BULLETIN No. 44

U. S. DEPARTMENT OF AGRICULTURE

DIVISION OF CHEMISTRY

SWEET CASSAVA:

ITS CULTURE, PROPERTIES, AND USES

BY

HARVEY W. WILEY

CHEMIST OF THE U. S. DEPARTMENT OF AGRICULTURE

PUBLISHED BY AUTHORITY OF THE SECRETARY OF AGRICULTURE

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF CHEMISTRY,
Washington, D. C., September 15, 1894.

SIR: I beg to submit for your inspection and approval the manuscript of Bulletin No. 44, giving a description of our investigations of the agricultural possibilities of sweet cassava.

Respectfully,

H. W. WILEY,
Chief of Division.

Hon. CHARLES W. DABNEY, JR.,
Acting Secretary of Agriculture.

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SWEET CASSAVA: ITS CULTURE, PROPERTIES, AND USES

DISTRIBUTION—NAMES—VARIETIES.

In the southern peninsula of Florida, and growing up well into the frost belt, is found in many localities a cultivated plant known as cassava, or sweet cassava. From a careful study of the climatic conditions under which the plant flourishes it is safe to assume that it may also be grown with success in southern Alabama, Mississippi, Louisiana, and Texas. Cassava is a name which should properly apply only to the purified starch derived from the roots of the plant, but it has passed into general use to designate the plant itself. Botanically, the plant is known as *Janipha manihot*, *Manihot utilissima*, *Jatropha manihot*, *Manihot aïpi*, *Manihot læflingii*, and *Manihot palmata*. One of its common names is manioc plant. The fleshy root of this plant yields the greatest portion of the daily food of the natives of many portions of tropical America, and one of its forms of starch is imported largely into this country as tapioca. It is a woody or shrubby plant, growing from fleshy, tuberous roots, the stems being smooth, with nodules where the leaves grow.

There is properly only one variety of the plant growing in Florida, while that variety which grows in the tropics contains so much hydrocyanic acid as to render it poisonous. The variety grown in the subtropical region of Florida, however, contains only a small quantity of hydrocyanic acid, and is therefore commonly known as sweet cassava. Some of the growers of the plant in Florida claim that two varieties grow in the State, one of which is poisonous on account of the large amount of hydrocyanic acid which it contains, and the other nonpoisonous, containing only a little hydrocyanic acid. It is quite probable, however, that after the poisonous variety has grown for a long while in a subtropical climate it would lose largely its poisonous properties. The leaves of the poisonous variety in the tropics usually have seven branches palmately divided. The leaves of the sweet variety are usually only five-parted. The botanists clearly recognize two distinct varieties. For instance, in the "Treasury of Botany," page 718, the following remarks are made:

It is quite clear that while the root of one is bitter and a virulent poison that of the other is sweet and wholesome, and is commonly eaten cooked as a vegetable. Both of them, especially the bitter, are most extensively cultivated over the greater

part of tropical America and yield an abundance of wholesome and nutritious food, the poison of the bitter kind being got rid of during the process of preparation it undergoes. The poisonous, expressed juice, if allowed to settle, deposits a large quantity of starch known as Brazilian arrowroot or tapioca meal, from which the tapioca of the shops is prepared by simply torrefying the moist starch upon hot plates, the heat causing the starch grains to swell and burst and become agglutinated together. A sauce called *cassareep,* used for flavoring soups and other dishes, particularly the West Indian dish known as *pepper pot,* is also prepared from this juice by concentrating and rendering it harmless by boiling. Another of the products of cassava is an intoxicating beverage called *piwarrie,* but the manner of preparing it is not calculated to render it tempting to Europeans. It is made by the women who chew cassava cakes and throw the masticated materials into a wooden bowl, where it is allowed to ferment for some days, and then boiled. It is said to have an agreeable taste.

CASSAVA AS AN ARTICLE OF FOOD.

The attention of the Division of Chemistry was first called to the cassava plant as an article of food and a possible source of starch, in 1888, in a letter received from Mr. R. H. Burr, of Bartow, Fla. Mr. Burr also sent a package of cassava roots. He described the plant and its uses in the following words:

> The roots do not last long after digging, drying up, or rotting. Since this variety of cassava is not the bitter or poisonous kind, it is generally known in Florida as the sweet cassava. The roots are fed to all kinds of stock in a fresh state, and are greatly relished. It has been sufficiently tested here to show its great value as a stock food. The yield under favorable conditions is astonishing. I have recently dug one plant of one year's growth which weighed 50 pounds, being at the rate of more than 1,500 bushels to the acre. Eight hundred to 1,000 bushels per acre can be confidently reckoned on.

The roots received by us were long and slender and of various sizes; some of them were quite 2 feet long, and weighed several pounds. The analysis of the sample, exclusive of the bark, calculated to dry substance, is given in the following table:

Serial number		5547
Ash	per cent	1.94
Oil (petroleum ether extract)	do	1.27
Ether extract (resins, alkaloids, organic acids, etc.)	do	.74
Alcohol extract (amids, sugars, glucosids, etc.)	do	17.43
Crude fiber	do	4.03
Starch	do	71.85
Albuminoids (calculated from nitrogen)	do	3.47
		100.73

In regard to the method of analysis little need be said; it was carried on in accordance with the well-established rules of plant analysis, as laid down by Dragendorff. The first extraction of petroleum ether gave the fat or oil alone, and the subsequent extraction with sulphuric ether gave the resins, alkaloids, and organic acids. That portion of nitrogen existing as amids was estimated in the alcoholic extract. The total nitrogen was also estimated and entered as albuminoids; a

small portion of the nitrogen has thus been counted twice in the total results, which add up a little over 100. A characteristic feature of the cassava root is shown in the large amount of substance present, soluble in alcohol. The amount of starch also compares fairly well with the best varieties of potatoes. On account of the large quantity of sugars present, the cassava root could be more economically used for the manufacture of glucose than for starch. There is no doubt, however, of the fact that a fine article of starch for the laundry or for food can be made from the cassava root growing in this country.

In addition to the fresh root above noted, two samples of the dried root or cassava meal have also been examined. No. 5922 was sent to us, described as pulverized manihot root or cassava flour. The root is first peeled, chopped into thin slices, dried in the sun two days, and pulverized. It was prepared by Prof. W. H. Kern, of Bartow, Fla. No. 5923 was labeled pulverized cassava, with the starch, or a portion of it, and glucose washed out, the remaining pulp dried in the sun; prepared by Prof. Kern.

Prof. Kern sent a letter with the samples, from which the following extracts are made:

> Allow me to say that, owing to the prodigious yield per acre of what we here know as cassava and its alleged value as a feed and food plant and for its yield of starch and glucose, it is attracting a very great deal of attention here now. The plant here grown is different from the manioc root of South and Central America; our root contains no poisonous elements which need to be dissipated by heat. It is customary here for many persons to make their own starch from it. The root, which must remain in the ground until one is ready to use it, is dug, washed, and its two inner and outer peelings removed; it is then grated and the pulp washed, the water poured off in a vessel and allowed to stand, when the pure starch settles in the bottom. The clear water is again drawn off and the starch allowed to dry. The pulp, after having the starch washed out, may be used at once in making puddings by the addition of milk, eggs, etc. This washed pulp may be sun-dried and thus kept, forming valuable meal or flour, from which nice bread may be made. Necessitated as we are in south Florida to buy all our wheat flour, anything which acts as a substitute, either in whole or in part, is of great value to us.

The analyses of two samples of flour are given in the following table:

Serial number		5922	5923
Water	per cent	10.56	11.86
Ash	do	1.86	1.13
Oil and fat	do	1.50	.86
Resins, alkaloids, and organic acids	do	.64	.43
Amids, sugars, glucosids	do	13.69	4.50
Dextrin, gum, etc., by difference	do	2.85	5.63
Crude fiber	do	2.96	4.15
Nitrogenous bodies	do	1.31	1.31
Starch	do	64.63	70.13

From the above analyses it is seen that the cassava can never take the place of the flour made from cereals as a food material on account of the small portion of nitrogenous matter which it contains. It seems

to me, however, that it might very well take the place of potatoes, and its value as a food should not be underestimated.

In order to get further information in regard to the growth and uses of cassava in Florida, a circular was sent to as many addresses as could be obtained of persons interested in its growth in that part of the State suited to its culture. This circular asked for information in regard to the time and method of planting, method of cultivation, kind of soil and fertilizers, proper time for harvesting, length of time the roots can remain in the ground, the effect of frost on the plant, the yield of roots per acre, their value as food, method of preparing for food and starch, profit of cultivating, and the certainty of the crop. In all, about three hundred answers were received to these questions. Some of these answers stated that the crop was not grown in the part of the State from which they were written. A few of the replies were unfavorable in regard to the utility and value of the crop. Nearly all of them, however, represented that the crop was a certain one, extremely valuable, and the roots an excellent food for man and beast.

Many of the correspondents give rather full notes in regard to the value of the crop and the localities in which it grows. In Florida it seems to flourish in almost every part of the State.

Mr. J. B. Pixton, of Ellerslie, Pasco County, writes:

I found it growing profusely in Taylor County, this State, some years since. The roots were thicker than a man's arm and about 4 feet long. The settlers almost live on it.

Taylor County is in the northwestern part of the State, bordering on the Gulf. The same writer says that in his locality it did not do so well and that he could make nothing of it.

Prentice Bailey, in an article in the Tropical Sun of February 9, 1893, published in Juno, Dade County, says:

I consider it superior to any root crop grown in this country. It is very productive; it has a remarkable immunity from drought, flood, and disease; it is easy to harvest, easy of cultivation, and occupies the ground during the whole growing season to the exclusion of noxious plants. The pork made from feeding it is solid and delicate as chicken, and the lard is as firm as that of corn-fed hogs. It produces a good flow of rich milk and a firm, golden butter. From 1 acre of cassava enough roots may be obtained to fatten 10 hogs or feed 3 milch cows during the entire year.

Mr. Bailey states that in his opinion it can be grown as far north as Atlanta, Ga., in which opinion, however, I am unable to concur, as preponderating testimony goes to show that the plant will not do well in localities subject to heavy frosts.

Mr. Fred W. Inman, of Winter Haven, Polk County, says:

There is no better food for stock, especially during the winter months. I have fed my cows, mules, horses, hogs, and poultry upon it every season for the past six years. It fattens better than corn. There is nothing grown in this country that can compare with it. It has no enemy but frost. I esteem this crop one of the most essential as well as profitable that the Florida farmer can grow. It furnishes food for my stock, poultry, etc., for about nine months in the year.

Mr. Sherman Adams, in the Florida Agriculturist, says:

Soil suitable for corn is appropriate for cassava. It must not, however, be wet land or land subject to overflow, as that will rot the tubers. Frost, if severe, will kill the plant so effectually that but a small proportion will sprout again. By saving the stumps when the roots are dug, and planting them, they will sprout and grow, though the tops be killed two or three times. There are about 2,740 hills per acre. On land that will not grow more than 5 bushels of corn per acre, cassava will average from 3 to 5 pounds per hill, or, at a very moderate estimate, 4 to 5 tons per acre.

Mr. S. W. Carson, of Midland, Polk County, says:

There is but one variety of cassava, viz, the sweet kind, grown in Florida. I have never seen any sample of the bitter variety. A Spaniard who was once conversing with me on the subject of cassava gave his idea as a proper definition of cassava as "the life of man." After cultivating the plant for a quarter of a century, I am ready to agree with him. If judiciously used it will reduce the grain rations for horses and mules at least one-half. For cows you may keep bits of it mixed in the slops and other food. I have never cooked it for stock, as I believe it is best fed raw. In feeding to fowls, it should be thrown into the yard in its raw state daily, but in small quantities. After feeding on it for one month any fowl will be fat enough to cook without lard or butter. Honey bees forage largely on the blooms; cattle eat with relish the tender shoots. The finest fowl yard imaginable could be made in a cassava patch by turning the fowls into the patch ten months after planting. The roots would supply them with food and the tops shelter them from the sun.

I regard the rolling pine lands, containing some willow oak, to be the best for cassava, and the southern counties to be best suited to it. Let the soil be well prepared by plowing and harrowing, rows checked about 4 feet apart, and one piece laid in each hill. I think they should never be closer together than 4 feet, and 5 would be better. Cassava has been known to grow for three years in this country. It will continue to grow until the cold kills it; then, by breaking off the stems when they are red, the stubble will sprout up in the spring. As to the seeds of the cassava, they will ripen in about one year. If puddings, custards, etc., are desired, the roots must be peeled and grated; salt, sugar, etc., may be used according to taste. The Spaniards make bread of it simply by grating the root, and adding salt and a little soda. Now, there is no doubt in my mind but that 30 tons of cassava root per acre can be produced. When I think of the tapioca, glucose, and starch there are in it, and how abundantly it can be turned into bacon and lard, milk and butter, mutton and beef, I feel confident that it will pay better than any other plant in the world.

Mr. Paul Dupuy, of Boardman, Marion County, says but little cassava is grown in that locality:

Some months ago I spent fourteen months in Brazil, where the mandioc plant is generally used as food by man and beast. In truth, it constitutes the bread of the country, being a general article of food for all classes. It is prepared for food in Brazil by grating it into a coarse pulp and pressing it to get rid of as much of the juice as possible, which contains a large proportion of hydrocyanic acid. The pulp is then placed in shallow copper pans and thoroughly dried over a gentle fire. In this condition it resembles corn grits, and it is eaten in this shape, or it can be cooked and prepared as corn meal and other starchy products. The sediment from the expressed juice, when dried, constitutes the tapioca of commerce. As a starch product I do not think it can be excelled, because of its enormous product per acre.

Mr. A. Stephens Means, of Johns Pass, Hillsboro County, says:

It has great value as stock food, being very rich in starch, and most animals eat it greedily. It is a nourishing food for man and can be used in a number of ways, as a substitute for potatoes, or the starch may be extracted and used for puddings, etc. Any soil suitable for potatoes can be used for cassava.

Mr. M. K. Lyman, of Lantana, Dade County, writes:

I have no success with cassava. I have made several efforts to raise the plant and have failed in every case. I have splendid success with tanyah, or taro. It makes a substitute for the potato all the year, being an evergreen, yielding edible roots the year around.

Mr. William Fisher, of Clay County, says:

Idoubt very much if cassava ever supplants the sweet potato as human food, for the Southerners like the sweetness of the potato and it can be cooked in one-third the time required for cassava. But as stock feed I believe the cassava is well worth a trial. In my judgment, the planting, cultivation, and harvesting of it would involve less labor than the potato; the seed is as easily wintered; the crop can be left in the ground all winter, and it yields more per acre than the potato and is apparently equal to it in nutritive value.

Mr. Stephen Powers, editor of the Florida Dispatch, says:

The plant is indigenous to the West Indies and to Africa. In the West Indies it is known as cassava, while in South America it is commonly known as mandioca, or manioca. The name yucca, which some people insist on giving it, is a clear misnomer, since the yucca belongs to the *Liliaceæ*, or lily family, while the cassava belongs to the *Euphorbiaceæ* family. The plant was eaten by the South American and Caribbean Indians centuries before this hemisphere was discovered by Europeans. Southey says of it: "If Ceres deserved a place in the mythology of Greece, far more might the deification of that person have been expected who instructed his fellows in the use of mandioca." In Brazil, in the form of coarse flour, a majority of the population use it the year round in lieu of bread. A mild intoxicant is also distilled from it which is the universal drink of the lower classes. The South American Indians use the following formula for manufacturing cassava beer: The roots are sliced, boiled till soft, and cooled. They are then chewed mouthful by mouthful, the masticated cuds being returned to the vessel. [This process, although not so stated in the description, is evidently intended to transform the starch into sugar by the action of the saliva.] The jar is then filled with water and boiled for several hours with constant stirring. The liquid is then poured off into another jar, half buried in the dirt floor of the hut in which the family lives, closely covered, and allowed to ferment two or three days. When required for use a fire is built around it, and the beverage is served steaming hot. It is not as palatable for human food as sweet potatoes, and to expect therefore to substitute cassava for either the sweet or the Irish potato would be a step from a higher to a lower civilization, but as a food for live stock it has a great superiority. It is worth at least 25 per cent more than sweet potatoes to produce milk or fat. With no more manure, and less cultivation than is required for Indian corn, it will produce an amount of feed worth at least four times as much for fattening animals and incomparably more for producing milk. It is easier to plant and cultivate than sweet potatoes, but harder to dig, so it may be called even on this score. With the same manuring it will yield 600 bushels per acre, while sweet potatoes will yield only 500.

Mr. J. H. Moore, of Keuka, Fla., in a letter to the same paper of November 24, 1887, describes some of the uses of cassava. From his letter the following extract is made:

Cut the stalks about 1 inch above the ground, just before frost; after cutting, the stalks should be left to dry in a cool place a few weeks, and then placed in a trench and covered until time for planting. Some save the stalks by keeping them in a dry, cool place until February and then planting. The roots should be dug as used; they will not keep in good condition out of the ground more than three or four days. It is perhaps the best feed we can raise for hogs; it is also a fine feed for poultry. We often bake it like sweet potatoes, and also slice and fry it like Irish potatoes.

M. Sacc has addressed a letter to the National Society of Agriculture of France concerning the cassava, which he calls *Manihot utilissima.* He is of the opinion that the poisonous varieties are different botanically from the innocent. Manihot is the bread of tropical regions. The innocent variety is cultivated in Bolivia, and the botanists there call it *Manihot aïpi.* The plant grows from 1 to 2 meters in height, with straight and naked stalks, since they only develop leaves at their extremities; the only care given to them in their cultivation is to keep them free from weeds. The roots, to the number of five to nine, are of the size of the closed hand. The following analysis of the roots of the *Manihot aïpi* is given:

	Per cent.
Water	70.29
Starch	14.40
Sugar, salts, and malic acid	1.01
Fibrin and yellow coloring matter	.08
Crude fiber	3.16
Ash	10.82

From the above it is seen that the roots of the tropical plant are quite different from those produced in our own country. In regard to the distribution of the two varieties, M. Sacc makes the following observation:

In Cuba I have seen only the poisonous variety. The same is true of Brazil, where I have not seen the *Manihot aïpi* except in the Swiss colony, Porto Real. As to the product of the two varieties, it is the same; the stalks, which are the size of the finger, are from 1 to 2 meters in height. I have not been able to analyze the leaves of this interesting vegetable, but as they are much sought after by cattle they are probably very nutritious.

These interesting facts concerning the cassava plant, derived from our own analyses and observations and from the correspondence noted above, have led us to believe that a wider knowledge of the properties of this interesting plant would prove of interest not only to the growers thereof, but also to capitalists and manufacturers, who might be interested in it as a promising source of food and as the raw material for the manufacture of starch and glucose.

A large quantity of the root, therefore, was obtained from Florida, the bark separated from the root, and each subjected to analysis with the following results:

	Peeled root.		Fiber after removal of starch.	Bark of root.	
	Fresh.	Dry.	Dry.	Fresh.	Dry.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Moisture	61.30	.....	.....	61.30	.....
Ether extract	.17	.44	.30	.66	1.70
Albuminoids (nitrogen × 6.35)	.64	1.66	1.02	2.29	5.91
Starch (diastase extract inverted with HCl)	30.98	80.06	64.64	.....	.....
Fiber	.88	2.26	10.68	3.83	9.89
Ash	.51	1.31	1.42	2.02	5.23
Undetermined	5.52	14.27	21.94	29.90	77.27
	100.00	100.00	100.00	100.00	100.00

With the starch in the analysis given above is reckoned also the soluble carbohydrates, consisting almost exclusively of cane sugar, and of which, in an analysis of another portion of the dry substance, as high as 17 per cent were found. In the laboratory it is not difficult to prepare crystallized cane sugar from the aqueous extract of the fresh pulp. We have made such a preparation. The percentage of sugar in the plant, however, is too low to excite any reasonable hope of the preparation of this article on a commercial scale. The most promising way to save it is by conversion into glucose, as indicated in another place. The undetermined portion consists of the digestible fiber and carbohydrates of the pentose series. The pentosans in the fiber were determined by the furfurol process, as modified by Krug, and the amount in the air-dried material was found to be 3.92 per cent, and in the material after the removal of the starch 5.33 per cent.

The fresh root was found to contain 38.7 per cent of dry matter, being considerably more than was found in the fresh sample of the previous analysis. Of this 38.7 per cent, 30.98 consisted of starch and soluble carbohydrates.

Experiments were made to determine the yield of air-dry starch which could be obtained from the roots by laboratory work. Two sets of experiments were made. In the first set the roots were pulped on a Pellet rasp, used for preparing beet pulp for instantaneous diffusion. Twelve kilos of the unpeeled root were rasped in this way and the starch separated by washing through a sieve of bolting cloth. The washings and settlings were collected and dried in the ordinary method of starch manufacture. The yield of pure starch was 3,105 grams, equivalent to 25.9 per cent of the total weight of the root. The starch was almost absolutely pure, containing only a trace of nitrogenous matter. In the second experiment 10 kilos of the root were ground in a pulping machine, used for preparing green fodder for analysis. The pulp was much less fine than that produced by the Pellet rasp. Treated in the same way, the yield of air-dry starch was 2,360 grams, or 23.6 per cent. One of the striking points in connection with the work is that the residue from the starch, which consisted largely of fiber, as will be seen by reference to the above analysis, contained still a large percentage of starch, showing that by the process employed the whole of the starch was not secured from the pulp. The diameter of the starch granules is a little over 0.01 mm., being about seven times smaller than the average of potato starch.

COMPARISON OF CASSAVA STARCH AND INDIAN CORN STARCH.

The illustrations given are from photomicrographs of the starch granules, which, for purposes of comparison, are accompanied by illustrations of the finest prepared Indian-corn starch.

Fig. 1, Plate I, shows the granules of cassava starch in plain light, magnified 150 diameters.

Fig. 2, Plate I, shows Indian-corn starch in similar conditions. The average size of the particles is the same in both instances, viz, 0.012 mm. The cassawa particles are more irregular in size, and are, moreover, to be distinguished from the maize particles by greater evenness of outline. The cassava, however, more nearly resembles the maize starch than it does any other well-known variety, and by reason of this resemblance could easily take the place of maize starch in the kitchen and laundry.

Fig. 1, Plate II, shows cassava starch magnified 150 diameters and viewed by polarized light. Only the larger particles are well in focus, nevertheless the cross can be seen on the smaller by close inspection.

Fig. 2, Plate II, shows maize starch in similar conditions. While it would be difficult in all cases to distinguish these two starches by the microscope, yet there are some points of difference, as have already been noted, by means of which the expert may usually be successful in the discrimination.

The cassava which grows in tropical regions contains a notable percentage of hydrocyanic acid, so great, in fact, that it can not be used directly as a food. The so-called poisonous cassava is boiled, to expel the hydrocyanic acid before being used for feeding purposes. A careful determination was made of the hydrocyanic acid in the fresh root and the amount was found to be in considerable quantity, but not sufficiently large to be alarming. Nevertheless, any possible danger could be avoided before using the material as a food by subjecting it to a sufficient heat to expel the hydrocyanic acid. The hydrocyanic acid seems to be distributed throughout the pulp, and particularly in the juices which can be expressed from the pulp. No injurious effect from the hydrocyanic acid has ever been observed in the case of animals fed on cassava in Florida.

The bark of the root was also subjected to analysis, as will be seen by reference to the following table. It contained no starch, the undetermined matter being chiefly digestible fiber and pentosans.

The mineral matters extracted from the soil are distributed as indicated in the table. The amount of ash in the root itself is quite low, showing that the cassava plant does not require a soil very rich in mineral constituents. The amount of mineral matter taken from the soil by 100 kilos of the fresh root is approximately only half a kilo. The albuminous matters are also present in small quantities, being only slightly larger in weight than the ash itself. The plant, therefore, is one which seems particularly suited to feed almost exclusively from the air and water, and hence is one which could be recommended on the sandy soils of Florida as a crop which would require the minimum of fertilization.

COMPOSITION OF THE ASH.

The ash of the peeled root and the bark of the root was subjected to analysis, with the following results:

Analysis of the ash of cassava root.

Constituents.	Peeled root.			Bark of root.		
	A.	B.	Mean.	A.	B.	Mean.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Carbon	0.30	0.31	0.31	0.79	0.77	0.78
Silica (soluble in solution of Na_2CO_3)	0.97	0.91	0.94	10.53	11.36	10.94
Silica (insoluble in solution of Na_2CO_3)	7.15	7.15	7.15	52.99	52.16	52.58
Ferric oxid (Fe_2O_3)	0.66	0.66	0.66	2.46	2.44	2.45
Calcium oxid (CaO)	10.63	10.64	10.64	6.58	6.65	6.62
Magnesium oxid (MgO)	7.36	7.35	7.35	3.31	3.33	3.32
Sodium oxid (Na_2O)	1.12	1.28	1.20	0.84	1.05	0.95
Potassium oxid (K_2O)	41.72	41.54	41.63	14.73	14.68	14.70
Phosphoric acid (P_2O_5)	15.58	15.59	15.58	2.44	2.46	2.45
Sulphuric acid (SO_3)	3.67	3.80	3.73	1.71	1.71	1.71
Carbonic acid (CO_2)	9.15	9.12	9.14	2.53	2.50	2.51
Chlorin (Cl)	2.76	2.75	2.75	1.41	1.42	1.41
Total	101.07	101.10	101.08	100.32	100.53	100.42
Oxygen equivalent to chlorin	0.62	0.62	0.62	0.31	0.31	0.31
Difference	100.45	100.48	100.46	100.01	100.22	100.11

From the above numbers it is seen that the ash of the peeled root is especially rich in potash, almost one-half of the total weight being composed of this substance. The potash is combined chiefly with carbonic and phosphoric acids. In the ash of the bark, as might be expected, silica is the predominant element, more than half the total weight consisting of this substance.

Assuming a yield of 5 tons of roots per acre, the weights of the important fertilizing materials removed by such a crop can be readily calculated from the data given.

Since the bark forms approximately 2.2 per cent of the entire root, the total crop would be made up of the following amounts of bark and peeled root which would contain the amounts of mineral matter given below:

	Pounds.	Pounds of ash.
Peeled root	9,780	49.88
Bark of root	220	4.44
	10,000	54.32

The more important mineral matters contained therein are:

	Ash from peeled root (49.88 pounds).	Ash from bark (4.44 pounds).	Total ash from 5 tons (54.32 pounds).
	Pounds.	*Pounds.*	*Pounds.*
Lime (CaO)	5.31	0.29	5.60
Magnesia (MgO)	3.67	.15	3.82
Potash (K_2O)	20.77	.65	21.42
Phosphoric acid (P_2O_5)	7.77	.11	7.88
Residue	12.56	3.24	15.60

The less valuable mineral plant foods, that is, those that are of so little note as to require no conservation or addition, amount to 15.60 pounds per acre and the more valuable to 32.72 pounds per acre.

Quite a number of preparations was made from the starch of the root, and among them may be mentioned: First, tapioca; the first portions of starch washed out, especially, produce an excellent article of tapioca when treated in the usual way. Second, glucose; both the fresh root and the extracted root yield full theoretical amounts of glucose, and samples of this article were made by the conversion of the starch both by sulphuric acid and diastase. The samples of glucose made from the starch were exceptionally good, especially when diastase was used, the glucose in this case containing large quantities of maltose. Commercially it would be more profitable to make the glucose directly from the fresh root, in which case the considerable percentage of cane sugar contained by it would be saved, whereas if glucose be made from the starch the cane sugar is previously washed out. On account of the presence of the bark, however, the glucose made from the whole root is not so fine in quality as that made from the pure starch. Third, alcohol; the glucose on fermentation affords the usual quantity of alcohol. Fourth, cane sugar; a beautiful preparation of cane sugar was made from the water used in washing out the starch. The amount of cane sugar, however, is not large enough to warrant its extraction on a commercial scale from the waters used for washing. It is, however, present in sufficient quantity to indicate that in making glucose it is better to use the whole root as indicated above.

The general result of the analytical work is such as to establish the fact that the cassava is a plant of high economic value and worthy of the attention of those interested in the carbohydrate products of the country.

FIG. 1.

METHODS OF CULTURE.

Cassava has been grown for one year on the Department Experiment Station at Runnymede (post-office, Narcoossee), Osceola County, Fla. The crop was grown as food for stock. The field in which the crop was grown is high pine sand, with almost no other ingredient. The illustration of the cassava given herewith is from a photograph of a plant taken from a field near the station. The soil on which it was grown was apparently pure sand. It represents the larger plants in the field, but not by any means the largest. The illustration (fig. 1) shows in a striking manner the stem and root develop-

ment. This plant, of which the photograph is given, was 5 feet high. The roots in the soil occupy a more nearly horizontal position than is shown in the figure. The thickened part of the stem to which the roots are attached, represents the cutting from which the plant grew.

Attempts were also made to grow the cassava in a piece of very wet muck land on the station in which sugar cane would not grow to any advantage. An immense development of tops was secured, some of the plants reaching a height of 10 feet and resembling young trees. The root development was fair, but not commensurately increased with the top growth. Some of the stems were easily 2 inches in diameter. On well-drained muck land I think the crop would be large and profitable.

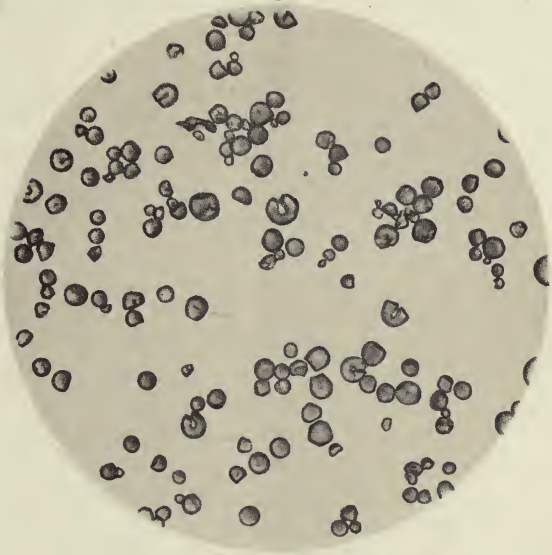
In sand land the planting should be preceded by the removal of stumps, sprouts, etc., and the soil given a thorough plowing. It is advisable to spread about 300 pounds of fine raw Florida phosphate floats or about 150 pounds of superphosphate containing 12 per cent available acid, to the acre. This may be applied as a top-dressing and thoroughly worked into the soil by a deep-running cultivator. The rows should be marked out in furrows 3 to 4 inches deep and from 3½ to 4 feet apart. To get a good stand, about double the number of cuttings required to produce 2,500 hills per acre should be planted. The excess of plants can be removed by a hoe as soon as vigorous growth is assured, leaving one hill each 3 or 4 feet. About 150 pounds of kainit per acre should be dropped in the hills before planting, together with an equal amount of cotton-seed meal, or half that amount of Chile saltpeter (nitrate of soda).

The cultivation should be such as to keep the field free of all weeds and the surface of the soil well stirred. While the plants are young deep cultivation is not objectionable, but as soon as the root system begins to develop, flat superficial culture must be practiced; not to exceed 2 inches in depth. Some cultivators draw the soil to the plant during cultivation so as to form a ridge at the time of laying by. Where nitrate of soda has been used an additional 50 or 75 pounds per acre should be sown broadcast just before the final cultivation. The above method is the one which should be followed for the poorest kind of sand soils, where a maximum crop is desired. For muck soils, the cotton-seed meal and nitrate of soda should be omitted and about 500 pounds of Florida phosphate floats used per acre. If sand soils are covered with a good layer of muck before the plowing the nitrogenous fertilizers may also be omitted or reduced in quantity.

In ordinary seasons with the treatment outlined above, a crop of from 4 to 7 tons per acre will be secured. On sand soils containing a little organic matter approaching the hammock variety, a fair yield of from 2 to 4 tons per acre will be secured by good cultivation without fertilizing.

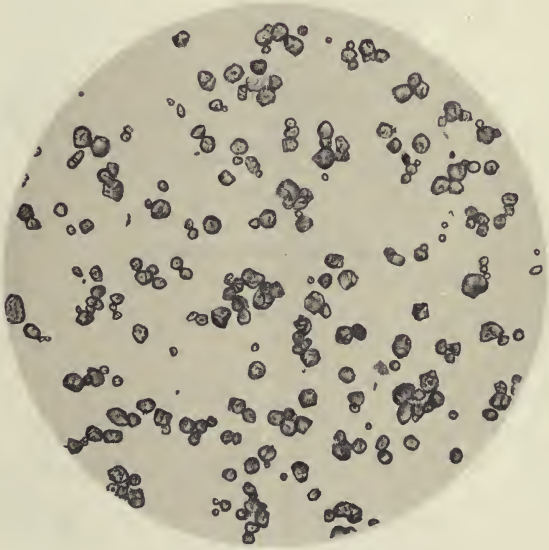
For seed, the stems of the unfrosted plants are cut into pieces about 6 inches in length, care being taken that each piece has two or more eyes. In planting, these pieces may be laid directly down in the fur-

Fig 1



CASSAVA STARCH X 150.
PLAIN ILLUMINATION.

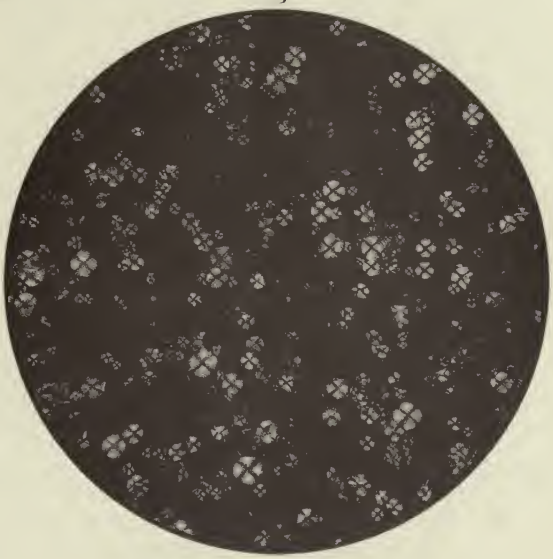
Fig 2



CORN STARCH X 150.
PLAIN ILLUMINATION.

A. Hoen & Co., Lithocaustic.

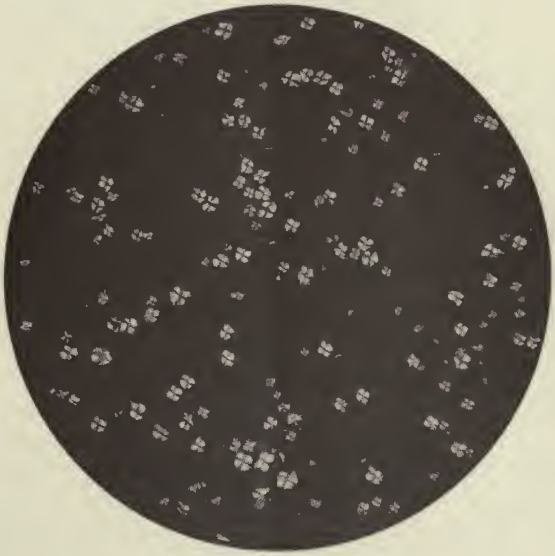
Fig 1



CASSAVA STARCH X 150.

POLARIZED LIGHT.

Fig 2



CORN STARCH X 150.

POLARIZED LIGHT.

A. Hoen & Co., Lithocaustic.

rows and covered, but the general practice is to place them obliquely in the furrows so that one end may not be covered. In case of a threatening frost before a field is ready for planting the unfrosted tops may be cut, thrown into heaps, and protected with leaves or trash from the action of the frost. They should, however, be embedded in moderately moist earth if they are to be kept before planting for any length of time. In case of frost before the seed is saved the stumps, i. e., the points of union of the top with the root, will usually be found uninjured, and these may be cut away and planted instead of the cuttings just described. The larger parts of the stems immediately above the ground make the best seed.

The roots should be left in the ground until they are needed for use, whether for food, for starch, or for glucose. The crop can be harvested at any time during the year, but the best season is from October to May. The roots should not be allowed to grow more than two seasons, and for most purposes it is believed that an annual harvest will prove the more profitable.

As is the case with all new and promising plants, the most extravagant statements have been made in regard to the amount of cassava which can be produced per acre. In many of the returns received from our correspondents in Florida, statements were made in regard to the yield which were entirely beyond the bounds of reason. These extravagant statements, of course, did not proceed from any desire on the part of correspondents to misstate the facts, but on account of their misapprehension of them. Statements of yield are made as a rule not upon accurately measured and weighed products, but upon a mere glance over a field or the taking of a few hills. It is easy, therefore, for the most honest and upright correspondent to fall into gross error in regard to the amount which will be furnished by an acre. In my own observation of small areas and from the accredited statements of those authorities which seem to merit the highest consideration, I am convinced that on the ordinary pine land of Florida, with proper preparation and cultivation and appropriate fertilization, a yield of from 4 to 7 or perhaps 8 tons per acre may be reasonably expected. It is difficult to see, however, how it is possible for such yields as have been reported, viz, 40, 50, and even 60 tons per acre, to be gathered. In exceptional conditions, as in the case with all crops, exceptional yields may be obtained, but these must not be considered in the practical study of the problem of profitable production.

The profit which the farmer may make from growing this crop, and the manufacturer from using it, should, in my opinion, be based upon a yield of 4 or 5 tons per acre. If it be desired to make starch from the plant, we may suppose as a minimum rate of yield that 20 per cent of the weight of the fresh root may be obtained as merchantable starch of a high grade. On a yield of 4 tons per acre this would amount to eight-tenths of a ton, or 1,600 pounds. Compare this with the weight of starch obtained from Indian corn producing 40 bushels per acre.

The yield of merchantable starch of a high grade may be placed at 35 pounds per bushel, which, for 40 bushels would amount to 1,400 pounds. It is thus seen that the rate of yield per acre in the matter of starch from cassava would be fully equal if not superior to that from Indian corn.

If the matter of the manufacture of glucose be considered the estimate is even more favorable. Our experiments have shown that after the removal of the bark the whole root may be rasped and treated directly for the manufacture of glucose, either by inversion with diastase or by treating with dilute sulphuric acid. In the latter case not only were the starch and sugar present in the root obtained as glucose, but also a considerable quantity of the digestible fiber. It is not an extravagant statement, therefore, to suppose that fully 30 per cent, on the weight of the fresh root, could be obtained as commercial glucose. This would give a yield per acre of 1.2 tons, or 2,400 pounds. These statements are made, of course, subject to the practical determinations of the manufacturer of glucose and starch from this plant. Attempts have already been made in the manufacture of starch, but of course the full development of this industry must await the investment of capital and the necessary adjustment of new machinery to new processes.

The object of the present bulletin is simply to point out the possibilities of the culture of cassava, not only for the farmer of Florida but also for the manufacturer and merchant.

In its preparation Mr. E. E. Ewell has conducted the chemical and preparatory work and Mr. G. L. Spencer has taken the photographs.

CONCLUSIONS.

(1) Cassava can be cultivated with safety and profit in the greater part of the peninsula of Florida, and probably also in southern Alabama, Mississippi, Louisiana, and Texas.

(2) It will yield with fair treatment on the sand soils from 4 to 5 tons per acre.

(3) It will give, when properly manufactured, from 20 to 25 per cent of the weight of the fresh root in starch of high grade.

(4) The starch is naturally in a pure state and no chemicals of any kind are necessary in its manufacture.

(5) The starch resembles in its physical properties the starch of maize and can be used as a substitute therefor in all cases.

(6) An excellent article of tapioca can be prepared from the starch of the cassava plant.

(7) Glucose can be prepared directly from the starch or more profitably from the pulp of the peeled root.

(8) The plant furnishes an excellent human and cattle food, deficient, however, in nitrogen. It would make a well-balanced ration for cattle when mixed with one-fourth its weight of cotton-seed oil cake.