S T A R C H

by

Jessie M. Hoover.

OUTLINE.

Starch

I. Definition and Distribution.

II. Common Use of Starch.

III. Uses

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Adulterants

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IV. Properties.

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Chemical

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V. Digestion

VI. Cookery

VII. Summary.

BIBLIOGRAPHY.

United States Department of Agriculture, Division of Chemistry.
Bulletin 58.

Scientific American. Vol. 53.

"Starch in Potatoes." Farmer's Bulletin 65.

"Starch Industries." Saddler.

Handbook of Industrial Organic Chemistry.

Manufacture of Starch from Potatoes and Cassava.
Bulletin 58, U.S.Dept. Agr., Div. of Chem.
Bulletin 58, Wiley.

Scientific American Supplement., Vol. 39.

A.B.Z. of Our Own Nutrition.

Schaffer, Vol. I.

Stevenson and Murphy.

United States Department of Agriculture.
Office of Experiment Station, Bulletin 31-40.

Lectures on Human Nutrition, Professor J.T.Willard.

"Starches," Ellen H.Richards - "Food Materials and Their Adulterations"

"Starches of Commerce" Ohio Farmer, Vol. 14.

"Starch", E.H.Knight, Am. Mech. Diet. Vol. 3.

Home Encyclopedia.

Industrial Chemistry, A.W.Blyth.

Manual of Practical Chemistry, Altfield.

Am. Agr. Vol. 42.

Treatise on Chem. Vol. 3, Part 2.

Hygiene and Public Health.

Handbook of Chemistry.

Science Gossip.

Chemistry of Plant and Animal Life.

STARCH.

Starch is a carbohydrate of complex composition having the formula $(C_6H_{10}O_5)_n$. The value of n is unknown but may be anything from 2 to 200. Because of the wide distribution of starch it is one of the most universally used foods, and occurs in almost all living plants - tubers, seeds, roots, green fruits, tree trunks, and in fact, in some part of every chlorophyl bearing plant at some time during its existence. Fungi does not contain it.

Rice is one of the common starchy foods. It is estimated that about two thirds the earth's population obtain their food from rice, this is true especially of the orientals. Those who live along the sea coast or near rivers have the fish to furnish some proteid variety and so become less weary of the monotonous diet. The people of tropical countries find bananas a very wholesome and nutritious form of carbohydrate food. Corn and wheat furnish two very common sources of starchy food in the United States.

The uses of starch are varied as food for animals is not its only use. The starch in the seed or tuber is placed there in order that the young and growing plant may have nourishment at once. These seeds contain ferments which acting upon the starch reduce it to maltose and from maltose to dextrose, which is soluble and assimilable by the plant. Sometimes wheat flour will not make good bread even when the greatest care is exercised, this is often due to the fact that the starch has already been converted to the simpler sugars by the enzyme or ferment present so when the yeast is added alcoholic fermentation sets up at once followed by acid fermentation and we

have sour bread if the process is long continued.

Starch, by its oxidation, furnishes heat and energy to animals when consumed as food. It increases peristaltic action by the irritation caused by the cellulose surrounding the starch. Potato starch is used in print factories, to thicken the material for printing for sizing cloth and warp yarn and to finish cloth after it is bleached and dyed. It is the foundation of all adhesive paste and the mucilage on the postage stamps is made from starch dextrinized by heat and nitric acid. Alcohol is made by steeping barley, corn or other grains in the presence of malt diastase, the starch being first altered to sugar and this then changing to alcohol and water. Glucose is a product of the hydrolysis of starch.

Because of its cheapness corn starch is a very common adulterant not only in wheat flour but in common salt. Plate VII, Fig. 1. Ordinary tapioca, Plate I, Fig.6. Baking Powder, Plate II, Fig. 3. Pulverized sugar, Plate II, Fig. 2. Cocoa, Plate IX, Fig.1 and 2. Ground white pepper, ginger and Victorex Baking Powder, Plate V, Fig. 1, 3, 6. Baker's Chocolate, Plate VI, Fig. 6. Baker's Cocoa and Celery Salt, Plate VII, Fig. 4 and 6.

Now starch plays an important part in articles which may become lumpy in the presence of the moisture of the air. Salt is much improved by being less likely to lump and baking powder is less likely to chemical reaction when starch is used as a drying agent. While starch is not harmful of itself yet one does not wish to pay from 40 to 75 cents per pound for cocoa or condiments and similar articles and receive a large percentage of starch which cost the

manufacturer from two to four cents per pound.

All starch grains are similar in their general structure, but they may vary in size, form and source. The accompanying plates show the form, size and markings of the granules from many sources.

The grains are all composed of starch granulose and starch cellulose, the granulose being the inner part. The size varies greatly, as nutmeg, Plate VI, Fig. 5, ginger, Plate V, Fig. 4, Lima beans, arrow root and tapioca, Plate IV, Fig. 2,3 and 4, navy beans, peas and sago, Plate III, Fig. 2, 5 and 6, bananas, Plate II, Fig.5, and potato, Plate I, Fig. 5 represent the larger varieties.

The smaller varieites are rice, corn starch, Plate I, Fig.1 and 2, wheat and cocoa bean, Plate II, Fig. 1 and 4, oat meal, rye, and barley, Plate III, Fig. 1, 3 and 4, pepper, ginger and mustard, Plate V, Fig. 2, 3, 4 and 5. Cloves, turmeric, cayenne and cinnamon, Plate VI, Fig. 1, 2, 3 and 4. Rice is one of the smallest, the granules being so small and compact render it difficult to hydrolize because of the difficulty of the water to find access.

The contour presents great differences. Potato, Plate I, Fig. 5. Wheat, cocoa, banana, Plate II, Fig. 1, 4 and 5. Oat, navy beans, rye, barley, pea, Plate III, Fig. 1, 2, 3, and 5. Lima beans, Bermuda arrowroot, Plate IV, Fig. 2 and 4. Nutmeg and cayenne, Plate VI, Fig. 4 and 5, and allspice, Plate VII, Fig. 3. All present a circular margin.

The angular edges are represented in rice and corn starch, Plate I, Fig. 1 and 2. Oats and sago, Plate III, Fig. 1 and 6.

Tapioca, Plate IV, Fig. 3, Pepper, ginger and mustard, Plate V, Fig. 2, 4, and 5, Turmeric and cinnamon, Plate VI, Fig. 2 and3.

The position and form of the hilum varies, some are located at one end of the starch grain as in potatoes, Plate I, Fig. 5, arrow root, Plate IV, Fig. 4, others are centrally located, as rice and corn, Plate I, Fig. 1 and 2, wheat, cocoa, Plate II, Fig. 1 and 4, oat, navy beans, rye, peas, barley, sago, Plate III, Fig. 1, 2, 3, 4, 5 and 6, lima bean, tapioca, Plate IV, Fig. 3, 4 and 5, pepper, Plate V, Fig. 2, turmeric, nutmeg and cayenne, Plate VI, Fig. 3, 4, and 5.

The hilum of some starch grains is a simple slit, potatoes and corn starch, Plate I, Fig. 2 and 5, peas and beans, Plate III, Fig. 2 and 5, lima beans and arrow root, Plate IV, Fig. 2 and 4, while in other grains the hilum is stellate as in rice, Plate I, Fig. 1, oat, rye, Plate III, Fig . 1 and 3, and nutmeg, Plate VI, Fig. 5.

Still another type of hilum is deep and cavernous as sago, Plate III, Fig. 6, tapioca, Plate IV, Fig. 3.

The hilum is a sort of nucleus about which the starch granules grows. It is observed that potato, wheat and arrowroot all have the concentric rings. These rings are probably the result of growth. Those having no rings appear smaller and are evidently younger. Pure potato starch in solution turns a ray of polarized light to the right, Plate II, Fig. 6.

Pure starch is a white, inodorous, amorphous, tasteless powder and can be preserved indefinitely. The texture of a cereal depends largely upon the size and shape of the starch grains, rice is hard, potatoes soft.

The most common test for starch is the use of a solution of iodine. Starch paste in the presence of iodine is a deep rich blue color. There is a great variety in the shades of blue produced by the iodine and paste, each kind of starch seems to produce its own peculiar tint.

Starch is insoluble in cold water, this is shown by mixing the two in making cold starch. The granules are suspended in the water while it is agitated but settle to the bottom when left quiet. In the presence of hot water the granules swell and form a paste which is almost clear and gives a blue color with iodine. Plate VIII, Fig. 2 shows paste made by pouring hot water over corn starch. Because of the insolubility of starch it is difficult to study the reactions toward different chemical reagents and this, together with the different shades of blue is probably the cause of such diverse and contradictory opinions concerning this class of food.

When treated with cold dilute caustic alkali starch grains swell. With cold dilute acids they loose their gelatinizing power. Starch paste is precipitated by tannic acid and is rendered soluble by treating with hot water, dilute acids and enzymes. It will not ferment with yeast. Yeast acts only on the sugars formed by action of heat, water and enzymes. When heated with concentrated sulphuric acid starch is blackened and is precipitated by alkalies. Dry heat has no effect unless it is over 110° C.

If the temperature be raised to 120° C dextrin is formed. The heat ruptures the starch cellulose and the starch granulose drops

- pop corn exemplifies this process.

Dextrin is soluble. It is intermediate between starch and maltose. The crust of bread is sweeter than the crumb, this is due to the dextrin formed in baking, the outside of the loaf being subjected to greater heat.

By treatment of starch with hot dilute acid it is hydrolized to maltose or grape sugar according to the following equations:

$$(C_6H_{10}O_5)_n + H_2O = \underset{\text{maltose}}{C_{12}H_{22}O_{11}} + \underset{\text{erythro dextrine - red with I}}{(C_6H_{10}O_5)_{n-2}}$$

$$\underset{\text{erythro dextrine}}{(C_6H_{10}O_5)_{n-2}} + H_2O = \underset{\text{maltose}}{C_{12}H_{22}O_{11}} + \underset{\text{achroodextrine - no color with I.}}{(C_6H_{10}O_5)_{n-4}}$$

The reduction of starch to dextrose has been utilized in the manufacture of commercial glucose. In Europe dilute sulphuric acid is used in the reaction and calcium carbonate is used to neutralise, thus: $H\ SO + CaCo = Ca\ SO + H\ O + CO$

The calcium sulphate is insoluble and so not harmful; but there is some objection to this method, because the pyrites used in the manufacture of the sulphur dioxide for sulphuric acid often contain arsenic and the poison may be directly introduced into the system in that way.

In this country hydrochloric acid is most commonly used and sodium carbonate to neutralize the acid.

$$2\ HCl + Na_2CO_3 = 2\ NaCl + H_2O + CO_2$$

the product being common salt, water, carbon dioxide. Some think the salt is an improvement to the flavor because the sweetness is

accentuated. As glucose is a simple sugar and soluble it is ready for immediate absorption; so glucose, instead of being shunned, should be used by persons of feeble digestion.

The dextrose formed in grapes or barley, if treated by an enzyme is converted into alcohol and carbon dioxide as follows:

$C_2H_{12}O_6 = 2C_2H_5OH + 2\ CO_2$

Certain enzymes act of their respective grains rendering the starch soluble. Every starch-bearing seed contains its own enzyme or unorganized ferment which renders the starch soluble. This starch is of use to the young plant in growth.

Starch when taken into the mouth should be well masticated in order that the enzyme ptyalin of the saliva may be thoroughly mingled with the mass. This changes a portion of the starch through a series of d extrines to maltose - a disaccharide. The saliva is an alkaline medium and the ptyalin acts most vigorously in an alkaline neutral, or faintly acid medium. The combined mass of insoluble starch, dextrin and maltose is acted on for a ti me (estimated by some authorities as thirty minutes) after it reaches the stomach; the action continues until the hydrochloric acid of the gastric juice changes the mass first to neutral then to faintly acid reaction when the process is checked and the ptyalin destroyed.

It is thought by some physiologists that peptone protects the ptyalin from becoming acidified at once. There is little action in the normal stomach on the carbohydrates. Shaefer says, "the maltose formed by ptyalin may be hydrolized to dextrose by hydrochloric acid sucrose inverted." As the food passes through the pylorous it

enters the duodenum and the pancreatic juice, an alkaline medium, begins its work here, the diastatic enzyme is amylopsin.

The amylopsin proceeds with the conversion of starch into the soluble form maltose, with great energy. Brown and Heron claim that the maltose formed by amylopsin is changed to dextrose by the intestinal juice, succus intericus, and an inverting ferment in the mucous membrane of the intestines. "Succus entericus possesses only feeble diastatic action on starch but has great power in converting maltose to dextrose." Experiments show that the blood stream does not carry maltose but does carry dextrose, therefore the maltose must be inverted before it reaches the circulation. Where maltose has been injected into the blood it has been thrown off by the kidneys without inversion. The blood maintains a certain percentage of dextrose at all times anything in excess of this amount may be stored in the liver or muscular interstices as glycogen, which is simply one of nature's provisions for "a rainy day".

One writer says that "the long and thorough cooking of starch is a modern way of infringing on mastication, because the starch already soluble and the mass so tender and soft does not need such thorough mastication."

After having tried a well cooked dish of cereal it is not likely that one will wish to return to the three or fifteen minute breakfast food. Plate VIII, Fig. 1,3 and 5 show the condition of corn, oats and wheat starch grains after five minutes rapid cooking. Fig. 4 and 6, ten minutes.

Many people find bananas very difficult of digestion, the

accompanying plate shows the bundles of starch granules from the ordinary banana filled with raw starch and surrounded by a protective cell wall, Plate II, Fig. 5. Bananas which are shipped north are picked while yet green and so the starch is not changed in the fruit itself. If the bananas were cooked and the starch liberated from the sac like cell wall, then the starch granules further cooked, the digestion of bananas would not be so difficult.

Starch which has once been converted to the soluble dextrins or maltose does not again become insoluble by evaporation. It is chemically changed.

SUMMARY.

Starches vary in size, contour and position and shape of hilum.

Starch is an universal food.

It is hydrolized by water, dilute acids and enzymes.

By processes of digestion and metabolism it is oxidized and converted into carbon dioxide and water.

By cooking starch it is rendered soluble and easier of digestion.

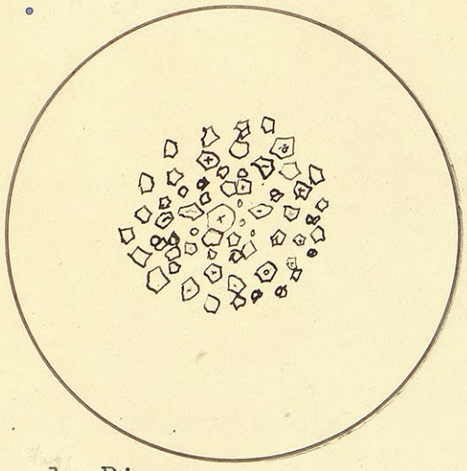


Fig. 1, Rice.

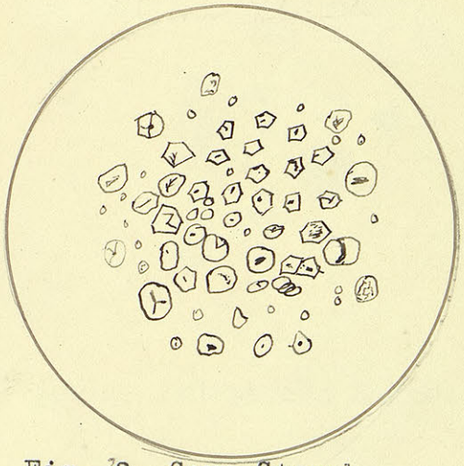


Fig. 2, Corn Starch.

Fig. 3, Soft White Flour - Shawnee Mills.

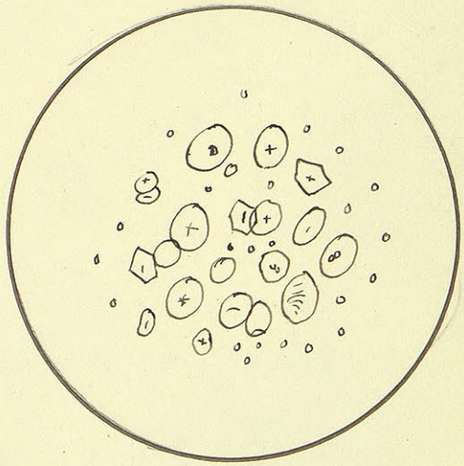


Fig. 4, Corn meal [illegible].

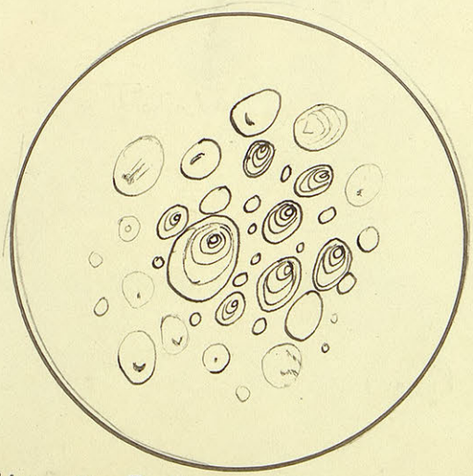


Fig. 5, Potato.

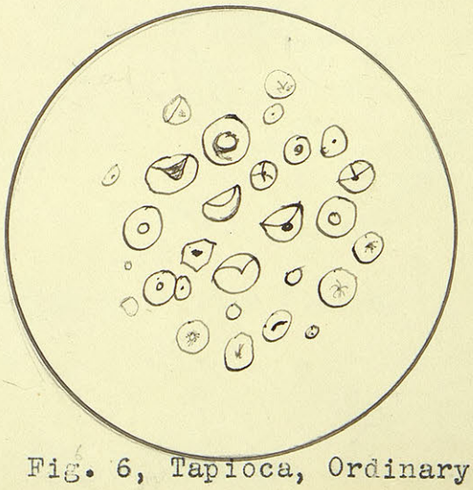


Fig. 6, Tapioca, Ordinary.

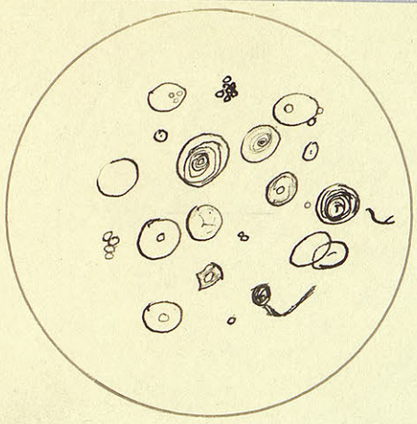


Fig. 1, Cracked Wheat.

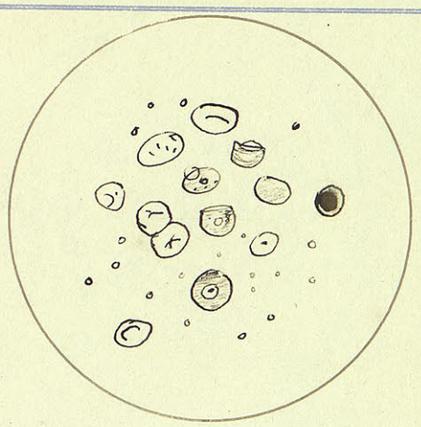


Fig. 2, Pulverized Sugar.

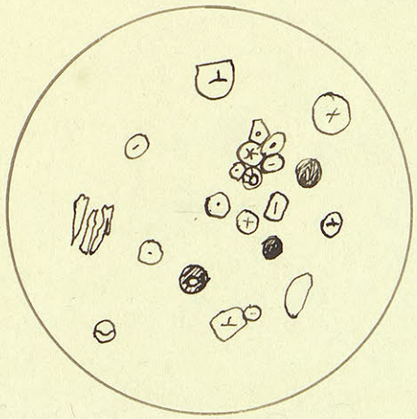


Fig. 3, Royal Baking Powder.

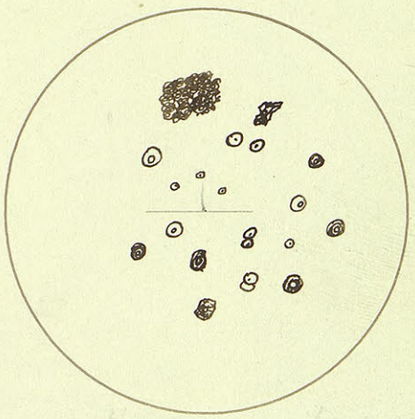


Fig. 4, Cocoa Bean.

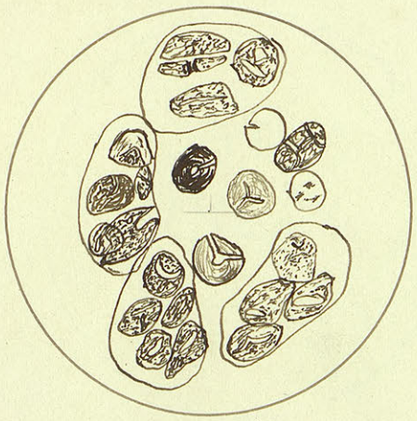


Fig. 5, Banana Starch.

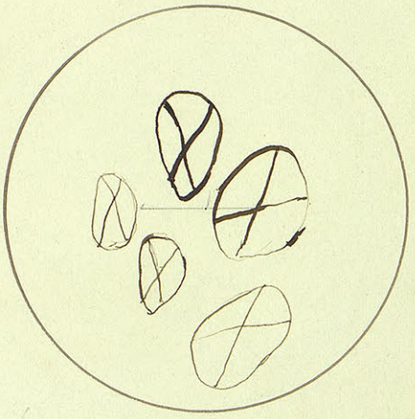


Fig. 6, Potato Starch.

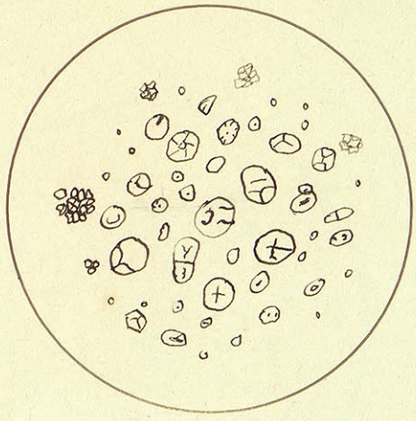


Fig. 1, Oatmeal.

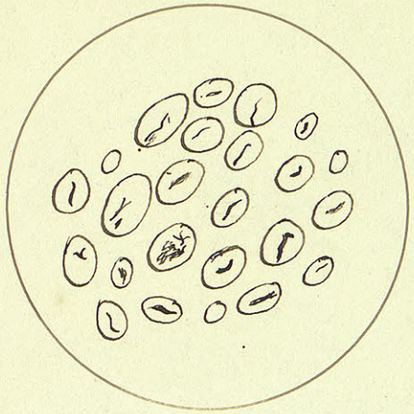


Fig. 2, Navy Beans.

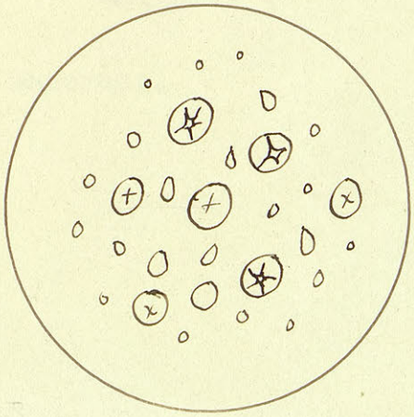


Fig. 3, Rye Meal.

Fig. 4, Barley.

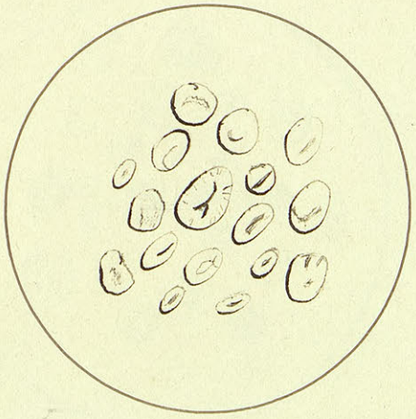


Fig. 5, Peas.

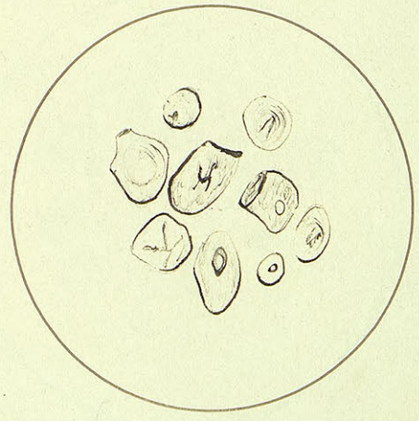


Fig. 6, Sago.

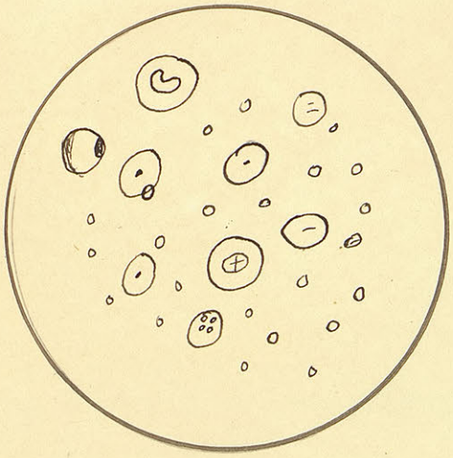


Fig. 1, Macaroni.

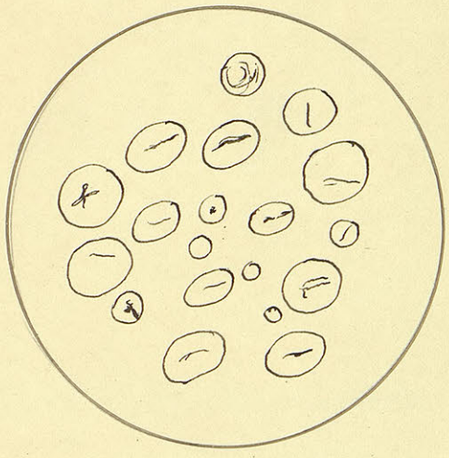


Fig. 2, Lima Bean.

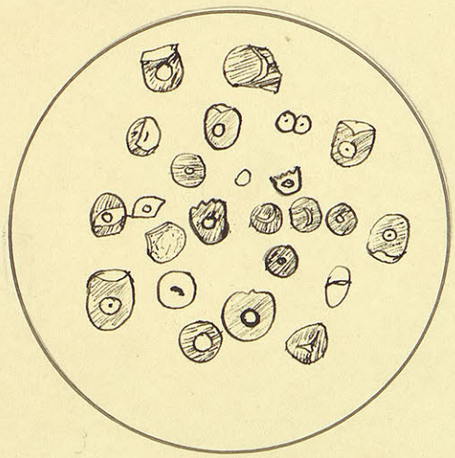


Fig. 3, Rio Tapioca, Pure.

Jas. P.Smith & Co., N.Y.

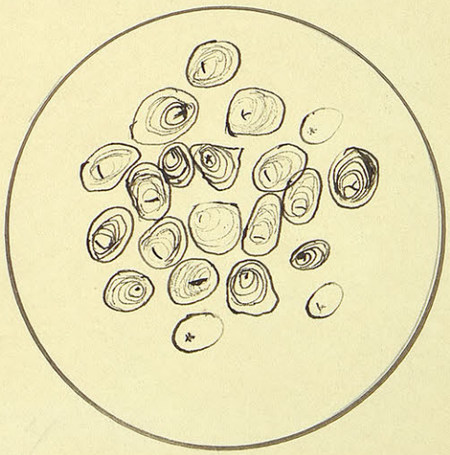


Fig. 4, Bermuda Arrow Root.

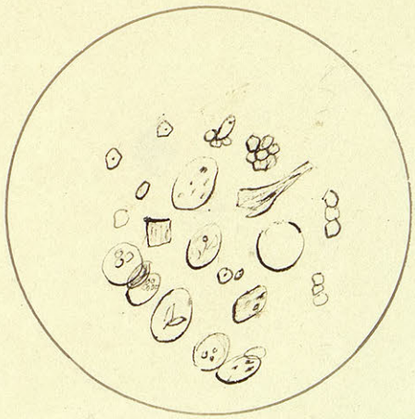


Fig.1, Powd Ginger, Adulterated.

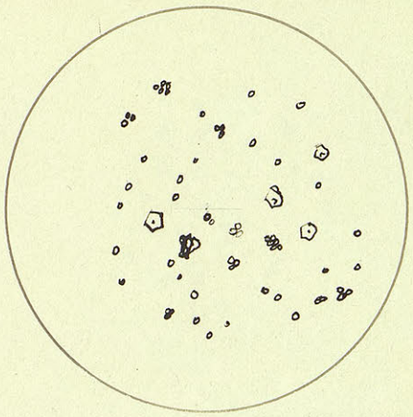


Fig. 2, White Pepper. Pure.

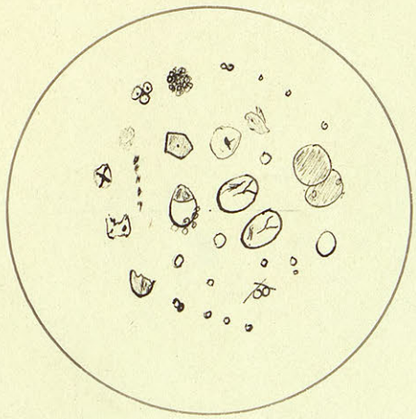


Fig. 3, White Pepper.

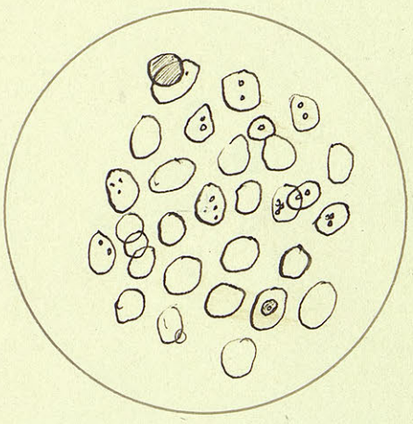


Fig. 4, Ginger. Pure.

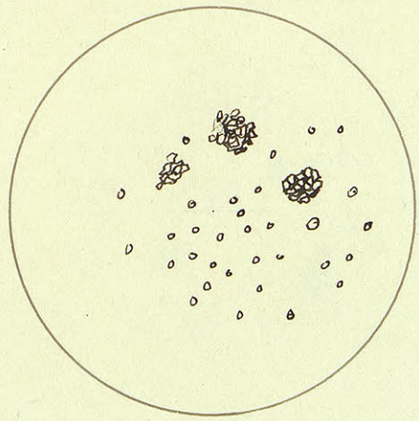


Fig. 5, Ground Mustard

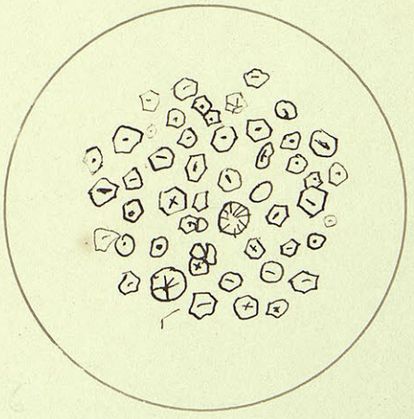


Fig. 6, Baking Powder. Victorex.

Parkhurst & Davis,
Topeka, Ks.

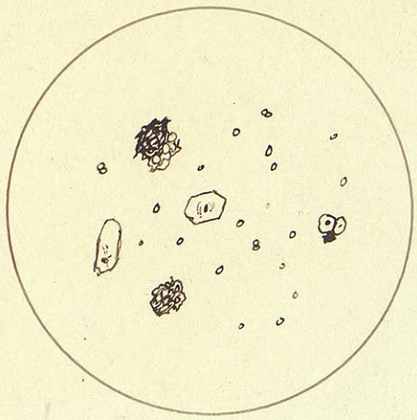


Fig. 1, Powd Cloves. Pure small oil drops.

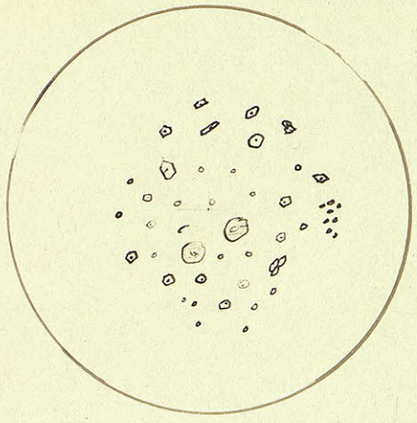


Fig. 2, Powd Cinnamon. Pure.

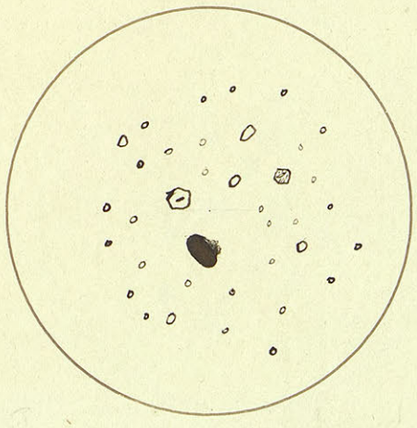


Fig. 3, Powd Turmeric. Pure.

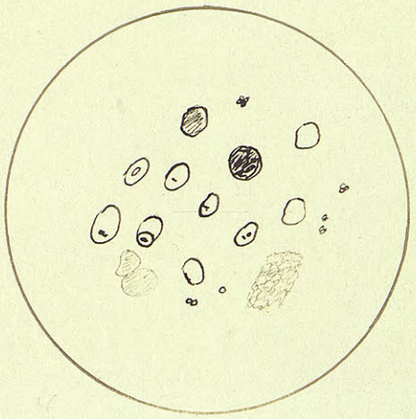


Fig. 4, Powd Cayenne Pepper. Pure.

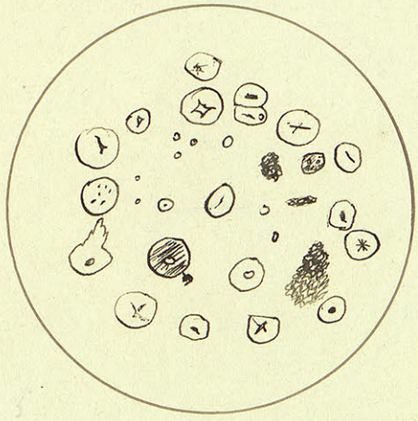


Fig. 5, Nutmeg.

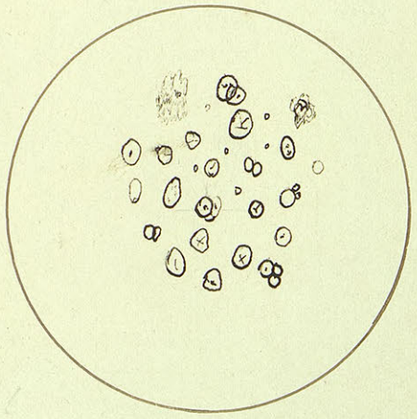


Fig. 6, Chocolate. Baker's.

Fig. 1, Salt, showing starch adulteration.

Fig. 2, Sweetened German Chocolate.

Fig. 3, Allspice, starch, resinous lumps, stone cells.

Fig. 4, Cocoa.

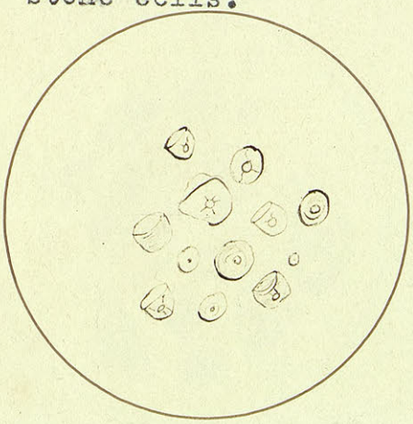


Fig. 5, Minute Tapioca.

Fig. 6, Celery Salt.
Franklin McVeagh, Chicago.

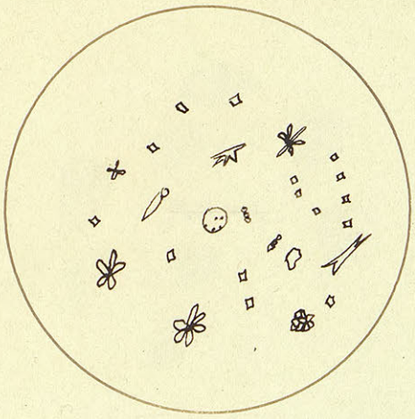


Fig. 1, Corn Starch, cooked five minutes.

Fig. 2, Corn starch stirred into boiling water.

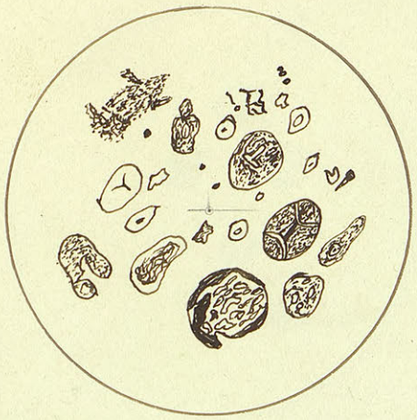


Fig. 3, Rolled oatmeal, cooked five minutes. Ordinary amt.

Fig. 4, Ten minutes.

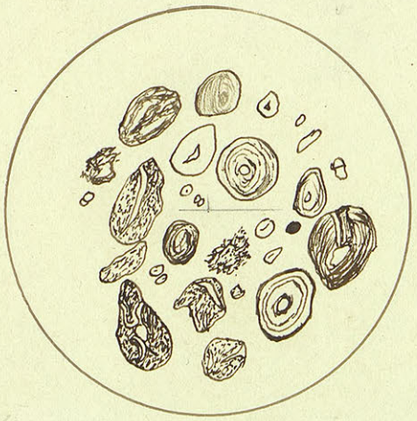


Fig. 5, Cracked Wheat cooked five minutes.

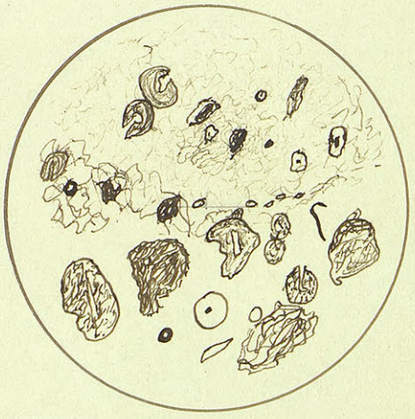
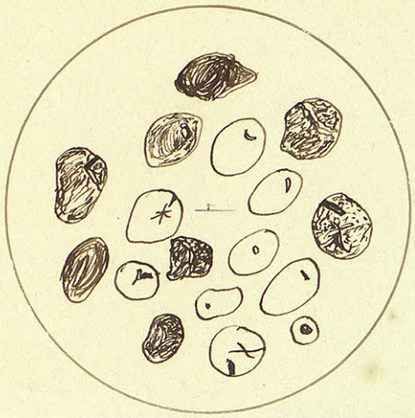


Fig. 6, Ten minutes.



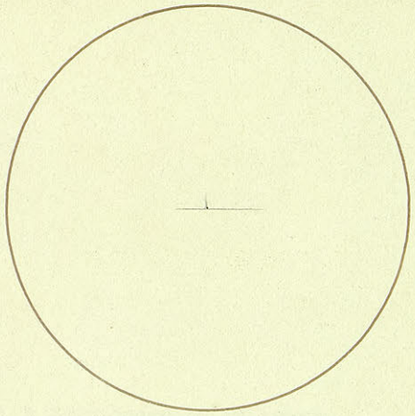
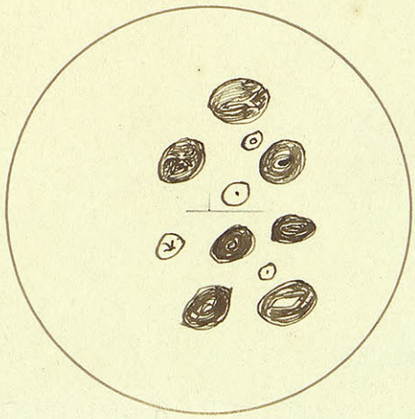


Fig. 1, Epps Cocoa.



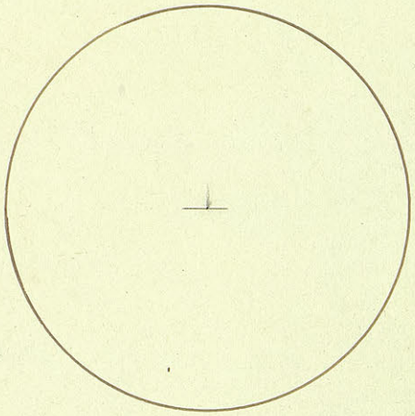


Fig. 2, Lowney. *Cocoa*