BULLETIN No. 50.

U. S. DEPARTMENT OF AGRICULTURE.

DIVISION OF CHEMISTRY.

COMPOSITION OF MAIZE

(INDIAN CORN),

INCLUDING THE

GRAIN, MEAL, STALKS, PITH, FODDER, AND COBS.

COMPILED CHIEFLY FROM THE RECORDS OF THE DIVISION OF CHEMISTRY,

BY

H. W. WILEY,

Chemist of the Department of Agriculture.

WASHINGTON:
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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF CHEMISTRY,
Washington, July 25, 1898.

SIR: I transmit herewith, for your inspection and approval, the manuscript of Bulletin No. 50 of this division, relating to the composition of maize in all its parts.

The material contained in this bulletin has been compiled from the records, mostly recent, of the investigations of the Division of Chemistry of the composition of maize. Some of the data have also been derived from the researches of the agricultural colleges and experiment stations. No attempt has been made to give a complete summary of the work which has been done in this country on this product, but simply to present, in a condensed form, the more important data in connection with its composition.

The immediate object of the preparation of this bulletin is to present it to the Third International Congress of Applied Chemistry, in Vienna. There is in Europe a considerable degree of prejudice against the use of Indian corn as a human food, and its value as a cattle food, both in respect of its grain and its stover, is not fully appreciated. It is believed that this brief summary of our present knowledge on the subject will prove advantageous both to the maize growers of this country and to the food consumers of Europe.

Respectfully,

H. W. WILEY,
Chief of Division.

Hon. JAMES WILSON, *Secretary.*

CONTENTS.

THE COMPOSITION OF MAIZE (INDIAN CORN) AND SOME OF ITS PRINCIPAL PRODUCTS.

Maize is the most important crop cultivated in the United States. The average area in maize for the ten years ended December 31, 1897, was 75,061,112 acres (30,376,815.86 hectares), and the average production of the grain of maize for the same period was 1,844,951,786 bushels (650,157,446.52 hectoliters).

Maize is not only valuable for the grain which it produces, but the fodder, stalk, or stover, has a high commercial value as feeding material and for other purposes. It is true that the greater part of the fodder at the present time is left upon the fields to be burned before the planting of the next crop. In the older parts of the country, however, the fodder is now carefully preserved and is found to be equally as valuable as the grain when prepared and fed in the proper manner. The purpose of this paper is to present, in a condensed form, some of the results of the extensive chemical examinations which have been made in the laboratory of the Department of Agriculture at Washington on the composition of Indian corn in its entirety, and especially in relation to some of its principal products.

In all parts of the country maize forms a considerable percentage of the food of our people, and especially is this true in the Southern States, where Indian corn bread, among parts of the population, is the chief bread food used. In various other forms, as hasty pudding (mush) and other methods of preparation, it enters largely into our dietaries. Although important as a human food, the principal use of maize is as feed for live stock; and it is also used for the manufacture of starch, of glucose, and of whisky and alcohol. On account of its great importance, a somewhat careful study of its composition is justifiable.

COMPOSITION OF THE GRAINS.

For the typical samples of grain grown in the United States and collected at the World's Columbian Exposition at Chicago the following represents the constitution:

Weight of 100 kernels...grams..	38.979	Crude fiber..............per cent..	1.71
Moisture................per cent..	10.93	Ash.........................do....	1.36
Proteids...................do....	9.88	Carbohydrates other than crude fiber.................per cent..	71.95
Fat and oil................do....	4.17		

The following table represents the maxima, minima, and means of the constituents of maize collected in all parts of the world:

Table of maxima, minima, and means of constituents of maize.

Kind of sample.	Weight of 100 kernels.	Moisture.	Proteids.	Ether extract.	Crude fiber.	Ash.	Carbo-hydrates.
Domestic corn:	*Grams.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Maxima	*a* 48.312	*b* 12.32	*a* 11.55	*a* 5.06	*b* 2	*b* 1.55	*b* 75.07
Minima	*c* 10.608	*b* 9.58	*b* 8.58	*b* 2.94	*d* 1	*a* 1.19	*a* 68.97
Means	38.979	10.93	9.88	4.17	1.71	1.36	71.95
Foreign corn:							
Maxima	*e* 46.487	*f* 12.60	*g* 11.55	*e* 4.85	*f* 2.20	*g* 1.80	*e* 71.85
Minima	*f* 18.428	*e* 10.43	*e* 9.80	*f* 4.02	*e* 1.57	*f* 1.26	*g* 68.02
Means	28.553	11.71	10.72	4.51	1.87	1.54	69.65
Means of samples from the United States exhibited at the Columbian Exposition (18 analyses)	38.979	10.93	9.88	4.17	1.71	1.36	71.95
Means of foreign samples exhibited at the Columbian Exposition (2 analyses)	28.553	11.71	10.72	4.51	1.87	1.54	69.65
Means of former analyses of the Department of Agriculture:							
United States	*h* 36.747	*i* 10.04	*j* 10.39	*i* 5.20	*i* 2.09	*j* 1.55	*i* 70.69
Northern States	37.320	9.98	10.64	5.11	1.41	1.54	71.32
Southern States	40.659	8.96	10.95	4.94	1.72	1.37	72.06
Middle West	32.457	12.33	10.89	4.97	2.22	1.43	68.16
Far West	37.528	9.50	10.43	5.30	2.47	1.55	70.75
Pacific Slope	27.900	9.78	8.14	6.40	2.07	1.48	72.13
Jenkins and Winton (208 analyses)	....	10.90	10.50	5.40	2.10	1.50	69.60
König (mean composition of samples from various localities):							
Miscellaneous origin (137)	....	13.35	9.45	4.29	2.29	1.29	69.33
Italian samples (24)	....	13.13	10.26	3.84	2.88	1.95	67.72
American samples (80)	....	10.02	10.17	4.78	1.67	1.40	68.63
Dent corn (149)	....	10.14	9.36	4.96	2.21	1.47	68.65
Sugar corn (27)	....	8.70	11.43	7.79	2.86	1.81	62.76
Southeastern Europe (19)	....	14.53	9.42	4.13	2.34	1.39	69.37
Southwestern Europe (8)	....	12.47	8.84	5.80	4.16	2.06	65.79

a Kentucky. *b* Indiana. *c* Wisconsin. *d* New Hampshire. *e* New South Wales. *f* Bulgaria. *g* Argentine Republic. *h* 1,211 analyses. *i* 114 analyses. *j* 202 analyses.

Comparing the means of the analyses of American samples with those of foreign origin, we are struck with the excess of moisture in the foreign samples. In those from southwestern Europe are found 4 per cent more moisture than in samples of domestic origin. Among the samples grown in the United States, those in the Middle West, viz, Iowa, Missouri, Nebraska, etc., contain the largest amount of moisture, while those grown in the arid region have the smallest amount. Of the domestic samples exhibited at the World's Fair it was found that the mean content of water was 10.93 per cent, nearly 1 per cent higher than the mean of former analyses of the Department. The weight of 100 kernels was a little more than that before found, and this is not a surprising fact, inasmuch as it would be natural for exhibitors to send not only the largest ears but also the largest grains to the Exposition. The percentage of proteids in the domestic World's Fair samples was surprisingly low, being about 0.75 per cent less than was found in the samples examined a few years ago. On the other hand, the percentage of carbohydrates was about one point higher than that obtained in the former work. In the above table will be found a convenient comparison of the means of maize analyses from all parts of the world.

The typical American maize has approximately the following composition:

Weight of 100 kernels.....grams..	38.00	Crude fiber.............per cent..	1.75
Moisture..............per cent..	10.75	Ash.......................do....	1.50
Proteids....................do....	10.00	Carbohydrates other than crude fiber..................per cent..	71.75
Oil.........................do....	4.25		

PROTEIDS OF THE KERNELS.

The maize proteids have been studied by Chittenden and Osborne, who divide them as follows:

Globulins: Unnamed, myosin, vitellin.

Albumins: (1) Existing in small quantities, (2) existing in small quantities.

Zeins: (1) Soluble in alcohol, (2) insoluble in alcohol.

Of these bodies the albumins have not been obtained sufficiently pure to give the final data of composition. The other proteids have the following composition:

Composition of maize proteids.

Constituent elements.	Myosin.	Vitellin.	Unnamed globulin.	Soluble zeins.	Insoluble zeins.
	Per cent.	*Per cent.*	*Per cent*	*Per cent.*	*Per cent.*
Carbon	52.66	51.71	52.38	55.28	55.15
Hydrogen	7.02	6.85	6.82	7.27	7.24
Nitrogen	16.76	18.12	15.25	16.09	16.22
Sulphur	1.30	.86	1.26	.59	.62
Oxygen	22.26	22.46	24.29	20.77	20.77

The relative quantities of the different proteids have been lately definitely determined, but the two zeins comprise by far the largest part. As a result of Osborne's latest determination, it may be stated that the mean percentage of nitrogen in maize proteids is 16.057, equivalent to the factor 6.23. This is so near the old factor 6.25 as to make unnecessary any correction in the percentages of total proteids given above.

VARIATIONS IN COMPOSITION.

Certain special varieties of early maturing maize, or sweet maize intended for table use when in the partially ripe state, are characterized by the large quantity of sugar which they contain, especially when the starch is still soft. In the earlier investigations of the Department it was noticed that the percentage of crude fiber was somewhat larger in varieties grown in the West and South than in those from the North and East, and, further, that in samples grown on the Pacific coast there was a slight deficiency of proteids. Further investigations, however, would be necessary to determine whether or not this apparent increase in fiber be due to the accidental constitution of the sample or to the real influence of the soil and climate. It is reasonable to expect that in some slowly maturing varieties, such as would grow in the Southwest and South, the percentage of fiber in the grain would be greater than in the more rapidly maturing varieties growing in the East and North.

In the case of sugar or sweet corn Richardson found the mean composition of 19 samples to be the following:

	Per cent.		Per cent.
Moisture	8.44	Ash	1.97
Ether extract	8.57	Proteids	11.48
Crude fiber	2.82	Carbohydrates, other than fiber	66.72

This analysis shows that the sweet corn has a considerably larger percentage of oil than the field varieties, and there is a larger percentage of sugar in the carbohydrates.

A study of all the analyses which have been made in this division reveals the fact that maize is one of the most invariable of the cereals, maintaining under the most different climatic conditions a most remarkable uniformity of composition, and varying chiefly in the size, color, and general physical characteristics of its kernels rather than in their composition. For detailed information in regard to the variations and general characteristics of different varieties of maize grown in different localities, Bulletins 1 and 45 of this division may be consulted.

MILLING OF MAIZE—QUALITIES OF MEAL.

The flour made from Indian corn is known in this country usually as corn meal. There are many different methods of preparing it. The simplest, and one of the most prevalent until within a few years, consisted in grinding the kernels between stones and using the whole meal, coarsely sifted, thus produced. Very large quantities of corn meal prepared in this way are still used throughout all parts of the country, especially in the Southern States. It is evident that this meal would have nearly the same composition as the kernels from which it is prepared. A finer grade of Indian-corn flour is produced by grinding as above indicated and bolting to remove a large portion of the bran.

The flour thus obtained differs only from that first described in having a smaller content of fiber and mineral matters, due to the removal of all or a portion of the bran by bolting. On account of the high percentage of oil in the germ of Indian corn, and by reason of its hygroscopic character, the flour thus prepared is apt to become rancid or moldy. To prevent this change and also to secure a more palatable grade of flour, the modern improved processes of grinding and preparing Indian corn have been introduced. Following is the description of the process of preparing the flour from Indian corn as practiced by one of the largest mills in this country.

The Indian corn is passed through a machine called a degerminator, which breaks the grain and loosens the germ, but does not separate it. The separation is made by means of bolting cloths and currents of air. After the germ and hull are removed the corn is ground between iron rolls properly corrugated. The meal is again submitted to the process of bolting and purification by currents of air and the refined product is the granular meal. The offal consists of the hull, germ, floury particles, and some of the flinty portion of the corn which is lost by the process not being sufficiently perfect to remove it and include it in the granular meal. The offal thus removed constitutes from 30 to 35 per cent of the weight of the corn, depending upon the conditions of the grain. Artificial heat is used in this method of manufacture. It insures better results, and the meal will keep longer. This granular meal is not in favor in the Southern States. They prefer a soft meal, made in the old way.

Aside from the method of manufacture there are two distinct kinds of corn meal in the United States distinguished by cólor, viz, the white and the yellow. White corn makes a flour which in color is quite like the flour made from wheat. On the other hand, yellow corn makes a flour of a rich yellow, which is highly prized in some quarters on account of imparting its color to the bread made therefrom. When prepared in the same way there is probably but little difference in the nutritive value and palatableness of these two varieties.

In Europe, as has been mentioned before, Indian corn is not considered fit for the manufacture of bread for the use of man. This prejudice seems quite baseless when we consider the very extensive use of this material for bread making in this country and the high nutritive properties which it possesses. With a diet of Indian-corn bread and pork the workmen of this country are capable of enduring the greatest fatigue and performing the greatest amount of physical labor. The high nutritive value of Indian-corn bread was well illustrated in a marked degree in the military service during the civil war between the States. Both experience and chemical analysis show that there is little, if any, difference between the nutritive properties of bread made from wheat and that from the whole Indian corn deprived only of the coarsest parts of the bran.

Microscopic Character of Meal.

Maize flour is of a yellowish or white color and rough to the touch. The starch is in grains of a tolerably uniform volume. The minimum diameter appears to be about 6 micromillimeters, while the largest may reach as much as 17 micromillimeters. The greater part have diameters of from 13 to 15 micromillimeters. The starch granules are polyhedric in shape when they come from the external zone. They are of rounded shape, on the contrary, in the floury zone. The upper face appears to be somewhat spherical. The hilum is punctiform and sometimes stellated. The concentric layers are well marked and the fracture is most frequently from the exterior toward the interior. Heated in water at 62.5° the starch granules swell up and become deformed, except a few—especially the smaller ones—which resist the action of water at that temperature.

In maize, as in oats, the starch granules are polyhedric, but the resemblance extends no further, the maize granules being larger and never becoming agglomerated and forming compound particles. Their action also on polarized light is characteristic. The starch granules of maize depolarize the light and present a black cross very marked and very distinct when the field is obscure. This cross persists for a long time when the field is illuminated little by little, and it is distinguished much more easily and with an illumination much more pronounced than that which suffices to extinguish this phenomenon in other common starches. Nevertheless, this cross is not long visible when the field is fully illuminated. With the selenite plates, by preference working on a neutral field, the grains of starch of the maize are seen to be colored red, with a green cross, or reciprocally. This coloration is very brilliant.

If the starch granules be treated with caustic potash, there is found in the midst of the débris a number of amorphous cellules of the amylaceous tissue irregularly arranged, in which may sometimes be distinguished a final residue of the protoplasmic matter which surrounds the starch granules.

The glutinous cells of maize resemble those of rye. They are disposed in a single row, quadrangular, a little rounded on the angles and much thicker on the exterior side than on the others. The starch cells of maize are easily distinguished from those of the rye by their form and by their action on polarized light.

Composition of Fine Meal.

The composition of the ordinary Indian-corn meal produced by grinding the whole grain and removing only the coarser bran is, as has already been said, practically that of the whole grain itself. Analyses of the refined Indian-corn flours show that they differ chiefly from the whole grain in having a smaller content of fat, fiber, and proteids and a correspondingly higher content of carbohydrates. The low content of proteids is due to the fact that the germ and the finer envelopes are rich in proteid matter and are removed in the process of milling. The low content of oil is due, of course, to the fact that the germ has been extracted. The content of fiber, while low compared with the whole grain, is high compared with a high-grade wheat flour.

A description of the samples analyzed and their composition follows:

Composition and description of Indian-corn flours.

[Purchased for United States Army by Maj. H. G. Sharpe, St. Louis, Mo.]

Serial No.	Moisture.	Proteids, N×6.25.	Ether extract.	Ash.	Crude fiber.	Carbohydrates.	Calculated calories of combustion.	Ascertained calories.	Description.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*			
15958	12.66	6.94	1.21	0.52	0.63	78.67	3,827.3	3,840	"Best."
15959	12.05	8.50	1.76	0.83	1.17	76.86	3,895.1	3,898	"Topeka."
15960	13.01	5.94	1.02	0.47	0.80	79.56	3,787.9	3,912	"Decatur."
Average	12.57	7.13	1.33	0.61	0.87	78.36	3,836.8	3,883.3	

RELATIVE NUTRITIVE PROPERTIES OF WHEAT AND MAIZE.

There is a widespread opinion that the products of Indian corn are less digestible and less nutritious than those from wheat. This opinion, it appears, has no justification, either from the chemical composition of the two classes of bodies or from recorded digestive and nutritive experiments. A study of the analytical data of the whole grain shows that, in so far as actual nutrients are concerned, the maize is fully as nutritious as wheat. The ash content of maize and its products is probably not quite so high as that of wheat, and there is, therefore, a silght deficiency of the mineral foods employed in the nourishment of the body. Inasmuch, however, as the cereals contain an excess of mineral matters above the needs of the body, this slight deficiency is of no consequence. In respect of its content of fat, Indian corn and its products easily take precedence of all the other cereals, with the exception of hulled oats. In round numbers, it contains twice as much fat or oil as wheat, three times as much as rye, twice as much as barley, and two-thirds as much as hulled oats. In regard to digestible carbohydrates, that is, starch, sugar, dextrin, and digestible fiber, it possesses a higher content than hulled oats, almost the same as wheat, and slightly less than rye or barley. Comparing the content of nitrogenous matters with that of other cereals, it is found that the first place must be awarded to oats, especially if they have been hulled. Indian corn, however, has nearly the same quantity of proteid matter as the other leading cereals, oats excepted.

EXPERIMENTS IN FEEDING MAIZE AND WHEAT.

In regard to the digestibility of Indian corn and wheat, it must be admitted that a larger amount of experience has accumulated with

Indian corn than with wheat. The low price of wheat in the last few years has, however, directed a considerable amount of attention to the use of that cereal instead of Indian corn in the feeding of animals. The data which have been obtained in this country, secured from comparative feeding experiments, are not always uniform. In some instances it has been found that, pound for pound, wheat gave a slightly better result in feeding animals than Indian corn, while in others the preference is given by the experimenter to Indian corn. In experiments made at the South Dakota station (Bulletin 38) pigs were fed with different cereals, among others with ground Indian corn and ground wheat. The comparative results obtained are as follows:

Summarized results of experiments with pigs.

Kind of cereal,	Weight of lot at beginning.	Average daily gain per pig.	Total grain consumed by lot.	Grain eaten per pound of gain.	Average gain.		Price realized per bushel of grain.	Shrinkage in dressing.
					Per 100 pounds of grain.	Per bushel of grain.		
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Cents.*	*Per cent.*
Lot 3, ground corn...	191	1.40	1,159	4.58	21.83	12.22	60.00	14.0
Lot 4, ground wheat.	205	1.32	1,144	4.81	20.79	12.49	58.39	16.5

In the data obtained in this experiment the Indian corn, pound for pound, was found to give the better results in every respect.

COMPARATIVE ASSIMILATION OF WHEAT AND MAIZE.

The comparative digestibility of wheat and Indian corn has been studied in the Minnesota station (Bulletin No. 36). The data obtained, with the exception of the digestibility of the ash, are as follows:

Digestion coefficients of wheat and other grains.

Constituents.	Cracked wheat.	Cracked corn.
Dry matter	82	90
Proteids	80	90
Ether extract	70	78
Crude fiber	60	48
Nitrogen-free extract	83	94

From these data it is seen that the wheat was slightly less digestible than the Indian corn. From a study of the data at the Minnesota station it may be stated that when corn and wheat are both selling at 50 cents per bushel, the 50 cents will purchase the same amount of digestible dry matter in both instances. In the case of wheat, however, the purchaser will obtain 2½ pounds more of digestible protein, and in the case of Indian corn 2½ pounds more of digestible carbohydrates. The quantity of heat generated by the food in each case is almost exactly the same. The result of these experiments, therefore, is to establish with certainty that the digestible coefficient of Indian corn is not inferior, but, if there be any difference, superior to that of wheat. Data of the kind mentioned above, based on carefully controlled feeding experiments, checked at every point by chemical analyses, are evidently of far greater value than those which are reported by the Kansas State board of agriculture for the quarter ending September 30, 1894, where circulars were sent to prominent growers of stock and reports of their observations on the comparative value of wheat and Indian corn were tabulated. As a result of the preponderance of testimony given by these circulars, it was concluded that wheat was superior to Indian corn, pound for pound, as a food for animals. These reports, however, were based merely upon observation, and were not controlled in any way by weighing or chemical analysis. The conclusion, therefore, is not valuable as evidence when contrasted with that of the feeding experiments at the Minnesota station above mentioned.

COMPARATIVE PRODUCTION OF PORK FROM WHEAT AND MAIZE.

In experiments made at the Ohio State University, collected in The Experiment Station Record, vol. 6, page 466, it was found that a bushel of wheat produced 13.7 pounds of pork, while a bushel of corn made 12.3 pounds. When the difference of weight between a bushel of wheat and a bushel of corn is considered, the actual gain, it is seen, is almost the same for both. Calculated on the market price of wheat and Indian corn, it cost $4.01 to produce 100 pounds' increase with wheat, and $2.85 to produce the same increase with Indian corn.

Carefully weighing all the reliable evidence at hand, the conclusion is inevitable that from the point of view of chemical composition, of digestibility, and of nutritive value Indian corn with its products, pound for pound, is fully equivalent to wheat. In the case of food for man, which this bulletin particularly has to consider, there must be taken into account the additional element of palatability. It is evident that in the case of two given foods of almost the same chemical composition, and of equal digestibility, the more palatable will be the more valuable food for man. In regard to palatability, as has already been mentioned, there is the widest difference of opinion. European writers on dietetics uniformly condemn Indian corn and its products as being unfit for food for man. On the other hand, the ample experience of our own country shows that it is an extremely palatable food, as well as nutritious, and a large part of our population prefer it, from a gustatory point of view, to wheat. It must be admitted, therefore, that in respect of palatability usage is an important factor, and it is evident that other nations, when accustomed to the use of Indian corn and its products as food for man, would find it equally as palatable as it is found to be in the United States.

BREAD FROM MAIZE MEAL.

Bread made from Indian corn is a popular diet in the southern part of the United States, although it is not used very extensively in the northern part nor in the western portions where Indian corn is most extensively grown. The best and most palatable breads made from Indian corn are those made from the coarsely ground meal which is simply sifted fine enough to remove the coarser parts of the bran. The meal is mixed with a little salt and water and baked into hard, unleavened cakes. In some of the more primitive methods of making this bread the dough is spread on an oak board and baked by exposure to the radiating heat of a wood fire. This kind of bread is known as johnnycake, probably a corruption of journey cake. In some parts of the North the term johnny cake is applied to a thick corn bread made of a mixture of corn meal, milk, eggs, salt, and baking powder. Indian-corn bread is sometimes leavened by a fermentation with yeast, baked in iron vessels, and is in this form known as pone. It is quite frequently leavened with baking powders, and the corn meal is sometimes mixed with wheat flour, either for domestic use or with fraudulent intent.

Ratio of Nitrogenous to Other Digestible Constituents.

From a study of the composition of the typical maize, as deduced by the examination of hundreds of samples by the Division of Chemistry, it is seen that the ratio of the proteids to other digestible matters (namely, carbohydrates + fat × 2.25) is about as 10 to 80, or 1 to 8. This is a somewhat wide ratio as determined by the ordinary rules of nutrition. When it is considered, however, that if we exclude the fat, which is the most digestible of the constituents of the maize, the ratio as given above is 1 to 7, it is seen that there is practically no objection, from a nutritive point of view, to the consumption of maize as food for man or beast.

Experience is also a factor of some value in this connection. Attention has already been called to the fact that the manual labor of the southern part of the United States is done almost exclusively on a diet of Indian-corn bread and fat pork. These produce a ratio between the protein and other nutrients even larger than the one given above. And yet with this food the most severe manual labor is performed in a climate which is excessively trying to the laborer on account of its intense heat. It should also be remembered, as shown in the data given on the relative digestibility of the protein in the Indian corn and in wheat, that in many instances it has been found that protein in Indian corn has the larger percentage of digestible constituents. Further, it should be remembered that in the data above stated the ratio is given upon the whole of the constituents as determined by chemical analysis, and not upon those only which are digestible, which is the usual method for calculating the proteo-carbohydrate ratio.

Judged, therefore, by chemical composition, digestibility, and experience, it is seen that the Indian corn contains a sufficient amount of protein to make a well-balanced ration for those engaged in manual labor. It is true that a ration made of Indian corn is more fattening than one based upon oats, rye, or wheat, but in case of manual labor this tendency to the accumulation of fat is corrected, and no trouble arises in that direction.

It appears that the fat materials of Indian corn are easily digested, well assimilated, and practically consumed without waste in maintaining a high degree of muscular exertion. Even should we grant a slight deficiency in the ration of corn bread due to the low content of proteid matter, it is certain that this defect would be remedied by the development of a variety of maize richer in proteid matter. This could be easily accomplished by pursuing the system of development which was used by this division in increasing the content of sugar in sorghum. Properly conducted experimental work covering a period of ten years would result in the development of a variety of Indian corn with a higher and reasonably constant content of proteid matter. This development could be secured by taking advantage of natural and cultural conditions, combined with chemical studies of the grains, selecting for seeds those which show marked increments in the content of the proteid matter.

MAIZE OIL.

In the manufacture of starch and glucose and in some varieties of maize meal the germ of the grain, which contains the larger percentage of oil, is extracted. From this germ a valuable oil is expressed, while the residue forms a food material as valuable in every respect as that derived by the expression of the oil from ordinary oily seeds. Maize oil is easily purified and forms a light, amber-colored, perfectly transparent liquid, without rancidity and of a pleasant taste. It has been used to some extent as a salad oil, and doubtless will in the future be very greatly employed for that purpose. It can also be used for lubricating delicate machinery, has fine burning properties, and can be used as a lamp oil. The coarser and less pure oil makes a valuable soap.

In general, it may be said that maize oil has a commercial value, gallon for gallon, quite equal to the oil derived from cotton seeds.

COMPOSITION AND PROPERTIES OF THE STALKS.

Until within a few years, the stalks of maize have been considered of no value for feeding or other purposes. The blades of the stalks have been used from earliest times as cattle food, and a portion of the stalks also has been eaten by the cattle, but their true value as feeding materials has not been appreciated.

In the investigations which are given here, it was first deemed advisable to determine the relative proportion of the distinct materials in the stalk, viz, the nodes or joints, the pith, and the outer hull. The material was prepared in the following manner.

DIVISION ACCORDING TO PHYSICAL PECULIARITIES.

The stalks were received in bundles consisting of pieces about 2 feet in length and free of blades and closely adhering envelopes. Since the constituents of the stalks vary greatly in their nature, it was deemed advisable to separate them first by mechanical means into groups of approximately like nature. To accomplish this purpose, the stalks were cut in such a manner as to separate the nodes as completely as possible from the internodes. It is evident that this separation is not complete, because of the difficulty of cutting the stalk in every instance at a point which is in the line of true demarcation between the two parts. After the nodes had been removed the internodes were separated, by means of a knife, into pith and external fiber. By reason of the sharp distinction which can be made between these two parts of the internodes, this separation was accomplished in almost a quantitive way. The respective per cents of the three parts separated are given in the following table:

	Per cent.
Nodes	26.08
Pith of internodes	20.25
Shells of internodes	53.67

In round numbers it may be said that 100 pounds of Indian-corn stalks contain 26 pounds of nodes, 20 of pith cellulose, and 54 of internodular shells.

GENERAL COMPOSITION OF PORTIONS.

Each of the various portions described above was ground to a fine powder and subjected to a general analysis. The results obtained are shown in the following table:

Analysis of stalks of maize.

Constituents.	Nodes.	Pith of internodes.	Shells of internodes.
	Per cent.	*Per cent*	*Per cent.*
Moisture	6.52	7.01	4.95
Crude fiber	37.94	41.44	46.01
Ash	2.11	2.80	1.94
Fat	.94	1.17	.78
Proteids	4.38	3.50	2.44
Carbohydrates other than crude fiber	48.21	44.08	43.88

DIGESTIBILITY.

The samples were subjected to artificial digestion in order to determine the digestibility of the proteids therein. It was found that the following percentages of the protein were digestible:

	Per cent.
In the nodes	60.05
In the pith	67.70
In the shells	71.72

From the above data it is seen that, in so far as the protein is concerned, the nodes are the least and the shells the most digestible, the pith occupying an intermediate position.

SOLUBILITY WITH SEVERAL REAGENTS.

It is important in studying the properties of the stalks to determine their solubility in different reagents. Since dilute acids and alkalies are the common hydrolyzing agents, the first determination was that of the percentage of material dissolved by these bodies. The process was conducted as follows:

Ten grams of the material were digested half an hour at three atmospheres with 200 cc. of 1.25 per cent sulphuric acid. After cooling the mass was thrown on a filter and washed with water until the acid reaction disappeared. The residue was dried and weighed. The percentages given below are on the material free of water:

Solubility of different portions in acid.

Division of the stalk.	Percentage undissolved.	Percentage dissolved.
Nodes	55.72	44.28
Pith from internodes	45.73	54.27
Shells from internodes	62.31	37.69

It will be seen by the above figures that this reagent reacts most vigorously on the pith and least vigorously on the shells, the nodes occupying an intermediate position.

DIGESTION WITH ALKALI.

The digestion with alkali was carried on at ordinary pressures and in the autoclave at a pressure of three atmospheres. The time of digestion in each case was half an hour. In each instance 10 grams of the different materials were digested with 200 cc of a 1 per cent caustic soda solution. The residue on cooling was washed thoroughly with water, then with dilute acetic acid, and again with water, dried, and weighed. The solubility of the different materials in this reagent under the two conditions named was as follows:

Solubility of different portions in alkali.

Division of stalk.	Digestion without pressure.		Digestion with pressure.	
	Dissolved.	Undissolved.	Dissolved.	Undissolved.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Nodes	44.28	55.72	51.45	48.55
Pith from internodes	45.74	54.26	53.11	46.89
Shells from internodes	43.12	56.88	48.03	51.97

The action of caustic alkali at atmospheric pressure and at a boiling temperature is less efficient than heating under pressure. The latter process dissolves about half of the material and the former about 44 per cent.

The pentose sugars, that is, those containing five atoms of carbon to each molecule, are the chief products of hydrolysis, bo h with acid and an alkali. They are recognized by the fact that when distilled with hydrochloric acid they give rise to furfurol, which can be collected and determined, and thus the actual quantities of these sugars, as well as the bodies in the cornstalk from which they are derived, can be approximately ascertained.

Furfurol Content of the Samples.

It is of interest to know what quantities of pentose-yielding bodies (xylan) are contained in the various samples. The furfurol determinations gave the following results:

Results for furfurol and xylan.

Division of stalk.	Furfurol.	Xylan.
	Per cent.	*Per cent.*
Nodes	13.75	22.53
Pith from internodes	12.98	21.29
Shells from internodes	12.56	20.60

Sugars.

The sugars which are formed by digestion with acid and alkali, followed by an acid, have both the property of rotating polarized light and of reducing an alkaline copper solution. In the absence of a better method, it is customary to report the whole of the reducing sugar as dextrose. This, at best, is only an approximation; but it is the only method available until more definite knowledge is obtained respecting the properties of the mixture of sugars in the products obtained.

In the data which follow, the sugars removed by the alkali were not directly determined. The total quantity of reducing sugars in the sample, hydrolyzed by dilute sulphuric acid, was determined; in another portion, the matters removable by digestion with dilute alkali were ascertained; and in the residue the remaining sugar-producing bodies removed by digestion with dilute acid. Xylose and arabinose, which are the chief sugars produced by the above-described operations, have reducing properties that are not greatly different from those of dextrose, and therefore when expressed in terms of dextrose a near approximation to the true amount of them is secured. The following data give the copper-reducing properties of the several products:

Copper-reducing properties.

Division of stalk.	Per cent soluble in H_2SO_4.	Per cent of reducing sugars as dextrose.
Nodes	44.28	28.86
Pith from internodes	54.27	23.10
Shells from internodes	37.69	25.48

These data show that more than half of the material dissolved from the nodes and internodal fiber consists of reducing sugars, while in the case of the pith, less than half of the soluble matter belongs to that category.

After heating the various samples with an alkali, the residues, after washing with water, and acetic acid and water, were digested with dilute sulphuric acid and the reducing sugars in the products ascertained. The following results were obtained:

Results for reducing sugars.

	Nodes.	Pith from internodes.	Internodal shells.
	Per cent.	*Per cent.*	*Per cent.*
Soluble in dilute alkali	51.45	53.11	48.21
Reducing sugars in residue after hydrolysis with H_2SO_4	14.97	10.07	11.15
Reducing sugars in original sample	28.86	23.10	25.48
Reducing sugars dissolved by alkali	52.22	56.41	56.24

The difference in the nature of the bodies dissolved by acid and alkali are brought out in a striking manner by the above data. The actual quantity of material dissolved by alkali is considerably greater than is removed by an acid in the nodes and shells and only slightly less in the pith. The bodies removed by alkali, however, contain only a little more than half the quantity of reducing sugar found in the matter removed by acids. For instance, it is known that xylan is quite soluble in an alkali. It is also soluble in an acid, being converted by the latter into xylose. The alkali, however, dissolves a large quantity of material which sulphuric acid does not convert into reducing sugars. In the nodes, sulphuric acid dissolves 44.28 per cent of matter which has a reducing power equivalent to 28.86 per cent of dextrose. In the same material, caustic soda dissolves 51.45 per cent of matters which have a reducing power equal to 13.89 per cent of dextrose. It is not convenient to directly convert the alkali extract into reducing sugars by hydrolysis with sulphuric acid, because of the large quantity of sodium sulphate which would be present. The approximate amount is therefore obtained by the indirect method given above.

Successive Digestion with Acid and Alkali.

The total quantity of matter dissolved by successive treatments of the samples at 3½ atmospheres with 1.25 per cent sulphuric acid and 1 per cent caustic soda solution is shown in the following tabular statement:

Solubility in acid and alkali.

Division of stalk.	Dissolved.	Undissolved.
	Per cent.	*Per cent.*
Nodes	66.19	33.81
Pith from internodes	64.36	35.64
Shells from internodes	60.57	39.43

The soluble matter is composed of the following parts:

Composition of soluble portion.

Division of stalk.	Reducing sugars (as dextrose).	Lignose (soluble), ash, protein, fat, etc.
	Per cent.	*Per cent.*
Nodes	28.86	37.33
Pith from internodes	23.10	41.26
Shells from internodes	25.48	35.09

The composition of the samples, as determined by successive digestion with acid and alkali, and determination of the other ingredients on a water-free basis, is shown by the following table:

Division of stalk.	Ash.	Fat.	Proteids.	Insoluble carbohydrates.	Soluble carbohydrates.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Nodes	2.26	1.01	4.69	33.81	58.23
Pith from internodes	3.01	1.26	3.76	35.64	56.33
Shells from internodes	2.04	0.82	2.57	39.43	44.86

These data show that if the matters are treated with both alkali and acid in preparing them for paper pulp they will yield of that material only about one-third of their weight. On the other hand, when treated by an alkali or acid alone they will yield about one-half of their weight as paper pulp.

KINDS AND QUANTITIES OF SUGARS FORMED.

The sugars formed by hydrolysis with sulphuric acid are principally (pentose) xylose and dextrose. The relative quantities of these sugars are difficult to determine with exactness. A satisfactory approximation may, however, be secured. The quantity of dextrose formed on hydrolysis may be determined with quite a degree of accuracy by fermentation. Theoretically, dextrose should yield half its weight of alcohol. Practically, in favorable condition for fermentation about 48 per cent of alcohol may be obtained. The conditions of fermentation in the present instances were unfavorable by reason of the great dilution of the saccharine solution. We may assume, therefore, that the dextrose present yielded only 40 per cent of its weight as alcohol. The quantities of dextrose obtained by this method of calculation are given in the following table:

Results for alcohol and dextrose.

Division of stalk.	Alcohol.	Dextrose.
	Per cent	*Per cent.*
Nodes	1.36	3.40
Pith from internodes	2.16	5.40
Shells from internods	1.92	4.80

Sugar in the Nodes.

In respect of pentose sugar it may be calculated on the assumption that all the pentose sugar present is xylose, or that it is a mixture of xylose with other pentose sugars. We prefer the former assumption. The quantity of pentose is therefore calculated by the formula (per cent furfurol $\times$ 1.64) $\div$ 0.88.[1]

The total quantity of furfurol in the nodes was 13.75. Of this quantity 92.73 per cent was extracted by the sulphuric acid, viz, 12.75. Then 12.75 multiplied by 1.64 equals 20.91, and 20.91 divided by 0.88 equals 23.76.

Adding together the dextrose and xylose the total percentage is found to be 27.16. The total per cent of sugar dissolved was found to be 28.86.

In this instance the quantity of sugars separately determined lacks 1.70 per cent of reaching the quantity determined as a whole by alkaline copper solution.

Sugar in the Pith.

The total sugars produced from the pith by hydrolysis with sulphuric acid were 23.10 per cent.

The total quantity of furfurol in the pith was 12.98 per cent, of which 94.22 per cent (equal to 12.23 of the weight of the substance) was removed by the sulphuric acid. This is equivalent to 22.77 per cent of xylose. The quantity of dextrose in the pith, ascertained by fermentation, was 5.40 per cent, which, added to the xylose calculated, gives 28.17 per cent, a quantity 5.07 per cent greater than was given by direct titration as dextrose.

SEPARATION OF CELLULOSES BY THE CHLORINATION PROCESS.

It will be observed from the foregoing data that when the materials under examination are treated successively with dilute acid and alkali under pressure, about two-thirds of the total quantity is dissolved. If, therefore, cellulose fiber were prepared by these methods, only about 33 pounds on each 100 pounds of the dry material would be secured. It is evident, therefore, that a method which would give a larger yield of cellulose from a commercial aspect would be more desirable. For this reason determination of the available cellulose is best secured by what is known as the chlorination method. This process is carried on in the following way.

About 5 grams of the finely ground material, free of water, are boiled for thirty minutes with a 1 per cent sodium hydrate solution in a vessel furnished with a reflux condenser. The undissolved portion is washed with water on a cloth filter and pressed to remove the excess of water, disintegrated, and placed in a covered beaker into which a slow stream of well-washed chlorin gas is conducted. The delivery tube conveying

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[1] Principles and Practice of Agricultural Analysis, vol. iii, p. 587.

the chlorin gas must reach to the bottom of the beaker. The moist fiber, under the action of the chlorin, changes in color to a golden yellow as the process of absorption of chlorin gas goes on. The chlorination should last for at least an hour. The chlorinated fiber is removed, washed two or three times with water to remove excess of hydrochloric acid, and placed in a 2 per cent solution of sodium or potassium sulphite. The mixture is gradually brought to the boiling point, a small quantity of 0.2 per cent caustic soda solution added, and the boiling continued for five minutes. This separation, as a rule, is sufficient to dissolve all of the lignone bodies present, and leaves a mixture of cellulose which consists of two kinds, known as α and β. The cellulose is obtained in a pure state by washing with hot water on a cloth filter. It is also bleached by immersion in a 0.1 per cent solution of sodium hypochlorite and afterwards treated with a 0.1 per cent solution of potassium permanganate. It is thoroughly washed free of these oxidizing solutions and finally bleached with sulphurous acid on the filter, well washed with water, pressed, dried, and weighed.

The quantities of cellulose obtained on the dry substance by this method were as follows:

Content of cellulose.

Division of stalk.	Total cellulose.	α cellulose.
	Per cent.	*Per cent.*
Nodes	50.96	35.12
Pith of internodes	51.57	33.07
Shells of internodes	53.44	40.35

SUMMARY OF ANALYSES.

Summing up the results of the investigations, in so far as they have been made, it is seen that the material examined consists of several different kinds of matter. It contains a small quantity of mineral matter, of ash, of proteid matter, and of matter soluble in ether, but is chiefly composed of carbohydrate material. This material is of various kinds. A part of it will yield by hydrolysis with an acid a small quantity of dextrose capable of fermentation. A larger part, on hydrolysis, is converted into a pentose sugar, presumably xylose, incapable of fermentation, but capable of reducing an alkaline copper solution. Another quantity, perhaps larger than that just mentioned, passes into solution under the influence of hydrolyzing agents, but does not seem to produce a sugar capable of reducing alkaline copper solution. The largest portion of carbohydrate matter consists of cellulose of two varieties, which may be designated as α and β. Both of these celluloses are insoluble in chlorin, but the β cellulose may be dissolved in dilute nitric acid. The bodies which are capable of yielding furfurol consist largely of xylan and allied pentosan substances. There is, however, as the data have shown, a considerable quantity of matter present capable of yielding furfurol on distillation with hydrochloric acid, and yet not possessing the properties of pentosan bodies. The character and quantity of this furfurol-yielding complex is not known, and requires further investigation for its separation and study. It is evident that the material could not be profitably employed as a source of ethylic alcohol, as the quantity yielded is not quite 2 per cent in weight of the whole mass. The possibility of obtaining methyl alcohol from this matter by distillation in closed retorts is a subject for further investigation.

MAIZE STOVER AS CATTLE FEED.

The relative proportions of the different parts of maize stover have been determined by the agricultural experiment station at Geneva, N. Y., with the following results:

Proportions of stover.

Division of stalk.	Weight.		Proportion.
	Grams.	*Pounds.*	*Per cent.*
Leaves and husks	25,021	55.0	65.2
Stalks minus pith	9,046	20.7	24.5
Pith	3,948	8.7	10.3

The chemical composition of the maize stover was found to be as follows:

Chemical composition of stover.

Division of stalk.	Moisture.	Ash.	Protein.	Fiber.	Carbohydrates other than fiber.	Fat.
Air-dry materials.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Whole stover	19.81	4.55	4.19	26.02	42.87	2.56
Stover without pith	12.21	4 58	4.60	28.55	47.35	2.71
Pith	13.27	3.92	3.02	29.15	45.77	4.87
Water-free materials.						
Whole stover	....	5.68	5.22	32.45	53.46	3.19
Stover without pith	....	5.22	5.24	32.52	53.93	3.09
Pith	....	4.52	3.48	33.61	52.77	5.62

Following are the figures obtained on the analysis of a sample of thoroughly air-dried maize stover, containing the whole plant with the exception of the root and ear:

	Per cent.
Moisture	9.80
Proteids	4.31
Ether extract	2.37
Crude fiber	28.29
Ash	4.50
Cabohydrates other than crude fiber	40.33

Maize stover in some form or other is one of the most abundant foods in the United States for all kinds of farm animals. In some localities it almost excludes other forms of coarse feed, such as timothy hay, clover, etc.

Preparation of Maize Fodder.

As has before been intimated, this fodder is often fed in the coarse state without any preparation whatever. In this condition a very large percentage of it is wasted, the cattle eating little except the blades, and perhaps some of the smaller and tenderer parts of the stalk. In the older parts of the country it is now becoming quite general to have the maize stover finely shredded before being fed. This not only increases the quantity which becomes available for feed, but also leaves the manure in a much better condition for spreading on the field.

SEPARATION OF THE PITH FROM THE FIBER.

The pith of the stalks, as will be seen further on, has valuable properties aside from its digestibility as a feed. In the separation of the pith, the outer portion of the stalk remains, and it has been found to be largely increased in value for cattle food by the separation of the pith.

Extensive experiments have been made in feeding cattle with this material, by the agricultural experiment station of Maryland and by the Geneva station of New York. The composition of the outer shell of the stalk when finely ground and subjected to analysis has been found at the Maryland station to be the following:

	Per cent.
Moisture	9.22
Proteids	6.38
Ether extract	2.84
Crude fiber	28.70
Ash	4.00
Carbohydrates other than crude fiber	48.86

Experiments were made in testing the comparative digestibility of the finely ground outer shell of the maize stalk in comparison with the coarsely shredded whole stover. The percentages of the materials digestible in these two products were found to be as follows:

Digestibility of ground and shredded stalks.

Constituents.	Ground shells.	Shredded corn fodder.
	Per cent.	*Per cent.*
Dry substance	57.6	46.8
Ash	1.9	1.3
Protein	3.8	1.6
Crude fiber	17.3	19.0
Carbohydrates other than crude fiber	32.2	23.2
Fat	2.4	1.7
Nutritive ratio	1:14.4	1:28.7

The general results of the feeding experiments made with this product show that as a feed the stover is greatly increased in value by the removal of the pith, the pith being less digestible and, on account of its high absorptive properties, consuming too much of the gastric excretions. There seems to be no doubt of the fact that the feeding value of the maize stover is very considerably increased both by the removal of the pith and by finely grinding the residual shells of the stalks.

PROPERTIES OF THE PITH.

The percentage of pith in the stalks and its chemical composition have been previously given.

The pith has a remarkably high absorptive capacity for liquids. Experiments show that it will absorb twenty-five times its weight of water.

Compressibility.—The pith is also capable of being compressed into a very much smaller bulk, but without losing its resiliency. The compressed blocks of pith still are to a certain degree flexible and are capable of absorbing immense quantities of water, but not so large as in the uncompressed state. This pith has been used with the greatest success in the construction of battle ships in the American Navy, the compressed blocks being placed between the two walls of armor and by reason of their resiliency they are found to completely close up the hole made by a projectile so as to prevent the entrance of water for a very considerable length of time. For this purpose it has been found to be immensely superior to other forms of pith which have been in use for this purpose heretofore, for instance the pith of the cocoanut.

Nitrating properties.—The pith, either directly or after extraction with a dilute alkali, is easily nitrated into all the various forms of material commonly made from cotton. It has many advantages over cotton for nitrating purposes, especially in the manufacture of explosives of all kinds, by reason of its more perfect keeping qualities. As is well known, the fibers of cotton are hollow and are filled with a mixture of acids during the process of nitration. It is found very difficult to remove these traces of acid by subsequent washing, and therefore the keeping qualities of explosives made from cotton are not of the best. The pith of Indian corn stalks is not open to the objection just urged against the fibers of cotton. It is easily nitrated, easily washed, and makes an excellent article for solution in amyl acetate or other solvent for the manufacture of varnish of different kinds and also for making substitutes for gun cotton for the purpose of manufacturing smokeless powder and other explosives.

COMPOSITION OF THE COBS.

The cobs of Indian corn have high nutritive values, but have been used in this country mostly for fuel, and not for cattle feeding. In the last few years they have been used in some localities for cattle feed after having been previously ground to a fine meal. The average composition of the whole cob, calculated from a mean of 18 analyses, is as follows:

	Per cent.		Per cent.
Moisture	10.7	Ash	1.4
Proteids	2.4	Crude fiber	30.1
Ether extract	.5	Carbohydrates not crude fiber	54.9

The cob contains a small interior core of fine pith. In the separation of the pith from the exterior substance the following proportions were found:

Percentage of pith	1.5
Percentage of shell	98.5

The pith of the corncob has many of the properties characteristic of that of the stalk, is finer in texture, however, and less absorptive. By experiment it was found that one gram of the air dry pith absorbs 10.43 grams of water. The chemical composition of the pith and the shell of the cob are found in the following table:

Chemical composition of corncob.

Constituents.	Pith.	Shell.
	Per cent.	*Per cent.*
Moisture	8.11	9.08
Ether extract	.52	.23
Fiber	34.15	32.17
Ash	2.43	1.55
Protein	2.06	1.75

Maize cobs are used to a large extent in the manufacture of pipes for smoking tobacco.

MANUFACTURE OF STARCH.

Practically all of the starch which is made in the United States is made from the grains of the Indian corn. In a few localities a small quantity of starch is made from potatoes, and in Florida and some other parts of the South still smaller quantities from the cassava. The starch of commerce, however, for the whole country is derived exclusively from Indian corn. The grains of the Indian corn contain from 60 to 65 per cent of starch, and nearly all of this is secured in commercial operations in a merchantable form. The process of starch making is extremely simple. The grains are softened in hot water until they can be easily crushed between stones or rollers into a fine pulp. This pulp is carried onto shakers lined with fine cloth, and as the pulp passes over these the starch is washed through the meshes of the cloth by a stream of water. It is customary in some localities to treat the separated starch with a dilute alkali, usually caustic soda, for the purpose of freeing it more completely from attached particles of a nitrogenous nature. The dissolved nitrogenous bodies and the alkaline waters are subsequently removed by washing with pure water. The starch is then allowed to settle, and the moist blocks are placed upon drawers and brought to the proper state of dehydration for commercial purposes. Starches intended for cooking purposes receive special treatment, and are purer and whiter than those made for laundry purposes. The quantity of Indian corn used for starch making in the United States is not actually known, but is doubtless greater than the amount used for glucose making.

MANUFACTURE OF GLUCOSE.

The manufacture of starch sugars of various degrees of hydrolyzation is an important industry in the United States. These products of the hydrolysis of starch are known as glucose or grape sugar. The glucoses represent those in which the hydrolysis is less complete, and consist largely of dextrin, dextrose, a little maltose, and water. These are made into thick and white sirups, used largely for table sirups, for adulterating molasses and honey, and for confectioners' purposes. Grape sugar is a term applied to the solid product obtained by the hydrolysis of starch in which the hydrolysis is carried to a greater extent, the resulting product consisting chiefly of dextrose. This product is chiefly used as a substitute for malt in the brewing of beer and ale. This industry has assumed immense proportions in the United States, the quantity of Indian corn annually consumed in the manufacture of glucose being about 40,000,000 bushels, or 14,095,922 hectoliters.

MANUFACTURE OF WHISKY AND ALCOHOL.

Large quantities of Indian corn are used in the United States for the manufacture of the beverage known as whisky. There is probably more Indian-corn whisky made in the United States than is made from all other grains combined. Indian-corn whisky is generally designated by the term "Bourbon," to distinguish it from the rye whisky, which is the other whisky chiefly used. The process of manufacture is entirely analagous to that used in making whisky from other cereal grains. The conversion of the starch into fermentable sugars is accomplished by diastatic action, and the resulting mash fermented and subjected to distillation. Certain volatile matters besides ethyl alcohol pass over into the distillate, especially of that group of higher alcohols known under the name of "fusel oil." The aromatic flavoring essential oils of Indian corn also appear in the distillate. After proper rectification the distilled whisky is colored with burnt sugar, placed in oak barrels, and allowed to lie in warehouses for from three to five years. During this period the fusel oils are largely oxidized to aromatic ethers, the whisky is rendered mild and agreeable in flavor, and the general improvement due to aging takes place.

Indian corn is also practically the source of all the commercial alcohols, Cologne spirits, high wines, and other alcoholic products made in the United States. The distillation of high wines, Cologne spirits. and alcohols is a great industry, consuming annually about 15,000,000 bushels, or 5,285,971 hectoliters of Indian corn.

BY-PRODUCTS IN THE MANUFACTURE OF STARCH, GLUCOSE, WHISKY, AND ALCOHOL.

The glutinous and other residues from the manufacture of starch, glucose, whisky, and alcohol are used as cattle feed. Formerly it was the custom to employ these waste matters in the moist state, but in most parts of the country this method has been superseded by the method of drying the residues and selling them in the practically anhydrous condition. In this state they are much more easily transported, the objectionable odors which were a predominant characteristic of the moist foods are removed, and the wholesomeness of the food is in every way promoted. The method of preparing these foods is practically the same as that used in the saving of residues from breweries for feeding purposes, and the nutritive value of the Indian-corn residues is quite equal to that of brewers' grains.

CONCLUSION.

An attempt has thus been made to briefly review the chief points connected with the constitution and economic value of the Indian-corn plant. It is predominantly the characteristic cereal crop of the United States, and its money value is, perhaps, greater than that of any one crop, with the exception of cotton. It has been shown that it is a valuable food for man and that it is the chief food of the domestic animals of our great country. In addition to this, large quantities of starch are made from it, and also glucose and grape sugar. It not only serves as our food, but also furnishes a part of our drink, in the form of the various grades of Indian-corn whisky. In addition to this, it is the source of an immense industry in the manufacture of alcohols, high wines, and Cologne spirits. The stalks, which a few years ago were considered an injurious residue, have been found to possess most valuable properties as cattle food. Especially is this true of the outer shells. The inner portion of the stalk—the pith—possesses remarkable properties as an obturator in the manufacture of battle ships. It possesses a high degree of resilience and porosity, and when perforated by a shot or shell it instantly closes the aperture made by the projectile, and thus prevents the entrance of water into the vessel. It also has peculiar properties rendering it suitable for the manufacture of pyroxylin varnishes, gun cotton, and high explosives. By reason of the nature of its construction it is easily nitrated. The acids are completely removed by washing, and the resulting compound is more stable, and therefore more valuable, than that which is derived from cotton under similar treatment.

It has been deemed wise to collect the above results of recent work which has been done in the Chemical Division of the Department of Agriculture on the subject of Indian corn, especially because the merits of this plant are not well appreciated in Europe, where Indian corn is not regarded as a fit source of human food, and where its genuine nutritive properties and the properties of the stalks are not known. It is believed that by calling the attention of the scientific men of Europe to Indian corn, good will result, not only to the country which is interested in the growth of this great cereal, but to Europe, where cheap and nutritious food products are desired.