassa in 480 c. c. of pure solution of soda of 114 sp. grav. Add the first solution gradually to the second, and dilute the deep blue clear liquid exactly to 1000 c. c. Every 10 c. c. of this solution contains 0.34632 grm. of sulphate of copper, and correspond exactly to 0.050 grm. of anhydrous grape sugar. Keep the solution in a cool, dark place, in well-stoppered bottles filled to the top, as absorption by carbonic acid would lead to the separation of sub-

* c. c. cubic centimeters. See table V.

† Fresenius's Quant. Chem. Analysis. London, 1860, pp. 576–9.

oxide of copper upon mere exposure to heat. This might be prevented, however, by the fresh addition of solution of soda. Before using the solution, boil 10 c. c. of it for some minutes, by way of trial, with 40 c. c. of water, or dilute solution of soda if there is reason to believe that the fluid has absorbed carbonic acid; if this operation produces the least change in the fluid, and causes the separation of even the smallest quantity of suboxide, the solution is unfit for use.

"*The process.*—Pour 10 c. c. of the copper solution into a porcelain dish, add 40 c. c. of water, or very dilute solution of soda if required, heat to gentle ebullition, and allow the sugar solution to drop slowly and gradually into the fluid from a burette or pipette divided in 1-10th c. c. After the addition of the first few drops, the liquid shows a greenish-brown tint, owing to the suboxide and hydrated suboxide suspended in the blue solution. In proportion as more of the sugar solution is added, the precipitate becomes more copious, acquires a redder tint, and subsides more speedily. When the precipitate presents a deep-red color, remove the lamp, allow the precipitate to subside a little, and give to the dish an inclined position, which will enable you readily to detect the least bluish-green tint. To make quite sure, however, pour a little of the clear supernatant liquid into a test tube, add a drop of the sugar solution and apply heat. If there remains the least trace of salt of copper undecomposed, a yellowish-red precipitate will form, appearing at first like a cloud in the fluid. In that case pour the contents of the tube into the dish, and continue adding the solution of sugar until the reaction is complete. The original amount used of the solution of sugar contains 0.050 grammes of anhydrous grape sugar.

"When the operation has terminated, ascertain whether it has fully succeeded—that is, whether the solution really contains neither copper, sugar, nor a brown product of the decomposition of the latter. To this end filter off a portion of the fluid while still quite hot. The filtrate must be colorless, (without the least brownish tinge.) Heat a portion of it with a drop of the copper solution, acidify two other portions, and test the one with ferrocyanide of potassium, the other with sulphuretted hydrogen. Neither of these tests must produce the slightest alteration. If the fluid contains a perceptible quantity of either oxide of copper or sugar, this is a proof that too much or too little of the latter has been added, and the experiment must accordingly be repeated. The results are constant and very satisfactory. Bear in mind that the solution of sulphate of copper must always remain strongly alkaline; should the sugar solution be acid, some more solution of soda must be added."

Second Method.—This may be resorted to in cases in which from the dark color of the saccharine fluid it is difficult to determine the exact point at which the process of reduction and separation is accomplished. In this case the solution of copper may be used in excess, and the suboxide which precipitates determined.

"This requires the same solutions as the first. Pour 20 c. c. of the solution of copper and 80 c. c. of water, or of highly dilute solution of soda, if required, (or a larger quantity of the copper solution diluted with water, or solution of soda in the same proportion,) into a porcelain dish. Add a measured quantity of the dilute sugar solution, but not sufficient to reduce the whole of the oxide of copper, and heat for about 10 minutes on the water-bath. When the reaction is completed. wash the precipitated suboxide of copper by decantation with boiling water. Pass the decanted fluid through a weighed filter, dried at 212° F., then transfer the precipitate also to the filter, dry at 212° F., and weigh. Or ignite the suboxide of copper with access of air, and convert it completely into oxide by treating with fuming nitric acid.

"100 parts of anhydrous grape sugar correspond to 220.5* of oxide of copper, or 198.2 of suboxide of copper,† or 155.55 of iron converted from the state of sesquichloride to that of protochloride. In the application of this method, it must be borne in mind that

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*Fehling obtained as highest result 219.4 grammes of oxide of copper.

† Neubauer found in his experiments with starch that 0.05 of the latter correspond to 0.112 of suboxide of copper. As 90 of starch gives 100 of grape sugar, 0.05 of the former correspond to 0 0555 of the latter. Accordingly 100 of grape sugar gives actually 201.62 of suboxide of copper, instead of 198.2.

the separated suboxide of copper will, upon cooling of the supernatant fluid, gradually redissolve to oxide, being reconverted into this by the oxygen of the atmosphere. Hence the necessity of washing the precipitate by decantation with boiling water."

The details of this method are thus given at length, for the reason that it is the test most depended upon for determining the quantity of grape sugar in a solution. With the exception, perhaps, of that given below, it is the only purely chemical process known that may be implicitly relied upon for its accuracy, and by means of which the result is reached with facility and dispatch.

An elegant quantitative test for cane and grape sugar has been proposed by M. Peligot, which I have found to give uniform results. I give this method as described by Dr. Ure. "Peligot's method depends upon the definite constitution of sugar lime, (or saccharate of lime,) its greater solubility in water than in lime alone, and the unalterability of this solution by heat. Soubeiran found sugar lime to consist of 3 equivalents of lime to 2 equivalents of sugar—*i. e.*, 84 parts lime to 342 sugar, or about 1 to 4. Ten grammes of sugar dissolved in 75 cubic centimeters of water, ground up with 10 grammes of slaked lime, filtered, and again filtered through the lime, 10 c. c. of the filtrate diluted with 2 to 3 deciliters of water and tinctured with a little litmus, are carefully neutralized with a measured volume of dilute sulphuric acid, (21 grm. oil of vitriol in 1 liter water,) and the quantity of acid used noted. It gives the quantity of lime neutralized, and from the above proportion the quantity of sugar present.

"If cane sugar is to be examined for starch or grape sugar, one test is made as above, and another in which the liquid is heated to 212° F., and then, when cool, tested with the acid. The lime solution with cane sugar becomes cloudy by heat but clarifies on cooling, while if grape sugar be present it becomes brownish yellow, and requires much less acid for neutralization. Indeed, a deciliter of starch sugar solution requires 4 c. c. of the test acid, or just as much as lime-water itself.

"The amount of sugar in a solution is estimated by the amount of lime which it will dissolve, and the lime is determined alkalimetrically by means of the acid. A table has been constructed by Peligot for calculating the results." (See Table IV.)

Unless there is some special reason for a different inference, the organic matter, other than sugar and salts, in a given sample of fresh, unclarified sorghum or maize juice may be approximately estimated at 1.6 to 1.7 per cent. The specific-gravity bottle or the hydrometer will indicate the per cent. of cane sugar only in a pure solution. Therefore, if the amount of the uncrystallizable sugar or glucose simply be determined in the sample, the crystallizable sugar may be estimated at the weight per cent. indicated by the hydrometer, diminished by that of the glucose previously ascertained, added to the percentage of organic matter and salts assumed as above. The rapidity with which this can be done, and its near approximation to the truth, will commend it to the practical operator as being the simplest and best test within his reach. There is no reason why after a little practice any careful person may not be able to test the value of any sample of cane approximately, within ten minutes after it has passed into his hands.

The hydrometer of Beaumé is the common form, but the scales of different instruments do not always correspond, and hence the continued liability to error. Every instrument before being used should be subjected to the following test: Place the hydrometer in pure water at a temperature of 60° F., and the point near the top of the stem to which it sinks is the 0 of the scale. Prepare a solution of 15 parts of common salt in 85 parts of water by weight, and at the same temperature as the above, and the place to which it sinks should mark 15° of the scale. The value of each degree of this scale expressed in specific gravities and correspondent per cent. of sugar are given in Table II.

A specific gravity bottle affords a convenient means of testing the accuracy of the hydrometer, and when an extrême degree of accuracy is required it should be used in its place. It is a bottle containing just 1,000 grains, or 100 grammes of distilled water at 60° F., when the stopper is inserted and the outside of the bottle is wiped dry. The stopper is of ground glass, with a hole through its center, or a groove cut in its side with a file to admit of the escape of any superfluous liquid in filling the bottle. When such a bottle cannot be had a phial of any capacity with a similar stopper may be used, and the exact weight of water at 60° F. which it will hold, ascertained. The specific gravity of the liquid to be examined is obtained by filling the bottle with it, and dividing its weight by the weight of the water which it will hold, previously ascertained.

Thus if the weight of the bottle full of water at 60° is 1,000 grains, and the weight of the solution of sugar at 60° F. is 1,083 grains, the specific gravity of the solution will be 1,083, divided by 1,000, or 1.083. Referring to Table II, we find that the specific gravity 1.083 corresponds to 11° Beaumé's hydrometer, or to 20 per cent. of cane sugar.

The saccharometer is a hydrometer upon which the per cent. of sugar may be read off directly, without reference to a table, and this form should be in general use.

I.

Table "showing the quantity of sugar contained in one hundred pounds of expressed cane juice, or syrup, of good quality, and also of the quantity of water that must be evaporated, to reduce the same to the state of saturated syrup at each degree. A saturated solution of very pure sugar contains five parts of sugar and three parts of water. This is indicated by 34° of Beaumé's saccharometer, at the temperature of 82° F."—*Dutrone.*

Table.

Degrees of density by Beaume's scale.	Weight of sugar in each 100 lbs. of juice or syrup.			Weight of water in each 100 lbs. of juice or syrup, beyond the water of solution.		
	lbs.	*oz.*	*dr.*	*lbs.*	*oz.*	*dr.*
1	1	13	6	97	...	15
2	3	10	12	94	1	14
3	5	8	3	91	2	13
4	7	5	10	88	3	12
5	9	3	...	85	4	11
6	11	...	7	82	5	10
7	12	13	14	79	6	9
8	14	11	4	76	7	8
9	16	8	11	73	8	7
10	18	6	1	70	9	6
11	20	3	8	67	10	5
12	22	...	15	64	11	4
13	23	14	5	61	12	3
14	25	11	12	58	13	3
15	27	9	2	55	14	1
16	29	6	9	52	15	1
17	31	4	...	50	...	...
18	33	1	6	47	...	15
19	34	14	13	44	1	14
20	36	12	3	41	2	13
21	38	9	10	38	3	12
22	40	7	1	35	4	11
23	42	4	7	32	5	10
24	44	1	14	29	6	9
25	45	15	4	26	7	8
26	47	12	11	23	8	7
27	49	10	1	20	9	6
28	51	7	8	17	10	5
29	53	4	15	14	11	4
30	55	2	5	11	12	3
31	56	15	12	8	13	2
32	58	13	3	5	14	1
33	60	10	9	2	15	...
34	62	8	...	...	...	...

II.

Table by Dr. Evans, showing the per cent. of sugar * in solutions of different degrees of density, according to the scale of Beaumé, and corresponding specific gravities.

Degrees of density—Beaume.	Specific gravity.	Sugar in 100 parts.	Degrees of density—Beaume.	Specific gravity.	Sugar in 100 parts.
1	1.007	.018	19	1.152	.352
2	1.014	.035	20	1.161	.370
3	1.022	.052	21	1.171	.388
4	1.029	.070	22	1.180	.406
5	1.036	.087	23	1.190	.424
6	1.044	.104	24	1.199	.443
7	1.052	.124	25	1.210	.462
8	1.060	.144	26	1.221	.481
9	1.067	.163	27	1.231	.500
10	1.075	.182	28	1.242	.521
11	1.083	.200	29	1.252	.541
12	1.091	.218	30	1.261	.560
13	1.100	.237	31	1.275	.580
14	1.108	.256	32	1.286	.601
15	1.116	.276	33	1.298	.622
16	1.125	.294	34	1.309	.644
17	1.134	.315	35	1.321	.666
18	1.143	.334			

III.

Table showing how a saturated solution of sugar is affected by being reduced to different degrees of density, as indicated by the thermometer, commencing at the point of saturation. This table was prepared with great care by Dutrone from actual experiments. By means of it the number of pounds of sugar, which will crystallize in syrup of any given density, as determined by its temperature at the boiling point, may be accurately predicted, and the number of pounds of water which it has lost by evaporation between the temperature of saturation and the given temperature. Also the number of pounds of sugar and water, respectively, which remain

* The standard should be dry, finely powdered loaf sugar, or pulverized and *dry* rock candy.

combined in the form of syrup, (drippings.) At 81.5° F. (22° Reum.) Dutrone found that three parts of water and five parts of sugar form a saturated solution. He formed a saturated syrup, therefore, consisting of 60 pounds of water and 100 pounds of sugar, and upon this the table is based.

If 160 pounds of such syrup be raised from the boiling point 219° F. to 232° F., (for example,) 33 lbs. 11 oz. 10 dr. of water will have evaporated; 56 pounds of sugar will crystallize when the syrup is cooled to the proper temperature and treated in the regular manner, and 26 lbs. 4 oz. 6 dr. of water and 44 lbs of sugar still remain combined.

To determine this it is necessary only to have a thermometer which will register accurately the temperature of the boiling syrup.

Degree of therm't'r Fahrenheit.	Weight of sugar which separates in crystals.			Weight of water evaporated.			Weight of sugar yet combined with water in the state of syrup.			Weight of water still combined with sugar in the state of syrup.		
	lbs.	*oz*	*dr.*	*lbs.*	*oz.*	*dr.*	*lbs.*	*oz.*	*dr.*	*lbs.*	*oz.*	*dr.*
219	0	....	....	0	....	....	100	....	....	60	....	....
221	8	....	....	4	2	24	92	....	....	55	3	2
223	19	4	....	11	8	14	80	12	....	48	7	2
225.5	30	....	....	18	....	....	70	....	....	42	....	....
228	41	....	....	24	9	10	59	....	....	35	6	6
230	52	....	....	31	3	4	48	....	....	28	12	12
232	56	....	....	33	11	10	44	....	....	26	4	6
234.5	60	5	....	36	3	....	39	11	....	23	13	....
237	63	4	....	38	1	....	36	12	....	21	15	....
239	66	3	....	39	4	....	33	13	....	20	12	....
241	69	2	....	41	7	10	30	14	....	18	8	6
243.5	72	1	....	43	4	....	27	15	....	16	12	....
246	75	....	....	45	....	....	25	....	....	15	....	....
248	77	7	....	46	7	4	22	9	....	13	8	12
250	80	5	....	48	7	8	19	11	....	11	8	8
252.5	83	3	....	50	1	10	16	13	....	9	14	6
255	85	....	....	51	....	....	15	....	....	9	....	....
257	87	4	....	52	5	14	12	12	....	7	10	2
259	88	6	....	53	1	6	11	10	....	6	14	10
261.5	90	1	....	54	1	....	9	15	....	5	15	....
264	91	4	....	55	3	10	8	12	....	4	12	6
266	92	7	....	55	12	....	7	9	....	4	4	....
268	94	2	....	56	7	10	5	14	....	3	8	6
270.5	95	5	....	57	3	8	4	11	....	2	12	8
273	97	....	....	58	6	8	3	....	....	1	9	8
275	98	2	....	58	14	8	1	14	....	1	1	8
277	99	2	....	59	7	10	14	....	....	....	8	6
279.5	100	....	....	60	....	....	....	....	....	....	....	....

IV.

Peligot's table for determining the per cent. of sugars in a solution by saccharate of lime.

Quantity of sugar dissolved in 100 parts of water.	Density of Syrup.	Density of Syrup when saturated with lime.	100 parts of residue dried at 120° (Cent.) contain—	
			Lime.	Sugar.
40.0	1.122	1.179	21.0	79.0
37.5	1.116	1.175	20.8	79.2
35.0	1.110	1.166	20.5	79.5
32.5	1.103	1.159	20.3	79.7
30.0	1.096	1.148	20.1	79.9
27.5	1.089	1.139	19.9	80.1
25.0	1.082	1.128	19.8	80.2
22.5	1.075	1.116	19.3	80.7
20.0	1.068	1.104	18.8	81.2
17.5	1.060	1.092	18.7	81.3
15.0	1.052	1.080	18.5	81.5
12.5	1.044	1.067	18.3	81.7
10.0	1.036	1.053	18.1	81.9
7.5	1.027	1.040	16.9	83.1
5.0	1.018	1.026	15.3	84.7
2.5	1.009	1.014	13.8	86.2

V.

Tables of Weights and Measures officially recognized in the United States by act of Congress. (Metric system.)

MEASURES OF LENGTH.

Metric denominations and values.		Equivalents in denominations in use.
Myriameter..	10,000 meters..	6.2137 miles.
Kilometer....	1,000 meters..	0.62137 mile, or 3,280 feet and 10 inches.
Hectometer ..	100 meters..	328 feet and 1 inch.
Dekameter ...	10 meters..	393 7 inches.
Meter	1 meter ..	39.37 inches.
Decimeter....	1-10th of a meter..	3.937 inches.
Centimeter...	1-100th of a meter..	0.3937 inch.
Millimeter ...	1-1000th of a meter..	0.0394 inch.

MEASURES OF SURFACE.

Metric denominations and values.		Equivalents in denominations in use.
Hectare......	10,000 square meters..	2.471 acres.
Are...........	100 square meters..	119.6 square yards.
Centare......	1 square meter ..	1550 square inches.

MEASURES OF CAPACITY.

METRIC DENOMINATIONS AND VALUES.			EQUIVALENTS IN DENOMINATIONS IN USE.	
Names.	No. of liters.	Cubic measure.	Dry measure.	Liquid or wine measure
Kiloliter or stere	1,000	1 cubic meter......	1.308 cubic yards.....	264.17 gallons.
Hectoliter.	100	1-10th of a cubic meter...........	2 bus. and 3.35 pecks..	26 417 gallons.
Dekaliter..	10	10 cubic decimeters.	9.08 quarts...........	2.6417 gallons.
Liter......	1	1 cubic decimeter..	0.908 quarts..........	1.0567 quarts.
Deciliter..	1-10	1-10th of a cubic decimeter.....	6.1022 cubic inches...	0.845 gill.
Centiliter.	1-100	10 cubic centimeters........	0.6102 cubic inch.....	0.338 fluid oz.
Milliliter..	1-1000	1 cubic centimeter.	0.061 cubic inch......	0.27 fluid drm.

WEIGHTS.

METRIC DENOMINATIONS AND VALUE.			EQUIVALENTS IN DENOMINATIONS IN USE.
Names.	No. of grams.	Weight of what quantity of water at maximum density.	Avoirdupois weight.
Millier or tonneau	1,000,000	1 cubic meter................	2204.6 pounds.
Quintal..........	100.000	1 hectoliter..................	220 46 pounds.
Myriagram.......	10,000	10 liters......................	22.046 pounds.
Kilogram or kilo.	1,000	1 liter.........................	2.2046 pounds.
Hectogram.......	100	1 deciliter......................	3.5274 ounces.
Dekagram	10	10 cubic centimeters.........	0.3527 ounce.
Gram.............	1	1 cubic centimeter	15.432 grains.
Decigram.........	1-10	1-10th of a cubic centimeter.	1.5432 grains.
Centigram	1-100	10 cubic millimeters.........	0.1543 grain
Milligram........	1-1000	1 cubic millimeter...........	0.0154 grain.

SYNOPSIS OF THE PROCESS.

1st. Heat the freshly expressed juice of cane, sorghum, or maize in a copper or tinned-iron vessel to a temperature (as shown by a thermometer suspended so that the mercury bulb is immersed in the juice) of 180° Fahrenheit, equal to 82° Centigrade.

2d. After the juice has been heated to 180° Fahrenheit, add and stir into it one fluid ounce of cream of lime to each gallon of juice, or from 5 to 7 pounds (pints) to each 100 gallons of juice.

3d. After adding and stirring in the cream of lime, heat the juice rapidly to the boiling point.

4th. When it begins to boil shut off the heat, or remove the vessel containing the juice from the fire, and so soon as the sediment begins to settle, draw off with a siphon (into tank as described in body of book) the clear liquid from the top until at least nine-tenths of the whole quantity of juice has been thus removed, leaving a thick, muddy sediment at the bottom.

5th. Sweep out with a broom this muddy sediment into a bag-filter, and add the filtrate as it passes through the filter to the clear liquid siphoned off.

6th. To the clear liquid thus obtained in sections 4th and 5th, and which should be allowed to cool to a temperature of 150° Fahrenheit (equal to 66° Centigrade) and not lower, there is now added of *solution B* one fluid ounce to each gallon of juice, or 5 to 7 pints to each 100 gallons of juice. *

* At least enough of *solution B* is to be added to completely neutralize the lime in the juice; and to determine this point, a slip of blue litmus paper is dipped into the solution, when, if enough of *solution B* has been added, the blue color will be changed to red.

7th. Evaporate rapidly, skimming from time to time any scum which appears upon the surface, and adding *solution B* in small quantities if the boiling juice will not turn the blue litmus paper red.

8th. When the thermometer in the boiling juice indicates a temperature of 235° Fahrenheit (equal to 112° Centigrade) the syrup should be withdrawn from the fire, and it should be kept to crystallize in a room of about 80° Fahrenheit, (equal to 27° Centigrade.) *

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* To facilitate crystallization a few grains of granulated sugar may be added to the cooling syrup when it has reached a temperature of 100° Fahrenheit, (equal to 38° Centigrade.)