

# **Part One**

## **Starch , Glucose & It Derivatives**



## CHAPTER - 1

### STARCH

Starch ( amyllum ) is one of the most abundant plant materials in the world. It is a carbohydrate - ( a very large group of compounds containing carbon , hydrogen , and oxygen, the latter two elements being essentially in the same ratio as they exist in water, namely, two atoms of hydrogen to one of oxygen . Hence the name carbohydrates , or hydrates of carbon ) - . Besides starch , carbohydrates include such important substances as cellulose, sugars, and gums, all of which are widely distributed as natural plant products Carbohydrates furnish the basic material for most buildings, paper , explosives , foods , alcoholic beverages, clothing , fuel , etc .

Carbohydrates are classified as : mono saccharides , di saccharides , tri saccharidbs , and poly saccharides . Mono saccharides are simple sugars with six carbon atoms which cannot be hydrolyzed to smaller molecules . Dextrose ( glucose ) is a mono saccharide . Di saccharides contain twelve carbon atoms and can be hydrolyzed to , two sample sugars . Di saccharides include : sucrose ( common sugar ) , lactose , and maltose .Tri saccharides contain eighteen carbon atoms and yield three molecules of simple sugars on hydrolysis . Raffinose is the best known tri saccharide . Poly saccharides which are very numerous , do not have the sweet taste of the other carbohydrates , are insoluble in water , and are of high molecular complexity .on hydrolysis , a poly saccharide molecule yields many molecules of mono saccharide . sugars , Starch , cellulose , and glycogen are polysaccharides .

Starch is formed in all green plants , probably first as soluble starch , and is stored as microscopic granules in all grains and tubers as a future food supply for the germinating seed . Hence it is commercially obtained from cereal grains such as corn , wheat , and rice ; from tubers such as the potato ; from roots such as the sweet potato , manioc ( the source of tapioca and cassava ) , and arrowroot ; and from the pith of certain palms such as the sago palm .

With the aid of radiant energy from the sun , the sugar glucose is formed in the leaves and stems from carbon dioxide taken in through the stomata of the leaves and from water taken in by the leaves or from the soil by root hairs . Oxygen is a by - product of this complex reaction and is returned to the air . The glucose normally diffuses as such to other parts of the plant or is converted to soluble starch which then diffuses out . If glucose formation exceeds the rate of diffusion , the glucose is transformed into higher sugars , starch , and cellulose. Starch is very rarely formed other wise .

Starch granules are usually formed in the cytoplasm of the chlorophyll - containing cells through the activity of the chloroplasts . They vary with light intensity from none to many , being most abundant in late afternoon . They may disappear entirely from these cells in the dark , when the photo - synthetic process is slight or absent ; the starch then, in soluble form , diffuses from the leaves to other parts of the plant or is reconverted into sugar by diastatic enzymes . Thus , plant leaves seldom contain starch in the early morning or on dark days.

The granules first appear as very small specks and increase in the cytoplasm during the period of light until they completely fill the cell. Temperature, moisture, carbon dioxide, and light are the principal factors influencing their growth. The granules vary widely in size and shape , even those from the same plant , having an approximate diameter of from 0.25 micron to over 100 microns. They are un-crystallizable and insoluble in cold water. They cannot escape the cell walls as such , but may be broken down into sugars by the action of diastase and other plant enzymes .

Starch is present in every plant in the form of stored food . It is organized into granules by leuco plastids , colorless plastids which are present in the cells of storage structures which light cannot penetrate , i.e ., the grains or endosperm of seeds , underground stem tubers , stems , piths , and roots . The quantity of stored starch is most abundant at the end of the growing period.

The first starch was probably obtained from wheat by the Egyptians, possibly also by the Chinese and Arabs. It was later made by the Greeks from Egyptian and Cretan wheat and called amylum. The grain was steeped in water and kneaded in cotton and linen cloth bags placed in containers of water. The starch was collected at the bottom of the container, the gluten which forms a large part of the nitrogenous material being retained in the cloth bag. The water was then poured or drained off and the starch dried as quickly as possible on porous bricks in the hot sun. Unless quickly dried, it became a sour mass.

Wheat starch was used by the Egyptians as food and for binding fibers to make papyrus, prior to 3000 b.c. Potato starch, first made in Europe during the sixteenth century, was much used in European royal courts about 1700 a.d. to stiffen and to give a fine finish to linens, also as a face powder and powder for wigs. Starch is now prepared on a large and increasing industrial scale from the parts of easily grown plants in which it is abundant (see Table 1.1).

The processes employed in the manufacture of starch vary with the raw material and the use to which the starch is to be put in general, many roots and tubers with a high content of starch can be broken up or rasped to open the cell walls, sieved with water through fine sieves, and refined to remove impurities. Some commercial starch raw materials require chemical treatment to liberate and purify the starch. The starch, having a specific gravity of about 1.5 when wet and of 1.6 when dry, usually settles out from water suspensions, especially if the granules are large. Wheat is less used than formerly and wheat starch is now obtained only to a relatively slight extent, or in connection with the production of gluten, mono-sodium glutamate, and amino acids, or when the wheat is in large surplus and available at a very low price and cannot be kept for a long time. Potato starch is produced mostly in the northern parts of Europe and in the United States and in Japan. Tapioca is produced in the largest quantities in Brazil and in the Dutch East Indies. The cyanide compounds present in the manioc roots (Manihot utilissima) are removed in processing. Sago starch is produced from the trunks of sago palm trees in the

tropics and is often refined in industrial countries . Rice starch is produced mostly in industrial countries from native or imported broken rice . Tous les mois is made from the tubers of *Canna edulis* . Some starch is made in the Orient from various *Orcbis* tubers . Some arrowroot starch is obtained from the roots of *Maranta arundinacea* , grown in the West Indies and Brazil. Banana starch is prepared from the unripe fruit of *Musa sapientium*

About one - third of the corn starch is sold as such : the remainder is converted before drying into corn sugar syrups ( corn glucose ) or solid glucose sugar . If purified sufficiently , solid glucose is marketed as dextrose or corn or potato dextrose . After drying, the starch - producing company may convert some starch into dextrin, a product structurally between starch and sugar ; or a dextrin manufacturer may buy corn starch , tapioca starch or flour ( manioc starch ) , and potato starch , and concert these into many kinds of pure and mixed dextrans and other adhesives and textile firajshes

Proteins , fats , and carbohydrates ( especially : starch , sugar , and cellulose ) , with water , represent the food needs of man and all animals . Starches are the storage carbohydrates and principal energy foods , although all carbohydrates and fats are eventually oxidized to produce most of the heat and energy of the body . Proteins , which are very complex nitrogen - containing compounds , also yield heat and energy in the animal body and produce blood constituents , etc . Starch , by digestion and assimilation , is either used at once or becomes partly converted into stored food as glycogen , the only animal starch , which is produced and stored in the livers of mammals .

***TABLE 1.1. Approximate Starch Content of Various Plants :***

<b>Plant</b>	<b>Percentage in Plant</b>
Barley	38 - 42
Buck Wheat	35 - 48
Corn	65 - 78
Nanioc	40 - 82
Oats	30 - 40

Potatoes	18 - 25
Rice	50 - 69
Rye	54 - 69
Sweet potatoes	15 - 29
Wheat	55 - 78

Most of the starch eaten by man and animals is in the form of mixtures such as cereal products and vegetables . The most commonly prepared starchy foods are bread and macaroni . Large quantities of starch , mostly corn starch , are used in making starch sugar (glucose), which is then used in large quantities as a general sweetening agent and in confectionery . Some is used as a food after surgical operations, being injected directly into the blood stream .

The food starches include arrow root , sago , manioc ( tapioca or cassava ) , potato , wheat , rice , and corn . They are used in making puddings , as pie ' fillers " and soup thickeners , and in gravies , general confectionery , gum drops , salad dressings and mayonnaise , jellies , wafers , etc . Slightly modified starches of various kinds are made with thick - or thinboiling properties and controllable fluidities for use in food products to aid their stabilizing and emulsifying properties.

Starch serves man not only as a food but as an important industrial material . It is used in textile mills as the leading thickener in calico printing pastes ; for dressing and finishing cloth ( plain , dyed , or printed ) ; as a general stiffening and finishing material ; and for sizing warp threads to give them the strength , smooth surface and resistance to wear while being woven into cloth in either slow - or high - speed looms . Some low - cost starch is also employed as a filler in coarse textile goods or cloth with a low count ( relatively small number of threads per inch ) . Starch is used in thin gelatinized form as a stiffening and finishing material in laundering . The trend now is somewhat toward soluble starch preparations .

The paper industry uses large quantities of starch , especially corn , potato , and tapioca , as a sizing material to aid in holding the

cellulose fibers together so as to make the sheet resistant to writing ink penetration ; to give paper a smooth and lustrous finish suitable for fine printing papers ; to bond fibers with clay , titanium oxide or other pigments , soap , and dye – stuff ; and to absorb and adsorb printing inks in high - speed printing presses to prevent offset . Starch is usually modified by enzymes for use in the paper industry . Another important use for starch is in the production of adhesives such as dextrin . Dextrin is used for gummed envelope flaps , stamps , and tapes , and as a binder in fireworks , match heads, and rugs . Starch and dextrin are both extensively used in some bill - board , wall paper , and office pastes and adhesives , and as bonding agents in plywood. Dextrins and some modified starches are commonly referred to as vegetable glues , as distinguished from the animal glues made from fish waste , animal bones and hides .

Starch is often a component in dry battery fillers , a diluent in some dynamites , a water absorbent in mixtures such as baking powder mixtures which decompose when they become moist , a filler in some soaps and insecticides , and an adhesive in making paper boxes . With a 1 to 2 per cent soda solution , it yields an excellent photographic mounting and library paste . It provides sheen and slip to rubber goods and serves as a dusting powder in their manufacture ; it is also used for coating molds in metal and alloy foundries

Some low – grad , low - cost starches are used as binders of coal and coke dust and fine screenings in making briquettes . In making a " cement " for some leathers and textiles , musty grain - either wheat , barley , or rye - is crushed , and a thick pulp containing starch is made with water . This is stirred to obtain a uniform mixture and allowed to ferment to a brown mass in tightly covered fermenters . with gas ducts leading to a boiler grate , until a very viscous paste is formed . The resulting paste is treated with a saturated alum solution to stop the fermentation and with chemicals to partially deodorize the mass or even to impart to it a pleasant odor .

Most starches yield thick - boiling pastes . For certain purposes as for penetration into fibers , a thin - boiling paste is needed . To



produce thin-boiling properties, the thick - boiling starch is heated with chemicals , usually an acid , or treated with an enzyme . Thus , a lower viscosity and a more penetrating paste is obtained . Many chemicals , including oxidizing agents , are employed in modifying starches . Such chemicals or processes , or their specific uses , are often patented..

The pulp from root and tuber starch factories is utilized as an animal feed . In the case of corn and wheat , the gluten and wastes both find use as a feed . Gluten as a diabetic food and as a source of sodium glutamate for soups , and corn oil for cooking use , are secondary products .

## CHAPTER - 2

### PHYSICAL STRUCTURE OF STARCH GRANULES

Starch granules appear in various sizes and shapes , most often having a rounded or spherical surface . When pure, the granules appear as a white, glistening , odorless , and tasteless powder . Starch cannot be crystallized, but under certain conditions of preparation and drying the granules mass in blocks. These may take on a prismatic shape . Starch is insoluble in cold water and in all neutral solvents . Starch from different sources can best be identified microscopically, especially by granule size and shape .

Under a microscope the starch granules are minute structures built up of molecules arranged in layers , usually concentrically. The size varies from less than 1 micron to about 150 microns (  $\mu$  ) , depending on the plant source . The shape of starch granules from different plants also varies from small polygons ( corn ) to large spherical granules ( wheat and rye ) . The hilum or nucleus is usually a dark spot eccentrically located in the granule . Possibly , as the granule develops in layers , the starch – amylose - forming material becomes temporarily exhausted and a layer of amylopectin , of slightly different composition , repeatedly builds up. Amylopectin forms especially on the surface of the granules within the cell walls in the plant .

*Microscopic characteristics of commercial starches are given below :*

**Corn** : Corn starch granules are quite uniform in size . The longest axis ranges from 10 to 30 ( 0.01 to 0.03 mm ) . They are more angular than the other common starch granules except rice , many being polyhedral. There is a central hilum: fissure is star – shaped ; rings are very slight ( 285 X ) .

**White Potato** : White potato starch granules are among the largest ; they have a characteristic appearance . For the longest axis or largest diameter the size range is from 1 to 120  $\mu$  , the average being about 30 to 40  $\mu$  . The small granules are round and the large granules are oval

or irregular , sometimes oyster - shell shape ; the hilum is eccentric , rings are numerous and complete . With polarized light , crosses divide the granules into four irregular surface sections ( 485 x ) .

**Wheat** : Granules of wheat starch are rounded ( almost spherical ) , show great variation in size . and are usually 5 to 50 u in diameter . There are more small than large granules , and few of intermediate size, rings are concentric,hilum is visible ( 400x ) .

**Tapioca** : Tapioca ( manioca or cassava ) starch granules are compound , made up of two to eight components . These compound granules break up in the starch extraction and purification process , often showing one or two flat surfaces . The component fragments range from 5 to 35 u ( 0.005 to 0.035 mm ) , an average dimension being about 15 u . Many granules are egg - shaped with one end cut off , leaving a concave surface . Some granules are curved on one side and irregularly flat on the other . The granules usually show a distinct eccentric hilum , and occasionally striations may be seen ( 400 X ) .

**Sago** : Sago starch granules are compound and of a tapered oval or elliptical shape , sometimes round, sometimes with projections, as in the pith of the sago palm trees. In commercial sago starch there are relatively few unbroken granules . There is a large granule component and there are usually a few small components . The large component or fragment is often conical in shape , with flattened ends , where the small components have been split off . The large components measure about 50 to 70 ,u, the small ones from 10 to 20 u. The hilum is eccentric ; the rifts are deep ( 400 x ) .

**Rice** : Rice starch granules are like those of corn but more angular . They are 2 to 10 u in diameter or for the longest axis ; rings are not evident ; hilum is central but distinct ( 400 x ) .

**Sweet Potato** : Granules of sweet potato starch more nearly resemble corn in shape than the other root , tuber , and cereal grain starches . They are more variable in size than corn and not as angular , some granules being almost round. There is a well - developed hilum ,

usually star – shaped ; sometimes there is an irregular polarized light cross , to 50 u , the average being about 17 u ( 485 x ) .

**Arrow root** : Arrow root starch is made up of simple granules some what like those of potato starch but smaller .

**Oat** : Oat starch granules are usually small ( about 5 to 12 u ) , and are often massed in small clusters , individual granules being separated by fine dividing lines . Rings and hilum are not noticeable .

**Buck wheat** : Buck wheat starch granules are of simple structure and polygonal in shape , of about 5 to 15 u , with an average of about 8 u . for the longest axis . There are some compound granules consisting of 2 to 10 components ; such components being often irregularly round .

**Rye** : Rye starch is made up of many small and a few large granules with a long axis ranging from 5 to 50 u , an average being about 25 to 30 u . Their shape is much like that of wheat -spherical, oval , and flattened spheres . The hilum is often quite marked ; there are stellate rifts and concentric rings or striations ( 400 x ) .

**Barley** : Barley starch , like wheat and rye starches , is made up of many large , many small , and varying quantities of medium - size granules . The form of the granules is less regular than that of wheat , being round, oval , elliptical, pear - , or kidney - shaped . Longest axis ranges from about 5 to 40 u , an average usually being about 30 u . No hilum is apparent . Fissures are rare and never stellate . Some granules show rings ( lamellations or striations ) ( 400 X ) .

Size of starch granules in general is largely dependent on the processing ; granules under 5 u are easily lost . There are some very small or young granules in the roots, tubers , and seeds of plants , the longest axis being under 1 u . Polarized light on most starches shows bands or crosses , generally radiating irregularly from the hilum in four directions .

There are many starches prepared occasionally , on a very small commercial basis, for specific purposes. Such may be various bean , pea , cereal , nut , seed , tuber , and root starches . These have definite microscopic characteristics which can be used in their identification .

Some starches , such as wheat and rye , require supplementary tests for certain identification . The microscopic shapes of starch granules , as stated above , are generalized . There may be many slight irregularities , as nodules on large granules , flattened sides , etc. , due to conditions affecting their growth or development .

## CHAPTER - 3

### WHITE POTATO STARCH SPECIFICATIONS

Some potato starch standards and specifications have long been in use in the European markets .The German grades , in 1925 , were principally the Prima or first - class starch , and Second Class.

Moisture content has been regarded as satisfactory at 20 per cent approximately the starch – air - moisture equilibrium .

Potato starch usually contains a very small quantity of organic acid . Prima starch , customarily , must be free of sand or dark specks and have a recognized good white color and a marked luster; it must also be almost free of potato oil odor or any other unpleasant or sour odor , and have a neutral taste .

And it suggested luster specifications based on average granule size as follows : finest quality starch, 0.0355 mm ; superior Prima starch , 0.0328 mm ; second product Prima starch , 0.021 mm ; Secunda starch , 0.0169 mm ; and Tertia starch , 0.0125 mm .

In Europe , leading potato starch markets require for a prima or first class potato starch one that is free of acid and chlorine , and that does not contain more than 20 per cent moisture . The term " prima " has come to mean recognized characteristics as regards color , luster, a low speck count, relatively low ash, taste , odor , etc . A good white color is usually desired and specified. Rotted potatoes, poor quality water , poor washing of the potatoes , poor processing , together with the presence of many very small starch granules, result in an " off " color and a low reflectance. Small potato starch granules have a high adsorptive and absorptive capacity for colors, odors, and other impurities. Hence, they are very difficult to purify . Rapid and early removal of protein water usually leads to the whitest starch . This can be measured photo metrically on a quantitative basis, and expressed on a percentage basis in terms of pure precipitated magnesium oxide as a standard .

Odor of a first grade starch must not be sour, musty, or otherwise unpleasant. Such odors are due to poor processing or to a lack of keeping a starch factory , starch slurry piping, and equipment clean. A material such as potato starch with proteins and mineral salts in the presence of moisture offers a most excellent opportunity for bacterial growth and enzymatic action . There is a small quantity of an oily material, known as potato oil , associated with potatoes and potato starch. The starch holds this oil tenaciously. In high quality dry starch there is usually a slight but not a disagreeable odor. A dextrin odor is sometimes noticeable due to some overheating during the drying process. Any dextrin is evident in the water-soluble extract. In the making of dextrin from potato starch, the trace of potato oil is changed unfavorably and goes over, into the,dextrin.

Then, if the dextrin is used for postage stamps or gummed envelopes, it becomes noticeable. The odor of the potato oil can be reduced or eliminated by drying either to a lower moisture content or in a vacuum drier in the starch drying operation. Hence, many specifications for starch for dextrin manufacture call for a low moisture content. Otherwise, the odor in the dextrin of gummed articles, as stamps and envelopes , must be disguised by perfumes or other chemicals.

Potato starch should always be free from chlorine, nitrogen, and sulfur. If chlorine has been used as chlorine gas introduced into the process water, or as a hypo chlorite, to destroy B. coli or for some bleaching action of impurities, proper processing should eliminate all of the free or combined chlorine . Sulfurous acid alone can bring about a whiteness or reflectance of 100 per cent relative to pure magnesium oxide or very close to it. The excess is always eliminated in the purification process.

### **Notes :**

(a) Grade AA (superfine) would be a special, extra quality premium scorch - superior to grade A, a large average - sized granule starch with only a small proportion of small granules, very clean, with

a low ash, and a reflectance of 97-100.

(aa) Grade A starch should also have (1) a "good" feel, (2) a crystalline, light - reflecting, or shiny appearance, (3) a good "crunch" when a sample is rubbed in the palms of the hand or pressed in a bag, (4) a good white color when viewed by the normal eye, and (5) practically no odor or only a trace of odor; not strong or sour. In classifying, no one item should necessarily fix the grade. A majority of the essential properties for a definite use should take precedence.

(b) The viscosity of starch pastes in water increases rapidly with concentration; hence, a 5 per cent paste has much more than five times the viscosity, of a 1 per cent paste. Viscosity of a 2 per cent paste is much over twice that of a 1 per cent paste.

(c) Textile manufacturers are primarily interested in a high viscosity and one which does not lose its viscosity rapidly when agitated and circulated by pumps in heated size make-up and warp-sizing tanks. A 500 Brabender unit viscosity for a 5 per cent paste corresponds to about 2700 centipoises for the same concentration. Some potato starch pastes have a viscosity of over 2700 centipoises for a 1 per cent concentration. For textile finishing, a grade A starch of high viscosity, reflectance, and cleanliness is desirable as the same starch would generally be used for both slash sizing and finishing. Dextrin is also used for sizing and finishing textiles.

(d) The paper industry is the one most concerned with starch specifications. Although a moderately high viscosity is desirable, low speck count, high reflectance, and a pH in the range of 6.5 to 6.9 is necessary. The narrower pH range is necessary because enzymatic conversion is greatly influenced by degree of acidity. Enzymes are costly and conversion of the starch must be uniform and to the same degree, on a continuing basis. Fortunately, it can be controlled to within a few units. In addition, paper mill operations are of such a nature that a variation in the raw materials can cause much difficulty. The starch may be used primarily as a binding material for cellulose fibers. Fine clays and pigments are bonded by starch to the cellulose



fiber base in printing and in coated papers. The paper, with its starch and other components, must absorb printing inks quickly and uniformly on the surface. The starch serves as an aid in quick drying without smudge or transfer in high-speed presses and without having the ink pick off flecks of coating. To prevent writing ink penetration, sizing is necessary. Paper specifications have been developed to a great extent and often include degree of whiteness and a limit to the number of specks for unit surface areas, folding and tearing strength, etc. In the preparation of paper . piilps for making paper, hydration of the cellulose in beaters and jordans is a factor and, if beater sizing is used, starch requires uniformity to meet the many laboratory tests to which paper is usually subjected. Starch hardens and stiffens a sheet of paper; heating during drying causes gelatinization. The paper then has a better "rattle" as well as greater resistance to ink penetration. Sodium resinate and alum are also used in paper sizes, alone or with starch. Therefore, a uniform grade A starch regularly meeting the needs of paper manufacturers is usually suitable for most other industrial uses except as a textile warp size. For the textile and paper trades, tolerances, expressed numerically, are desirable. They can only be developed after much study, without haste, and by agreement among producers, dealers, and consumers.

(e) For many purposes, a grade B starch would be suitable. Although for fine laundry work, a grade A would be desirable, a grade B could be used, and often is. For preparation of chemical derivatives, only a grade A or AA should be used.

(f) In preparing leather from animal hides, a grade B or C starch is suitable in dehairing, plumping, and tanning processes.

(g) For food purposes, such as its use as a soup thickener, in making fine salad dressings, in confectionery, bakery goods, etc., grade B, free from B. coli, would be sufficiently pure.

(h) As a binder in plywood and in coal dust briquettes, grade C would be used. Low cost would be an essential factor in such operations. The coal briquettes with their starch binder should be run

through a low - cost water - proofing bath on an endless belt to prevent disintegration caused by air moisture changes which may occur during storage.

(i) As a circulating mud component in petroleum and other drilling operations, the lowest grade starches would suffice.

(j) For slip in rubber goods, large granule size is desirable. For making nitro - starch explosives, a small - granule starch of grade A of general purity and from which unused nitrating acid can easily be removed by washing, is necessary .

(k) In the preparation of starch acetate and other starch derivatives, high purity and uniformity are essential properties.

(l) Although specifications are of principal interest to the consumer, analysis of starch and interpretation of analytical data are of great importance to the starch manufacturer in maintaining quality and uniformity and in controlling various units in processing.

(m) Powdered potato starch is a material of such particle size that at least 90 per cent of dried and sieved potato starch passes through a 200 - mesh to the inch sieve. It may have been pulverized in a mill or in a blower and then sieved, or simply dried and sieved.

Pearl starch is a mixture of lumps and fine particles, as removed from a dry house or mechanical drier, which has no. been pulverized in a mill or blower, and which has not been sieved.

### **Moisture :**

German standards for potato starch moisture are: not over 20 per cent for "superior" and 20 per cent for "prima." Naturally, the starch manufacturer will increase his production costs and dust difficulties and obtain lower yields by excessive drying. There fore, European starch manufacturers usually dry potato starch to about 19.0 to 19.5 per cent moisture. Some American potato starch manufacturers dry regular commercial starch to about 18.5 per cent, unless otherwise

specified. A dextrin manufacturer may specify 14 per cent moisture in America and sometimes about 7 or 9 per cent in Europe.

### **Ash :**

The ash in a potato starch is due to a small quantity of potassium phosphate and a trace of other salts. A very slight trace of iron is present due to the potatoes and to the use of iron and steel pipes, and equipment. A high ash indicates the presence of impurities. Ash content of a grade A potato starch is normally about 0.2 to 0.3 per cent. It should never exceed 0.5 per cent.

### **Viscosity :**

Viscosity Unit is the tangential force acting on one of two parallel planes, each one cm square and one cm apart to cause a velocity of one cm per second of the movable plane relative to the fixed plane, the space being filled by a liquid, a starch paste, a solution, oil, or a colloidal - type material. It can also be regarded as the resistance to the flow of a liquid or a gas, or a measure of the combined effects of adhesion and cohesion.

For example , if a fluid ( usually a viscous one ) fills the space between two parallel planes a definite distance apart (S), then the tangential force (F) required to maintain a velocity (V) of one plane with respect to the other will cause a rate of shear equal to  $V/S$  through the substance. Obviously, the force (F) is equal to that caused by the internal friction of the substance. The ratio of this force to the rate of shear is called the coefficient of viscosity, expressed by the Greek letter -  $\eta$  ( eta ) ; hence  $\eta$  equals  $FS/V$  and  $F$  equals  $V/S$ . The scientific unit of viscosity is the "poise." Fractional units then are the decipoise ( one - tenth of a poise ) , the centi-poise, and the millipoise.

For convenience, specific viscosity rather than absolute viscosity is used. Specific viscosity expresses viscosity in terms of some standard, usually water, as unity.<sup>3</sup>

Viscosity of 1 per cent potato starch pastes made with distilled

water heating the starch - water suspension to 100°C in 7 minutes and holding in at 100°C for 8 minutes, yields potato starch viscosities usually from about 900 to 7000 centipoises. Many factors influence viscosity. The Stormer Scott, Engler, and Dudley viscosimeters are extensively used to determine starch viscosity. There are also many other means for determining viscosity. Some textile mills and laboratories use a Brabender viscosimeter or amylograph with a chart drum, paste cup, heating element, and stirrer. A record maximum viscosity in Brabender units and drop in viscosity with temperature and time is recorded on a chart. A reading of 500 Brabender units for a 5 per cent starch paste corresponds to about 2700 centipoises. The Corn Industries, Caesar, Brookfield, MacMichael, and "Falling Sphere" are other viscosimeters often used by starch chemists

### **Granule Size :**

Common American and foreign varieties of potato starch usually have a maximum granule size of about 80 u, 0.08 mm (0.003 inch), with some granules exceeding 100 u. The longest measurement across a granule is usually given. This is the longest axis and is often referred to as the diameter, although few potato starch granules are circular in cross section. The smallest granules are under 1 u. and the average for common American and European varieties is between 32 and 37 u. Luster is dependent not only upon the granule size but also upon the purity of the starch. Samples tested by the writer yielded results about as follows: B.K.M.F., the highest quality European starch in 1-938, was 42 u. Average foreign and domestic superior, prima, or class A starch is then about 0.032 to 0.037 mm (32 to 37 u) : second grade or class B potato starch, 0.020 to 0.035 mm; and third grade or class C potato starch, under 20 u. The starch from dust rooms connected with mechanical driers, after being drawn through cyclones and fans, has an average granule size of about 0.020 mm.

Quality cannot be judged from granule size alone; in fact, for many uses, it is unimportant. For some purposes, a small granule size is preferred. Luster is also affected by overdrying, and a very noticeable loss in luster occurs when the starch has been dried to

below 10 per cent. Then, the large starch granules often have a broken or fissured surface, instead of a smooth one.

A grade A potato starch will have the largest granules and represent the best processing. Some German starch chemists grade potato starch by granule size as follows :

Over 0.035 mm	Extra superior AA
0.032 - 0.035	Superior A
0.020 - 0.031	Grade B
0.012 - 0.019	Grade C

The smallest size granules are the most difficult to purify, holding both colors and odors by surface adsorption and by absorption. Brown starch

usually is made up mostly of grade C and poorer quality granules. Starch from dust rooms connected with rotary driers is of a B to C grade. In processing, the smallest granules with high absorptive power for colors and odors may be lost or eliminated due to the porosity of the filter or centrifuge cloth used, or to loss as dust.

### **Microscopic Appearance :**

Microscopic appearance can best be determined by examining a drop of starch in suspension. One part of starch suspended in 10 to 50 parts of distilled water on a slide and covered with a cover glass will show not only the size but the kind of starch present, the condition of the granules, and presence of foreign material. Overdried, large starch granules have cracks or fissures in the surface and a rough appearance. With good refining, proper selection in mesh size of refining screens and silks, and tabling or centrifugal refining, practically no skin or fiber pieces should be found in a high-grade starch. Varying quantities of the impurities from the potatoes, such as cellulose ( cell wall fibers ) , skin pieces, dirt, etc., are often found in starch. Coal dust particles and dirt from roadways, etc., are drawn by drier fans into a starch factory and are evident in the finished starch under a microscope , but not to the unaided human eye.

Iodine staining is some times help ful .

### **Impurities ( Dirt ) , in Starch When under Water :**

Insoluble impurities in starch can be detected by placing a 25 gram sample of starch in a 25 ml beaker, adding 100 ml of distilled water, stirring thoroughly with a 0.5 cm glass rod, and allowing the starch to settle. Then any particles that are lighter than water will float. The water should be clear and brilliant with a grade A or high-quality starch and there should be no specks on the surface of the water.

At the interface between the starch and the water layer, particles lighter than starch (sp. gr. about 1.5) will become evident. Here, too, there will be some almost transparent cell-wall fiber and fine skin pieces, unless the starch is well refined. A magnifying glass(3x) will often make particles evident which are not seen by the unaided human eye. A good quality starch shows no or only a relatively few specks; a well refined starch shows no fiber at the starch and water interface.

At the bottom of the beaker and under the starch, particles of carbon with a density of about 1.8 to 2.2 can be seen. Coal specks, drawn by suction into the starch factory or blown in by wind currents, become evident here. Dirt particles from any nearby road on a windy day.

### **Quantity of Acid :**

Some European specifications require that a Superior, or Prima, starch shall be free of acid, as indicated by a litmus test. Much starch, however, yields an acid test to litmus and is otherwise of an A or a Superior grade. The acid may be butyric or lactic. Such acid may be due to rotted potatoes, bacteria, to insufficient purification, and to slow drying with insufficient circulation of air. Acids, such as butyric and lactic, are weak and yield a wine-red color with litmus. Sulfur dioxide is extensively used at the grater sump to destroy the enzyme tyrosinase and other enzymes which yield a reddish protein water and cause fermentation; sulfur dioxide yields sulfur-ous acid, and if this is not neutralized in the washing process by hard water, etc., or washed

out of the starch, a strong acid reaction to litmus (onion red color) may be obtained. A good grade starch should not have acid in excess of that which can be neutralized by 6 ml of 0.1N sodium hydroxide for a 25 gram sample, using 0.1 per cent phenolphthalein in 50 per cent water-alcohol mixture as an indicator. Starch containing acid with an equivalent of over 10 ml of 0.1N sodium hydroxide is probably sour. The 25 gram sample used for impurities and hardness can be used for determining quantity of acid.

### **Sieve Test , Particle Size :**

Particle size can be determined by sieve tests to three sizes for many years: particles coarser than 100 mesh, particles from 100 to 200 mesh, and particles finer than 200 mesh. Two sizes of brass sieves, 100- and 200 mesh, with pan and cover, are used. A 25 gram sample is taken for 5 , 6 , or 8 inch diameter sieves. Any materials not passing the 100 - and 200 - mesh sieves are transferred to paper and then to the pan of a small accurate scale or balance, and weight to centigrams is noted. Residue weights are multiplied by 4 to obtain per cent. In sieving

### **Reflectance or Color ( Degree of Whiteness ) :**

Reflectance, or degree of whiteness, is of value in connection with the manufacture of coated papers, in the sizing of fine papers and textiles, and in cases where color is a factor. Paper manufacturers often have a specification for the whiteness of the paper they sell. Since measurement or estimation of reflectance or whiteness is difficult with the unaided human eye, a photometer such as the Brice-Keane Photometer is often used. In this photometer, a galvanometer indicator is deflected by the reflectance and is restored by turning the graduated knob dial to bring the indicator back to the "dark" reading (  $0^\circ$  on scale ) . As a standard for comparison a calibrated white plate in terms of pure precipitated magnesium is used. This white plate is a fused mass of silica in a dish. The surface should be washed occasionally.

## **Pulp and Fiber :**

(a) Pulp and fiber can be tested for by placing 2 grams of starch in 10 ml of distilled water in a graduated centrifuge tube, and centrifuging. The water layer should then be clear and colorless. Pulp and fine fiber can be seen between the water and starch layers if present.

(b) Pulp or fiber can also be separated by suspension of a 25-gram starch sample in 100 ml of distilled water and washed through a 200 - mesh brass sieve. The pulp or fiber can then be washed from the wire into a graduated tube, settled for an hour, and the volume measured, or the solid material can be filtered by suction, dried, and weighed.

A grade A starch should yield a clear water extract and no pulp or fiber ( or only a very slight trace of fiber ) . The results should be in agreement with the microscopic appearance.

## **Chemical Residues :**

Nitrogen from the nitrogenous compounds present in the potatoes, and chemicals used in processing, should all be eliminated in the washing or refining operations. Therefore, chlorine, sulfur, or nitrogen, either free or combined, should be absent in a grade A starch.

One set of potato starch specifications for the textile industry recently published by one potato starch manufacturer is as follows:

Color tone	None—must be pure white.
Odor	Sweet , characteristic ; never moldy .
Pulp and fiber	Traces , only allowable .
Cleanliness	Free of dirt , specks, grit, or other foreign matter
Ash	0.2 to 0.3 per cent.
Acidity	6 to 7 pH ; preferably acid.
Protein	0 ; the pure carbohydrate contains none.
Viscosity	Uniformly constant, after leveling off.
Moisture	Under 18 per cent.



## CHAPTER - 4

### OTHER POTATO PRODUCTS

#### **Potato Flour :**

A some quantity of potatoes is normally used in making potato flour or meal . Potato flour contains starch, protein, etc., whereas potato starch is essentially a pure carbohydrate . Cost of starch is about twice that of wheat flour and the latter has a much greater food value. It is used mostly in the baking of rye bread where about 5 per cent of potato starch, introduced into the dough, increases moisture retention and the shelf - life of the bread. Demand for rye bread is somewhat limited to sections of a country such as in the middle western section of the United States. A little potato flour is also used in some wheat breads and in a few other foods , as in potato puddings, etc.

Potato flour production requires a better quality of potatoes than does potato starch. Because of the better quality of potatoes used and because more heat is needed for cooking and drying, production cost is necessarily higher than that of starch. The machinery needed includes a washer, a picking table, conveyor, cooker, screw conveyors, double - roll flaking machine, blower, flake conveyor, grinding mill, and flour bolt .

The washed potatoes are moved over an endless belt conveyor where workers remove defects. The peeled and selected potatoes are then loaded into steam autoclaves or cookers with capacities of one-fourth to one - half ton. The potatoes are steamed and cooked thoroughly at 116°C and 5 pounds pressure in 10 to 15 minutes. The cooked mass is then dumped or dropped into a hopper with a screw conveyor which moves the potato mass to a distributing hopper at the top of a pair of large, enclosed, steam - heated, rotating, stainless - steel - surfaced drier drums. As the mass leaves the hopper, it is further mashed and pressed by small rolls against the large drier rolls in order to form a thin even film or layer which is quickly dried. A

stream of air is then blown over this film. On the discharge side of the drums, " doctors " ( flexible steel knife blades ) remove the film , leaving the drum with a clean polished surface. The film of potato meal then falls into spiral conveyors near the lower sides of each drum and is broken into small pieces which are conveyed to a bin or hopper over the powder mill. The powdered meal either drops or is conveyed into a flour bolt or to a sieve, sieved or screened, and then conveyed to a bag filler .

### **Dehydrated Potatoes :**

Although potato dehydration is a regular practice in Europe as a stock feed, it is essentially only a wartime industry in the United States. Dehydrated potatoes may be in the form of slices, strips, or "dice" ( cubes ) , or in riced form ( shreds ) . For human food, potatoes of the same grade as those for potato flour must be used—essentially food quality potatoes. The procedure for all types of dehydrated potatoes is to wash them first in a regular potato or vegetable washer and pass them through an abrasive peeler, lye bath, or pressure steam cooker, and then to wash them over stippled rubber rolls. This practically removes all of the skin. The peeled potatoes are next conveyed over a picking table, on a belt of white rubber, where many workers remove defective material. Passage through a cutting machine of the Urschel type yields either slices, strips, or cubes (dice). The potato pieces are next washed and blanched. Blanching is done by passing the potato pieces through a steam tube on an endless stainless-steel belt or through hot water in a commercial blancher at a temperature of practically 100°C for a few minutes. Cold water sprays remove surface starch, and the pieces are finally conveyed to driers. The drying may be done on stainless - steel, open mesh, wire belts in a drier of the one - level, single, or double successive belts of the Proctor & Schwarts - type driers , in tunnels, or in cabinets.

For tunnel drying, the potato pieces are spread on wire trays. These trays are stacked on cars which are slowly passed through heated tunnels. Steam is passed through fin heater tubes to heat air drawn by large fans through the tunnels, usually on a parallel flow

basis. Fresh air may also be blown in directed currents over steam pipes and the hot air then over and about the potato pieces. In some cases, trays, with their uniform load of blanched potato pieces, are stacked in cars and held in cabinet driers for a sufficient period of time to effect thorough drying .

After they are dried, the potato pieces are dumped and shaken from the wire trays, or fall from a drier conveyor belt, into one or more hoppers, then onto white picking belts under good light where defective or overheated pieces can be picked off by hand or sucked off by use of a vacuum hose.

Well - prepared dehydrated potatoes should have a light amber or straw color, should be odorless, and should be reconstituted to pieces about as firm as they were before drying. They should not be gelatinous or leathery. The blanching process destroys enzymes which cause color changes and which decrease storage life. As with potato chips, reducing sugars ( if present to over 0.2 per cent ) may yield an undesirable brown color. There fore, potatoes for dehydration, for potato chips, shoestring potatoes, or the frozen French fried form, are usually purchased with consideration of reducing sugar. Otherwise they are stored for a sufficient time to decrease the amount of reducing sugar in sufficiently warm or heated storage, with or without blowers. Warm air blown or drawn through the sectional potato storage reduces the time and space needed for this purpose. As in starch factories, frosted potatoes, if warmed, involve a change of reducing sugars to higher sugars and starch.

Dehydrated potatoes are reconstituted by adding water and by cooking for a short period. They are prepared for table use, especially as mashed potatoes.

Dehydrated , riced ( shredded ) potatoes, easily reconstituted and cooked as mashed potatoes, are prepared from whole peeled potatoes which, after being cooked, are forced through food presses with extrusion plates containing holes preferably of 1 / 8 inch in diameter ( ricers ) . A rotating cutter produces shreds of a given

length. The pieces are then dried, inspected, and packaged. In peacetime, this type is desirable in some lunchrooms for rapid service.

Hotels , restaurants , and various types of institutions use potatoes as a low – cost , high - energy food. The demand may be for several types, such as baked, boiled, fried, French fried, escalloped, mashed, etc. Hence , potatoes are purchased principally in 100-pound bags by such large users, and are peeled by mechanical batch abrasive peelers. Dehydrated potatoes find their greatest use as a carbohydrate food for soldiers in localities where transportation and storage of fresh food are impossible or difficult.

### **Potato Chips :**

Also some quantity of potatoes of good quality are used annually to produce potato chips. Potatoes for chips, as for dehydration, are purchased with low reducing - sugar content . Storage for a sufficient time, often about a month, in relatively warm storehouse bins, may be needed to lower reducing - sugar content. Potatoes in sequence of longest storage are used first.

Essentially , the potato chip process involves washing ; mechanical peeling; slicing in a cutting machine of the Ursche! type; passing through hot fat as in the Ferry potato chip machine which is fitted with a stainless-steel wire belt; cooling; inspecting; and packaging in tin cans, moisture-proof cellophane, or other moisture-tight containers. The hot fat or oil in which the potatoes are fried is often continually circulated and purified, and a small quantity of antioxidant materials added. An upper wire mesh belt may be needed to hold the sliced potatoes down against the carrying belt and to control uniform time and period of heating in the hot molten fat or oil

### **Frozen French Fried Potatoes :**

It can be estimated also some quantity of good quality potatoes are used in making frozen French fries. The process is the same as that for making potato chips, except that the Urschel cutters are set for strips instead of slices or dice. The hot fried strips are cooled quickly,

then chilled, packaged, and placed in frozen food storage. They must be shipped to market in refrigerator cars or long distance refrigerator trucks. Frozen French fry plants are often located in or near the potato growing sections, the freezing equipment sometimes being used for other frozen foods processed during the summer. Some frozen French fries are prepared in well - established frozen food plants.

As with potato chips , a golden yellow color is desired. High reducing sugar in the potatoes, due to chilling or too cold storage, produces a brownish colored product . Hence, there is a need to buy potatoes with a low reducing - sugar content, and to ship and store them in such a way as to keep the reducing sugar below a specified percentage amount .

### **Shoestring Potatoes :**

Shoestring potatoes are a form of fine strips of potatoes usually cut in an Urschel cutter. Except that they are cut in narrow strip form, they are

handled much as are potato chips. They are usually marketed in the form of strips of about one- eighth inch square cross sections of varying lengths, and packaged in cans.

### **Canned Potatoes :**

Canned potatoes are sometimes prepared in potato products plants, small potatoes being graded to the desired size, mechanically peeled, blanched, and pressure canned. The market for canned white potatoes is limited to localities where potatoes are not normally available and only if transportation costs or conditions permit. They are normally used as boiled small whole potatoes where fresh potatoes are not available as in remote camps.

### **Stock Feed :**

Potatoes for stock feed need not be peeled but only washed, cooked, and dried in a thin layer on a large diameter drum drier. A

spiral conveyor breaks up the thin sheet into flakes. Obviously, the care in processing is less than for human food and there is little or no inspection. Use for stock feed is limited to localities where potato and processing costs are low or when and where potatoes are in large surplus .

There are many factories in Germany , in which dehydrated potatoes were prepared for human and cattle use . Occasionally, small quantities of potatoes are subjected to acid fermentation in silos and used as cattle feed. Percentage composition of potato flakes is of the order: water, 17 ; crude protein , 6.7 ; digestible material, about 90; crude fat, 0.1 ; carbohydrates, 73.0 ; and crude fiber, 2.0.

### **Potato Alcohol :**

Potato alcohol is probably the purest ethyl alcohol ( ethanol ) made commercially. Ethyl alcohol is usually made from waste or low-cost petroleum distillation gases, low - grade corn , blackstrap molasses, and acetylene. Such materials have a lower raw material cost than potatoes, per wine gallon of alcohol. Fine French perfumes are made from potato alcohol. In Europe , potato alcohol is the lowest - cost common ( ethanol )

Butyl alcohol was also made from surplus subsidized potatoes in established plants when the price of surplus potatoes and of butyl alcohol permitted. The existing controls; requirements that potato alcohol be labeled vegetable alcohol or vegetable spirits; high beverage alcohol taxes; and the high cost of potatoes - all these factors make it impossible to produce potato alcohol . Conditions and controls may change, eventually, and potato alcohol may then enter the field.

This is a possibility from the fact that more alcohol can probably be produced from an acre of potatoes than from an acre of corn.

The general process for making ethyl or butyl alcohol from potatoes consists of :

- (a) washing the potatoes in a conveying flume ;

- (b) cooking them in a Henze or continuous process cooker ;
- (c) cooling the mash ;
- (d) malting to obtain sugar ;
- (e) fermentation with yeast or the butylic bacillus to obtain ethyl or butyl alcohol ; and
- (f) distillation.

## CHAPTER - 5

### CORN STARCH

Corn ( maize ) is a native of tropical America and was known to prehistoric man. The plant is an annual and varies greatly in height from a few feet to about fifteen feet. The pollen is scattered by the wind from the panicle, which forms the head of the plant, and is caught by the long silky styles attached to the ovaries of the pistillate flowers which have developed on the fleshy cob. The cob is held in the axils of the side leaves of the stalk.

The embryo of corn ( maize ) is relatively large and very rich in oil and proteins. Germ oil ranges from about 6 to 9 per cent; hence, the need for separation of the germs before preparing corn starch. Corn oil, pressed from the germs, purified, and marketed as a cooking oil or liquid fat, sometimes appears under trade names such as "Mazola." Because oil is of greater value than starch, there is a trend to produce industrial varieties of corn with higher oil content.

Corn starch is produced most extensively in the United States where there are now about seventeen large plants producing corn products, and to a lesser extent in countries such as Canada and Argentina, and where sufficient supplies can be obtained by means of an economic two - way transportation. Hungary is a large producer of corn which is normally shipped to corn starch factories in northern Europe. Consumption of shelled corn for producing corn products such as starch, glucose, corn oil, and feed , Corn is largely grown in relatively warm countries or where hot summers with warm nights prevail .

#### **Varieties and Characteristics :**

There are many varieties of corn. Kernels may be large or small and have various form details. Corn grown in the central United States is mostly the yellow or white Dent variety, while that grown in the northern part of the United States and in Canada is of the more quickly maturing Flint variety. A different construction of the kernels



gives an indented form for the Dent variety and a smooth form to the Flint. The horny layer or hull of Flint corn encloses the starchy endosperm completely, whereas in Dent corn, as the hull dries and shrinks, the endosperm is exposed, causing a "dent." Ears of Flint corn are long and slender up to about 16 inches with about eight grain rows, whereas Dent ears are shorter and thicker with 16 to 24 grain rows. Corn has been subjected to much breeding, and some Dent corn ears are now as long as Flint ears.

Although most ears of corn are white or yellow, there are other colors such as red, blue, and black. Cross breeding can bring about ears with mixed kernels of many colors.

Corn contains less protein than wheat or oats but usually much more fat. Because it has a small proportion of zein, the alcohol-soluble protein, it does not yield a good dough for baking. Corn bread, however, is commonly made in the southeastern part of the United States. Other materials such as egg whites and egg yolks are added to reduce crumbling. Corn meal and corn flour are also extensively used in making pancakes, johnny – cake , etc.

***The average percentage composition of corn, as follows :***

Moisture ( water )	13.15
Nitrogenous substances	9.12
Fat	4.36
Carbohydrates	69.15
Fiber	2.46
Ash	1.56

**Corn Starch Production :**

Corn is the principal crop grown in the United States from the viewpoint of volume, acreage, and value, and it is an important factor in the nation's growth with yields of the order .

About 85 per cent of the corn crop in the United States is used on the farms where it is grown as an animal feed \* or as a direct human food. The remaining 15 per cent finds use in hundreds of ways

directly or indirectly. Some is dry-milled to make breakfast foods, corn meal, and hominy grits. Large quantities of corn and corn by-products are converted by feed manufacturers into livestock and poultry feeds . Some corn is wet - milled and fermented to yield alcohol for industrial and beverage purposes. Corn - using or corn products companies produce starch , glucose syrups , dextrose , oil , and by - product feed .

Corn are wet - ground after steeping and separated into the germs, hulls, gluten, starch, oil, and by-product feed. The starch represents about one - half of these products. Some is sold as such and some converted into glucose, syrups, dextrose , soluble starch , starch compounds , dextrin , etc . Some of the starch and starch product uses are discussed or listed near the end of this chapter .

Pure white crystalline corn sugar ( dextrose ) has sweetening properties about three - fourths that of cane or beet sugar ( sucrose ) . Its food value is about the same as cane sugar; its digestibility is very high .

Production of mixed corn feeds , using corn, corn starch , oil by-products, corn alcohol, distillers' grains, etc., is very great in USA

Corn alcohol ( ethyl alcohol ) is also produced in tremendous quantities. Production is largely dependent on the supply of corn , its price, competition for raw material, supply, demand, price of ethyl and butyl alcohols, competition with ethyl alcohol made in other ways, government controls, etc. Distillers' grains are an excellent cattle feed

### **Production Processes :**

The manufacture of corn products in the world is highly developed . There are many large plants . The corn kernel has approximately the following percentage composition : starch, 55 ; other carbohydrates ( mostly sugars with some dextrin ) , 15 ; proteins, 10.5 ; fat, 5; ash, 2.5; and water, 12. Of the proteins, the albumin is soluble in water and the gluten is soluble in dilute caustic alkali .

Corn starch ( or cornstarch ) is produced in manufacturing plants operating with high efficiencies. Differences in corn varieties lead to variations in corn - starch processes. The corn arrives at the corn-starch factory by trucks, box cars, boats, or barges. It is unloaded usually by various kinds of mechanical devices and is bucket - elevated to storage bins at the top of the starch factory or silos. Gravity flow is employed as much as possible . The corn is first cleaned to remove foreign matter such as dust , chaff , pieces of cob , broken kernels , and other impurities.

The cleaned corn kernels are separated into four main products which are then converted into many others. Basically the separation is simple. However , it is very complex as to details and involves a heavy investment for an economic unit. The oil - bearing germ is commonly removed first, then the hulls and bran, and then the gluten, the starch being left. The germs yield corn oil and corn oil meal; hulls yield bran; and gluten yields livestock and poultry feeds, also glutamates. The starch is sold as such or converted into many products: corn dextrins, syrup, sugars, and a small quantity of derivatives. Thus, over two hundred products, or variations of products, are often made in one plant.

### **Steeping :**

The corn is steeped in wooden vats , usually in a weak sulfurous acid solution, concentration of acid being about 16 to 20 per cent. Steeping in dilute sulfurous acid solution for about two days gradually dissolves components of the corn kernel and prevents fermentation and putrefaction. The steep water is pumped to the feed house, the acid is neutralized, and the mixture is concentrated and added to the gluten feed before drying. A valve in the bottom of the vats permits the removal of steep water, and another larger valve is for the discharge of the steeped corn. Many ingenious types of steep vats for corn have been developed, including conical bottom tanks and vats which can be quickly emptied and thoroughly cleaned. The steep water is often kept in circulation by means of steam syphons.

The steeping process is always carried out with warm water. 43 to 71° C . Clean wash water containing about 0.25 to 0.35 per cent sulfur dioxide is used. Steeping is continued with frequent changes of steep water , sometimes on a countercurrent flow basis involving three or four vats , until all of the corn kernels are swollen and soft .

The sulfurous acid is made at the starch factory by burning sulfur to sulfur dioxide in a simple sulfur burner and dissolving the sulfur dioxide in water, which flows countercurrent to the sulfur dioxide gas, in large wooden tanks or in towers filled with coke. A lead flue in the latter connects the top of the tower to an exhaust fan which draws the gas upward between the pieces of the coke and forces any unabsorbed gas out of the building .

### **Germ Separation :**

The softened grain is then moved by screw or other conveyors and passed through coarse disk mills or mills with corrugated crushing rolls, in a slow stream of water, to break up and slightly grind the endosperm mass and to liberate the oil - containing embryos. The mass of hulls, embryos and endosperm, thoroughly steeped, is then diluted with water, the specific gravity adjusted, and then passed through long V - shaped germ separating tanks, with gentle agitation. Screw conveyors at the bottom remove the starch pulp mass, and traveling-chain mechanical skimming paddles at the top move the floating embryos to the discharge end continuously. The oily nature of the embryos makes them float readily. The wet, ground corn undergoes fermentation very readily and must be held, or handled, with some dilute acid as sulfurous acid or with a dilute alkali. The adhering starch is removed from the germs by washing them over perforated metal screens and conveying them to the oil house.

### **Bran Removal :**

The wet degermed - corn mass of starch, bran, gluten, and fiber is then thoroughly ground or milled, usually in buhrstone mills, and the starch and gluten rubbed from the hulls and fiber. The mixture is

then repeatedly sieved through a series of inclined reels fitted with wire or coarse mesh silk and then through shaker sieves with pockets, fitted with fine mesh silk. These reels and sieves remove starch from the gluten, hulls, and fiber. The coarse overflow material is usually reground and sieved a second time. The wet bran is pressed, dried, and sold as corn bran containing about 14 per cent protein. In some cases the starch slurry is first passed through a reel and only the coarse material is passed through a fine or stone mill.

### **Gluten Removal :**

To remove the gluten in solution, sulfurous acid is used if the starch is to be converted into glucose. If the starch is to go to a general or special market, sodium hydroxide ( caustic soda ) or sodium carbonate ( washing soda ) solution is often added in vats. The overflow from the sieves, or residue, goes to a fodder pulp press in the feed house. The press effluent goes to a collection vat, then is pumped back to the starch house and through a shaker sieve fitted with No. 12 ( 125 mesh ) silk ; the residue goes back to the pulp press. All coarse material is thus pumped to the feed house where it is pressed, added to concentrated steep water, and dried.

The starch slurry is next adjusted to about 3 to 4° Be ( sp. gr. 1.02 to 1.03 ) and resieved through No.16 silk attached to the frames of shaker sieves. The residue is passed back to the pulp press. The starch milk is then separated from gluten and fine fiber by the use of settling tables or centrifugal classifiers . Adjustments of the concentration of starch in the slurry can be accomplished by use of a circular tank with a cone bottom .

With good flow control , the gluten and fine fiber then flow off to be collected in vats, are concentrated and are usually dried with the pressed pulp for use as a cattle feed. The starch settles out and can be handled as described under the tabling separation of potato starch. If the starch is to be converted entirely into glucose, the residual acid does not need to be washed out. Otherwise it is resuspended, treated with a very little sulfurous acid , resieved , retabled , reslurried ,

dewatered , and dried . After removal of the gluten, the starch is separated from the slushing water by rotary filters of various types.

The construction of continuous vacuum or suction filters is based on the principle that a drum with a large surface area, covered with filter or strong porous cloth such as suit - pocket cloth, is partly immersed in a tank with a constant level of purified starch slurry. Pipes and valves connect with the drum, or the inner wall section of the drum, so that the starch slurry is drawn against the filter cloth. The water passes through, while the starch remains on the surface as a layer or sheet of moist starch with about 40 to 45 per cent of water. The starch layer or cake is removed on the discharge side of the drum by a " doctor " blade , some times with the aid of an air pressure compartment controlled by a valve as in the Bird vacuum filter, or by means of strings under the cake which remove the starch and deliver. It onto aprons of belt driers, to spiral or bucket conveyors which move the damp starch to other driers .

In the alkali process, the coarsely sieved starch slurry from the mills is concentrated by classifiers to a 3 to 4°Be slurry ( 1.02 to 1.03 sp. gr ) , and treated with about 0.7 per cent of its own dry weight of caustic soda or with sodium carbonate . This slurry is then tabled or passed through centrifugal classifiers to remove gluten and fine fiber, as in the acid process.

Alkali treatment with caustic soda or with sodium carbonate facilitates the separation of oil and starch from the coarse and fine ground corn mass and also dissolves water - and acid - insoluble gluten, and thus yields a whiter and purer starch. With such purified starch, the associated alkali can be neutralized by sulfurous acid and the starch washed with water , filtered , worked up to a slurry of 22°Be in a vat, and then flowed into cloth-lined . sectional box filters or other types of filters . When drained or separated to about 45 per cent of water content , the resulting masses of starch are removed and placed on porous bricks to set , and are then stoved or the starch is dried in mechanical driers . The brown crust of about one-fourth of an inch which collects on the surface of stoved starch is cut off, and when

the moisture has been reduced to about 30 per cent, the starch is wrapped in light blue paper and further dried, often for use as a special laundry starch. This starch, formed by alkali treatment, is a thin-boiling starch. Thin-boiling starches are also made by treating wet starch with hydrochloric acid and drying at temperatures of not over 65 to 70°C or below the gelatinizing point .

Acid starch is pure white, whereas alkali starch has a yellowish tint. It can be whitened by a subsequent sulfurous acid treatment. Acid starch yields a thin paste, whereas alkali starch yields a relatively stiff paste. Starch made by both the acid and alkali processes can be made thin - or thick - boiling by further acid or alkali treatment.

### **Drying :**

Corn starch is dried to from 10 to 15 per cent moisture either on the racks of hand trucks in steam - heated, well - ventilated drier rooms or large cabinets, or in various types of mechanical, or flash driers. The temperature in the dry rooms or cabinets is held at first to below 37°C and finally raised to 50 to 60°C . The dried starch can be sieved on various types of shaker sieves to various lump sizes and to fines. Starch from the driers can also be passed directly through powder mills and sieved.

In the flash drying of corn starch, the slurry is dewatered in a centrifuge to a cake with about 35 per cent moisture. This cake is fed to a mill with large rotor which disperses the starch into a stream of hot air. The drying is instantaneous and the starch is blown upward for collection, and separation of moist air, in a cyclone. Stainless steel equipment is used.

Corn starch is some times mechanically distributed in thin layers on trays which are stacked on trucks and then dried in tunnel driers or kilns. Ring - story turbo driers are also employed. Moisture is thus usually reduced from about 40 to 45 per cent to 10 or 12 per cent.

### **Milling or Grinding Dry Starch :**

Pearl, or small lump starch, mixed with fine particles or powder, is often sold as such, especially where it is to be suspended in water and made into a paste. For most purposes, it is now powdered to pass a 200 - mesh sieve or screen . As finely powdered starch or starch dust yields explosive or flash - burning mixtures with air, the powdering mills are often lined with copper or brass to prevent the ignition of starch dust by sparks . Also , magnetic separators are usually installed ahead of the mills to remove any stray particles of steel which have accidentally been introduced .

### **Lump or Gloss Starch :**

Lump or gloss starch, often preferred for domestic laundry use, is prepared by subjecting hot starch to high pressure in strong steel cylinders in which it remains until it becomes a hard mass. It is then cooled, broken up into small lumps, graded into suitable sizes, and packaged in cartons. Automatic weighing, packaging, and wrapping machines are employed.

### **Yield :**

Yield of corn starch varies with the quality of the corn used. It is usually about 30 pounds of starch per 56 - pound bushel of No. 3 corn or about 50 to 60 per cent of starch. A second grade starch, usually worked up into glucose, may represent about 5 to 10 per cent of the weight of the corn taken. The oil germ , hulls , and gluten represent about 30 to 35 per cent .

A bushel of corn by the wet process containing about 16 per cent moisture often yields about 35 pounds of pearl starch, 1.6 pounds of oil, and about 19 pounds of gluten and oil residue cattle feeds.

Corn starch is used as edible and laundry starch; as a water adsorbent in baking powders; in the textile industry for finishing and filling cotton and other textiles; for paper sizing; and for adhesives, pastes , and gums . As a water - absorbent material, it is dried to a low



moisture content, sometimes to 5 per cent in vacuum driers. Some corn starch is converted at the factory into glucose by hydrolysis with hydrochloric acid, neutralizing with milk of lime, filtering, bone coaling, again filtering, and vacuum concentration.

Corn starch, mostly made as above indicated, yields a viscous paste described as thick boiling and is suitable for sizing coarse count textiles although a thin boiling starch can also be prepared. Its viscosity is lower than that of wheat or potato starch. Some corn starch is converted into dextrin.

### **Corn Oil :**

The corn germs or embryos are washed to remove adhering starch, dried in cylindrical driers, ground, and pressed in hydraulic presses, or ground and extracted in oil expellers to obtain the crude corn oil. The oil, mostly olein and linolein, commands a high price and is used as a food oil or for making soap by hydrogenation, etc. The oil cake is regarded as superior to cotton or linseed oil cake and contains about 20 per cent of proteins. The oil can be refined by simple chemical treatment. It is sold in tank cars, trucks, drums, cans, or bottles.

### **Corn Gluten Feed :**

The hulls which overflow from the silk bolting cloth screens and the gluten are often mixed together and filter-pressed, cotton cloths and large filter presses being used. The water passes through and enters the plant sewer. When the hydraulic filter presses are opened, the cakes of wet feed material fall onto a belt and are mechanically conveyed to a drier room where this material is added to concentrated steep water and the mixture is dried in rotary steam-tube driers. The dry material is ground, screened, binned, tested, and bagged as corn gluten feed. This is an excellent dairy and stock feed, containing about 40 per cent protein.

The cake from the oil expellers drops out at the end of the machine onto a conveyor often located on the floor below, to be

ground and bagged . As corn oil cake meal, it is valuable as a hog and cattle feed, being rich in protein and oil, or liquid fat, that was not expelled. The oil cake meal and the gluten feed are shipped by box cars in bulk to large cattle feeders or are automatically weighed, bagged

The pulps from the presses following the first separating reels or sieves, residues from the first washing sieves, and sludges from the refining sieves are also pressed and dried. In the alkali process, the gluten from the classifiers or tables is collected in vats and treated with sulfurous acid which precipitates the gluten. This can be separated by draining, added to the pressed pulp, and dried as a part of the corn gluten feed.

### **Composition of Corn Pulp Feeds :**

the percentage composition of pulp feeds is about as follows :

Water	8.5 to 13.3
Nitrogenous material	14.7 to 35.9
Crude fat	1.9 to 12.7
Non - nitrogenous material	
including some starch	1.8 to 57.3
Crude fiber	3.2 to 18.0
Ash	0.9 to 1.5

Laboratory control of raw material, material in process, and finished products is necessary. By - product grain pulp feeds are usually sold with a guaranteed or specified analysis.

As corn products plants are large units, usually located in corn growing centers, huge quantities of steam for driers and evaporators are needed. Stoker coal, powdered coal, oil, and natural gas are the common fuels. Steam turbines driving large generators provide the power for the operation of many motors , elevators, conveyors, grinding machinery, pumps etc .

Large acreages of sorghum, millet , waxy maize , and kafir corn

are now grown in the south central United States, especially in Texas. Caranuba wax is now largely replaced by sorghum waxes. Lindemann reports the percentage chemical analysis of the three groups of sorghums grown as follows :

	<b>Mixed Type</b>	<b>Kafir</b>	<b>Wax Type</b>
Water	10.13	10.40	12.72
Ash	1.97	2.17	2.30
Protein	14.45	13.88	12.19
Starch	64.68	52.7	58.40
Crude Fat	3.64	3.97	3.73
Crude Fiber	1.77	1.97	3.87
Tannin	0.0049	0.0061	0.1588

percentage yields of products from sorghum and corn as follows :

	Sorghum	Corn ( Maize )
Starch	51.0	59.0
Bran and crude fiber	8.0	7.7
Protein	6.9	6.3
Oil cake	14.4	3.2
Oil	1.4	2.7
Wax	0.5	----

Hybrid corns, sorghums, " waxy corn ," or "waxy maize," are corns having a surface like a hard wax when the kernels are cut. Such sorghums or "waxy corns" yield starches which have properties more like those of tapioca and are extensively used for purposes for which tapioca was almost exclusively used . In 1951, "waxy corn" production and use were well established.

### **Uses of Corn Products :**

Corn starch , like other commercial starches, has a great many uses. These include domestic use as food in puddings, as soup and gravy thickeners, as a cold or hot water laundry starch, as a preferential water absorber in baking powders ; in the manufacture of

confectionery; in sizing and finishing textiles and papers; as a binding agent in papers; in making adhesive pastes; in conversion to dextrans which are the bases of many adhesives; in syrups and sugars; as a binding and diluting agent in making pharmaceutical products such as pills and tablets; in cosmetics ; as an adhesive for asbestos; in explosives , etc.

Corn oil is used as a cooking and salad oil; in bakeries to prevent dough from sticking to pans, metal sheets, or belts; and in such diverse products as mayonnaise, textile dressings, soaps, and pharmaceuticals. Corn meal is a valuable cattle feed component. Corn syrup is used in baking, tanning, and tobacco conditioning; for mixing with maple and cane syrups; and in beverages , confectionery, canned fruit, ice cream, jams, jellies, and preserves .

Dextrose solutions are injected intravenously after surgical shock or severe injury. Corn bran, hulls, and gluten solids are sold as such or in mixtures with other materials for livestock and poultry feeds.

Steep water , rich in proteins, is now used as a food for molds to yield drugs such as penicillin , and concentrated for mixing with hulls and bran as a feed.

During the past few decades, monosodium glutamate has come into extensive use for flavoring soups .

The alcohol - soluble protein of corn ( zein ) is now being used to an extent of about 30 per cent of the quantity present to reduce moisture absorption of wool, also serving as an extender, and to improve the " feel " and appearance . Zein , as plastic , is also used in sheet form . the wool – zein mixture is known as ,, Vicara ,,

## CHAPTER - 6

### WHEAT STARCH

Wheat, as a cereal, is probably the most important food material for the great majority of the Caucasian race. The extensive Mongolian race uses the cereal rice as its principal food. The use of wheat is principally in connection with the making of flour for bread in many attractive, readily digestible, nutritious, and palatable forms. For making bread, the alcohol - soluble protein "gliadin," the most important component of gluten, is an important binding and leavening factor, together with the various components, especially starch. Much wheat is also used in the form of a large variety of prepared breakfast foods, in puffed and shredded forms, partly dextrinized, malted and sweetened, etc.

"Bread wheat" is the result of hybridization of the wild wheat of Asia with wild grasses of the eastern Mediterranean countries. Cultivated even in prehistoric times, wheat was then an important food. It was undoubtedly the "staff of life" of early peoples, of the Nomads, the Egyptians, and all the world Biblical times. It is now produced in all the world.

#### **The Plant :**

The wheat plant is an annual, or, occasionally a biennial slender grass of varying height. It grows well in the subtropical and temperate zone sections of the world, in fact, it can be grown in the very hot humid regions of the tropics and even to the edge of the Arctic regions, and from sea level to an altitude of about 12,000 feet (in Tibet).

Operations of planting and harvesting wheat are mostly mechanical, suitable to large - scale operations, and usually involve soil preparation, seeding, and simultaneous cutting and threshing.

Although wheat, in order to grow well and to mature, requires an average temperature of about 13°C for about three or four months of

the year, it can withstand considerable severe winter weather, even to about  $-29^{\circ}\text{C}$  .

The variety preferred differs widely with the locale. The important basic types are soft , semi – hard , hard , and durum ( macaroni ) wheats . The last named is the hardest and is high in gliadin. The soft wheats grown in warmer climates contain less gluten and yield white flours . Some wheats are " bearded " .Winter wheats are seeded in the fall , and after fall rains develop a root system which carries the plant through the winter, usually under a covering of snow. Spring wheats are planted during the spring and in colder climates. Some soft varieties are reddish in color; others, as hard winter wheats, are white.

### **Kernel Composition :**

A minute wheat kernel is a single seed, enclosed in a tightly fitting multiple skin or wall. Besides the protein, fat, and carbohydrate (mostly starch), the wheat seed is rich in nonprotein nitrogenous compounds potash, phosphate, lime, magnesium, etc. Therefore, a rich soil is needed or sufficient fertilizer must be applied to obtain economic yields . Water is present in the wheat grain to the extent of 10.0 to 14.1 per cent, an average amount being about 12 per cent.

Wheat is usually harvested by large combines, the grain being loaded directly into bags or into large trucks . Growers retain the best kernels as seed; the grain is either hauled to a local mill on a railroad siding or to a grain elevator for a short - or long - term storage, or loaded into box cars and then hauled to mills in wheat flour production centers or to mills or grain elevators at navigable water harbors, where it is stored until milled or exported.

### **Grain Structure :**

Cereals generally bear exposed seeds comprising the husk, kernel , and embryo . The husk is the horny substance which is separated and marketed as bran. It is a tough material made up largely of ligno cellulose and protects the delicate embryo and kernel. The

starch is contained in the kernel together with proteins and mineral salts, especially phosphates. Gliadin is the most important wheat protein.

The wheat kernel or seed is made up of the embryo or germ and the endosperm, with the bran as a tough protective covering of many layers. Flour and starch are obtained from the larger part of the seed, which is the endosperm.

The wheat embryo is situated at one end of the kernel and germination occurs at this point, forming the root and stalk of the young plant . It is high in protein , iron , phosphorus , vegetable oil ( liquid fat ) , and vitamins ( riboflavin and niacin ) , and is often separated in the milling process

Wheat grains are made up of four outer layers. The three thin, outermost layers are called the " skin " .The next inner or fourth layer contains most of the coloring matter of the bran. These four layers or skins represent about 5 per cent of the weight of the grain. The skin is composed mostly of cellulose and mineral matter. The fifth, a thick layer making up about 8 per cent of the grain by weight, is usually referred to as the aleurone layer which is rich in protein. Varying proportions of these five layers are present in flours leading to whole wheat, graham, and other kinds of flours. The germ is often removed with the skins to yield commercial wheat bran, or separated and sold as wheat germ.

Cracked wheat is made by the coarse grinding of wheat kernels between corrugated and decorticating rolls. Puffed wheat is made similarly to puffed rice by heating the grain in sealed pressure cylinders for about an hour at about 550 °C . The heat converts the grain moisture into steam and when the pressure is released the grain bursts, puffs up, or "explodes," yielding a particle several times its original size. Wheat middlings are particles of grain separated in the milling and bolting process.

## Wheat Flour :

Wheat flour like other cereal flours can be classified according to the degree of hulling prior to milling. Whole wheat flour has most of the skin layers; graham flour has less. White flour contains only the endosperm, the bran ( skin layers ) and the germs ( embryos ) being removed before milling .

The presence of germs in whole wheat or graham flour causes it to deteriorate more rapidly than white flour; hence it must be used soon after production or be chemically treated.

At the flour mill, the wheat is first cleaned by sifting and by exposure to air currents, scoured, and then passed through decorticating, corrugated rolls to crack open and loosen the hulls. The flakes of bran and the flattened germs are removed by sifting, and the mixture is repeatedly passed through milling rolls and sifted through silk bolting cloth, first coarse, then fine, until there is a satisfactory separation. About 70 to 80 per cent of a fine white flour is obtained. As wheat flour deteriorates quite readily due to enzymatic and moisture action and because it also easily becomes contaminated by small insects, it is usually treated with chemicals which have a bleaching and preserving action.

Wheat entering a flour mill is made up of grains of the same grade but from widely divergent farms and areas and is, therefore, much blended. Wheat from individual farms may vary widely as to protein content from about as low as 7.0 to as high as 18.00 per cent. Within a single head of wheat, a variation as great as 6 per cent is sometimes found and the top kernel of a spikelet tends to be lower in protein than the remaining kernels .

### *Wheat flour has the approximate percentage composition:*

Water	8 to 12
Carbohydrate , almost entirely starch	60 to 80
Protein	8 to 15
Fat	1 to 3



Wheat flour requires good, well-ventilated storage conditions. Although shipped for a long period of time in strong cotton bags or in hard-wood barrels , much is now shipped in multiwall, strong, special kraft paper bags of about 96 - , 48 - , and 24 - pound capacity, which .can be loaded into box cars carrying from 20 to 40 tons. Under certain conditions, the box cars are first sprayed with chemical insecticide sprays and lined with kraft paper. Action of cold water on wheat flour yields a water extract containing a small quantity of hydrolysis products of starch such as maltose and dextrin which may be about 3.5 per cent. A small quantity of wheat albumin is also dissolved.

### **Wheat Starch :**

Wheat starch was produced in ancient Egypt and Greece, probably by fermentation of enough of the other components to liberate much of the starch.

The starch was used to stiffen linens; such linens have been found on mummies. It was also used in making papyrus, an early Egyptian paper, and to give a stiffening and finishing effect to linen during the sixteenth to eighteenth centuries in Europe . Wheat was the third largest source of commercial starch produced in the United States , following corn and potato . Rice , tapioca .

Most of the wheat starch on the market during the twentieth century was produced from low - grade wheat or wheat flour in Europe .

*The following table indicating the percentage composition of three of the cereals grown in the temperate zone :*

	Wheat	Barley	Corn (Maize)
Starch	58 - 63	55.0	65.9
Gum	3.0	5.5	2.3
Cellulose	2.9	17.0	1.6
Protein	13.5	10.5	10.0

Fat	1.5	3.0	5.1
Salts	1.7	2.0	1.6
Water	14.1	12.5	13.5

*And the following table give the average percentage composition of soft wheat, which is best for making starch , is :*

	Soft Wheat	flour Wheat
Water	13.56	13.30
Nitrogenous substances	12.42	11.38
Crude fat	1.70	1.93
Crude fiber	2.62	1.83
Ash	1.79	1.78
Sugars , gums , etc .	3.82	1.28
Starch	64.07	68.50

The chemical difference between the grain and the flour is due to loss of some components of the hulls especially of fiber and nitrogenous material , and an increase in starch .

The procedure for determining the recoverable starch content in a sample of wheat involves kneading a weighed sample of the finely crushed grain or of the flour in a linen bag in successive quantities of water; filtering to remove albumin and other water - soluble material; resuspending the starch in fresh water; filtering ; drying first in a low-temperature oven at about 60°C and then to constant weight in an oven at about 100 to 105°C : and converting the bone - dry starch yield to commercial starch with the desired moisture.

There is a very marked physical and chemical difference between the components and structure of potatoes and cereal grains. Much more elaborate means must be employed to separate starch from cereal grains due to the presence of considerable quantities of gums, fats, and proteins .

There fore , the extraction and purification processes for wheat and corn starch differ widely from those for the potato, an underground stem tuber . As most of the wheat starch is produced in Europe, economical considerations require that imported low-grade wheat flour be utilized instead of the wheat kernel or grain . Cereal grain starches , because of their relatively large quantities of proteins,

must be dried to about 12 per cent moisture ; moist commercial cereal starches are less stable and undergo decomposition more readily than potato starch , which commonly contains 18 to 20 per cent moisture. This greater degree of dryness prevents cereal starches from packing readily under pressure and makes them less suitable than potato starch for making tablets and pellets. They also dust more readily, are less transparent , have less luster or crystalline appearance, and more readily form explosive mixtures with air. Wheat starch resembles potato starch in that the granules are built up of definite , super imposed layers . The wheat granule inner layers are much denser than the exterior, as is evident in their behavior to warm water. Potato starch, with uniform water and heat penetration, generally gelatinizes slowly between 65 and 85°C , while wheat and corn starch gelatinize at a higher temperature. The literature contains many tabulations of starch gelatinization temperatures, of importance in making starch pastes. These temperatures are influenced by the hydrogen ion concentration ( pH ) .

Commercial wheat starch, normally is obtained from the grain or the flour. Its specific gravity is 1.5. It is insoluble in cold water, alcohol, and ether.

### **Wheat Starch Production :**

If wheat flour is placed in a well - tied and closely woven linen or cotton bag and kneaded under water in successive portions, the water becomes milky with starch until in the final water treatment no more starch is separated. By settling the milky starch suspension and by decanting the supernatant solution, a residue of starch is left. This may be resuspended in water and filtered on filter paper, preferably by slight suction, and dried. There is left in the bag a brownish, sticky mass of gluten. This is largely a mixture of proteins and gives excellent tests for such material. When dried, gluten shrinks and yields a horn-like mass which is stable in dry air but which decomposes in moist air, and like most proteins or mixtures containing them, yields offensive odors. Commercially, large quantities of wheat and corn gluten are prepared as diabetic foods or in food mixtures in which

starch is to be eliminated . As gluten is largely a mixture of proteins , it can be treated with chemicals and solvents and separated into its various proteins .

There are two principal methods of obtaining wheat starch, the older or fermentation method and the levigation or kneading method. In the former, the gluten becomes almost worthless, the starch remaining because of its greater resistance to water and to the action of dilute chemical solutions. Yield is small; there is also the problem of stream pollution. This process, followed for centuries, has been largely superseded by the kneading process, which is much simpler and saves the gluten; however, the fermentation process will be outlined here for general interest and purposes of comparison.

### **1 - Fermentation Method :**

As mentioned above, the essential purpose of the old Holle fermentation process is to destroy as much of the gluten as possible so as to liberate the more resistant starch, which is present in much larger proportion than gluten in wheat and in wheat flour.

Steps in the fermentation process are steeping ( the softening in, and absorbing of, water ) , crushing the softened grains, and fermentation to destroy the gluten by chemical and biochemical reactions, thus obtaining soluble waste products. These steps are followed by levigation or separation of starch from the fermentation liquor, refining to remove impurities, and drying . The purified starch can also be colored or molded for some markets .

#### **Steeping :**

Steeping the whole grain is a slow process; hence, the outer skin or bran is usually loosened beforehand by crushing and screening. Steeping is done in wooden, cement - lined brick, or concrete tanks or vats, fitted with discharge pipes which are covered with strainers. Rectangular vats often have rounded corners . The crushed grain with bran removed is fed into the tank through a wooden chute. Water is admitted at the top, albuminated steep water is wasted at a proper

level and, when action has continued sufficiently, the steeped, softened grain is discharged through a large pipe. Conical bottom steel tanks are also employed .

Steeping is carried out by filling the vat or tank to about 0.8 of its capacity and adding water to fill it. After several hours, the water volume has decreased as the grain has softened and absorbed water. Both frequent but complete changes of the steep water and relatively high temperatures speed up the softening process. One change of water may involve contact with ground wheat for about 8 hours. Action of water is never continued after decomposition begins. Vats set into the ground floor aid in maintaining a more uniform temperature. Total steep time is about six days for soft wheat and about eight days for hard wheat, and is usually about halved for summer temperatures. When the grain bends easily without cracking the hull, the steeping is complete. Then, if the grain is cut through with a sharp knife and examined with a magnifying glass, water absorption, swelling, and color of the inner starchy zone should show uniformity with that of the outer starchy zone.

### **Crushing :**

The steeped grain is crushed or ground in powerful grist mills of various types. One mill consists of a hopper with feed roll and a regulated feed slot underneath. The uniformly fed soft grain is crushed between finely ribbed or fluted rolls. To prevent damage to the rolls by small, hard stones, a weighted lever controls the spacing so that the stones pass through. The soft crushed grain then falls or flows into a fermenter vat in which chemical changes occur leaving the insoluble starch.

### **Fermentation :**

Wheat fermenting vats may be similar to the steeping vats with arrangements to maintain a uniform temperature. Water is first run into the vat, then the soft crushed grain, then more water until the mixture can just be stirred with difficulty. The vat should not be more than

three - fourths full as much gas is formed and the mass expands. Due to the unpleasant odor, the vats are fitted with tight covers and ducts with suction fans or a draught to draw or force the gases under the grate of a boiler. Passing of such fermentation gases directly into the air of a highly populated community constitutes a nuisance. Fermentation begins spontaneously within a few days, depending on the temperature, or it can be started in a short time by seeding with liquor already fermenting. Most industrial fermenting liquids also start up a biochemical reaction in crushed wheat very readily .

The fermentation of the softened, crushed wheat mass can be accelerated by raising the temperature with hot water. At 25 to 30°C , fermentation is violent and is completed in 5 to 6 days; whereas at 14 to 18°C the fermentation proceeds more slowly and will require almost twice as much time. The temperature must not drop to 10°C and should be kept up to at least 20°C from the viewpoint of time consumption per ton of starch produced. Slow fermentation also involves a starch loss.

During the fermentation, gas bubbles and a thick froth are produced, also ethyl alcohol. The enmeshed liquid becomes turbid due to liberated starch.

After the alcoholic fermentation with its associated evolution of carbon dioxide ceases, the froth or " head " collapses and other fermentations occur with formation of lactic acid, butyric acid, acetic acid, and other compounds . These secondary fermentation processes involve the formation of a very disagreeable odor.

The quantity of gluten is decreased because of solution in the acetic and lactic acids formed and because of decomposition. The organic acids aid in freeing starch from adhering gluten. However, only by experience, frequent tests , and formation of a surface mold can the operator determine when the starch, both qualitatively and quantitatively, has been liberated to the most economical extent .

## **Separation of Starch :**

Separation of starch from the fermentation mass containing viscous gluten is accomplished by sieving on a shaker sieve fitted with horse-hair cloth, coarse silk, or heavily tinned copper. Extraction drums into which batches of the starch mixture can be introduced are also employed. These drums have wooden ends and a framework to support linen cloth . A perforated hollow axle permits water , under pressure, to be forced against the linen to wash out the starch .

## **Refining of Starch :**

The turbid starch suspension from the extraction washer is flowed into large, shallow agitator vats. When a vat is filled the agitators are introduced gradually, the mixture stirred, agitator raised, and the starch allowed to settle. Chemicals, in small quantities, such as sulfur dioxide, chlorine, phenol, salicylic acid, etc., can be added to prevent mold growth . The supernatant liquor is drawn off and wasted although some is used to initiate fermentation in succeeding batches. The solids in the washed starch mixture separate according to their respective densities. The starch, being the heaviest, settles first. Above the starch is a layer of gluten and starch. Above this is a brown sludge of gluten and fine fiber. These are then separated .

The sludge can also be flowed off, aided sometimes by light scrapers. The starch - gluten mixture is then gently hosed and scraped off to another vat where the starch is resuspended in water and the starch separated on a series of short tables to recover a second grade of a slightly yellow starch .

The crude starch is then suspended in fresh water and agitated, passed through a refining sieve, and collected in a smaller vat. After settling for about two days, the water is drawn off, and the surface is cleaned by a gentle stream of water and a scraper to remove the brown - colored scum. The starch is then removed by shoveling into buckets and transferred to the driers. The once-washed starch may be washed a second and even a thirddtime in vats. This procedure produces a purer

starch, and also removes most of the remaining gluten which, if left, makes starch granules adhere together to form blocks or lumps. If purified sufficiently, the lumps crumble to a powder when dried.

In larger plants, the wheat starch, after sufficient washing, is separated as a thick slurry by means of imperforate centrifuges, the purest starch being forced against the wall of the centrifuge bowl. Then in succession, inward, are the thinner layers of impure gluten-starch, and then a thin layer of gluten with some fine fiber. The layers can be plowed off separately, resuspended in water, and the starch purified and separated by use of a perforate bowl dewatering centrifuge as is often used in the final separation of starch in a potato starch factory. The impure gluten - starch layer from the imperforate bowl centrifuge is purified by resuspension in water, agitation, and separation, in the same manner as the best quality starch, but yields an inferior grade. Instead of separating the washed starch by means of a perforate bowl centrifuge, it is sometimes drained in filter boxes to obtain a columnar prismatic structure and then gently and progressively dried.

### **Drying Wheat Starch :**

Wheat starch with a little gluten present does not readily separate out hard in a settler. Thus, a strong, coarse, unbleached cloth is placed over the drained and gently scraped starch. Over this, about a four-inch layer of dry starch scrapings is placed. The dry starch draws up water from the wet starch mass below until it is sufficiently dry to be cut up with spades, loaded into wooden or metal buckets or canvas baskets, and hoisted to the dry room. As damp wheat starch, which contains a little gluten, decomposes more quickly than does potato starch, it must be dried promptly. Slowly dried wheat starch becomes grayish in color at the surface as a mold develops .

Before the use of dewatering centrifuges , the starch was often dried on plaster or gypsum tiles in stove - heated dry rooms with suction fans for ventilation. In most large factories, dewatering centrifuges or suction boxes similar to those used in rice starch



factories are employed. In these suction boxes or suction molds, fitted with sieve bottoms covered with filter cloth and then tapering below into a suction pipe , the pressure differential quickly removes considerable water.

Wheat starch is dried on trays in kilns, the temperature being very gradually raised from 30 °C to 75 °C . Wheat starch is often purchased in the form of short prisms and the market still frequently demands such wheat starch. As the cakes of starch dry on trays, the outer layers flake off due to the effect of air and heat on the gluten and the shrinkage of the gluten in the starch. This layer is removed by a scraping machine as described elsewhere. The starch is then left on boards or tables in a dry room for a short time until the starch crumbles readily.

If a pure white wheat starch without a yellowish tint is desired, powdered starch may be mixed with a little dextrin solution and the resulting cakes of starch wrapped in paper and dried slowly to obtain lump starch with radial cracks.

For a fine wheat starch powder, elimination of almost all gluten is necessary. This is usually accomplished by adding ammonium hydroxide to the final wash - water and having a sufficiently high temperature at the end of the drying. For highest possible yields, thorough processing at each step is essential and small quantities of chemicals used to prevent mold growths, etc., are all eliminated by proper final washing and drying, leaving no odor or chemical residues.

We states that at least 1.5 per cent of soluble gluten must be present to impart cohesion to wheat starch and that up to 3 per cent is contained in many commercial samples of lump wheat starch. The gluten imparts a yellowish tinge to wheat starch .

All wheat starch waste with a sufficient quantity of starch, including the trimmings from block starch, is collected in a vat, held under a little water, and subjected to refermentation ( if no chemicals have been added or are present which inhibit fermentation ) . The

gluten then gradually decomposes and starch can be removed at the bottom, the gluten concentrating in the upper layers. The bottom layer starch is purified as before, while the concentrated gluten mass is used as a feed material for hogs or ( in Europe ) as a fertilizer. Use of sour fermentation liquid which contains organic acids such as lactic and acetic, dissolves gluten. Thus, impure waste starch may be mixed with such sour liquor in a vat, the gluten solubilized or decomposed, and the starch then recovered and purified. Employment of chemicals to solubilize gluten usually makes the separated gluten mixture unsuitable as a feed ; hence it is used as a fertilizer. The starch recovered from wastes is always of a second grade, and is used as an adhesive and in calico printing where the yellowish color is not undesirable.

## **2 - Modern Methods of Producing Wheat Starch :**

Gluten is both valuable and plentiful in wheat and worth saving. Whole wheat or wheat flour, after the; bran has been removed, can be used in separating gluten from the starch by a kneading method. A highly milled white wheat flour would obviously be difficult to use because of its tendency to form a tough dough. Therefore, from the viewpoint of the over-all economy, coarsely ground wheat, after separation of bran and germ, is often employed according to the Alsatian and the Martin methods.

### **A - Alsatian Method :**

The steps in the Alsatian method are: steeping; crushing and extraction by washing out starch; purification; and drying.

Steeping is carried out as in the fermentation process already described, using frequent changes of water of 30°C in a vat, cold water being warmed by steam. When the steeped grain, pressed between the thumb and forefinger, bursts easily to yield a starch milk, the steep water is run off, the free water drained away, and the soft starch discharged through a valve , often into strong bags of such mesh as to permit easy passage of starch while holding back the

gluten. The bags of starch are then passed between a series of pairs of rounded, smooth, corrugated rolls with wide flutings, or between a single pair, under water in shallow tanks, counter-current to a slow stream of water. The rolls are set to yield smaller openings as the starch is squeezed out and the operation is continued until no economically extractable starch remains. The starch accumulates in the extraction or accumulation vats .

The bags are then opened and turned inside out, and the gluten is removed. As the bags must be kept clean for efficient and speedy extraction of starch, they are dried and brushed. In some foreign countries the bags of starch are then sometimes extracted with hot dilute alcohol solution in a closed extractor, in a small nearby building, to remove the gluten. Dilute low-cost acetic acid is also used to dissolve the gluten. The acid bath is followed by an alkali bath and wash water until the final wash water is acid - and alkali-free. The bags can then be dried, brushed clean with power - driven brushes, turned back to normal position, and stored for reuse. In Europe , the waste liquor is usually flowed onto agricultural land for its fertilizer value .

There are many arrangements of rollers and sieves to squeeze out starch and to separate it from particles of gluten. Series of pairs of rolls are used and water is sprayed on the top rolls. The gluten passes between other squeeze rolls and then to the coarse and eventually the very fine sieves. Countercurrent extraction and washing procedures are sometimes employed so that the gluten with the least adhering starch receives fresh water. The sieves over which gluten passes must be cleaned often.

A number of commercial extractors are in use. One of these, made by Starcosa, consists essentially of a shaft with strong arms revolving in a perforated cylindrical drum with water sprays to wash starch through the perforations into a trough from which it can be flowed off to purifying sieves and tanks. At the ends of the rotating drum is a door through which gluten, etc., can be automatically discharged.

Some extractors are set at an incline to facilitate the discharge of gluten. Shaft and stirring arms are often easily removable for cleaning. Wheat from the squeezing rolls is often fed directly to such extractors, two extractors being fed by one set of squeezing rolls, so that one extractor is in operation while the other one is being cleaned.

The crude starch milk containing starch , fine fiber ( cellulose ) , water, and gluten is passed onto fine silk refining sieves, the starch and water passing through. The starch milk is then tabled in such a manner that gluten flows off the tables with cellulose fibers. The starch can also be removed by settling in vats and by imperforate centrifuges. The separated starch, still retaining some gluten, can then be soured or treated with dilute acetic acid in vats and the gluten dissolved. The small quantity of gluten can also be removed from the starch by fermentation. Purification in vats by suspension in water, vigorous agitation, settling, draining off wash water., and removing scum can also be carried out as described for potato starch .

The purified , washed , white starch, now containing only a little gluten as determined by protein or combined nitrogen tests, can be resuspended and separated in a dewatering centrifuge or in suction boxes and then dried on trays in kilns to obtain lump or crystal wheat starch or in mechanical driers, according to the procedure for wheat starch, which has already been described .

Starch which cannot be economically purified and also waste starch can be worked up as a second grade. With gluten present, water is sometimes removed by use of a plate filter press. The starch with a little gluten accumulates on the filter-press cloths. When the press is opened, the glutinous starch mass can be scraped off and the press cloths cleaned. The starch can then be dried for use as an adhesive, textile paste thickener, etc., where a first-grade starch is not needed.

### **B - Martin Process :**

The Martin process, now the most important, is used in Europe and in the three wheat starch factories in the United States. A low-

grade wheat flour is kneaded to a stiff dough, about of the order 5 to 2 ( 5 flour to 2 water ) or 4 to 2 in bread kneading machines. There are many such machines and, because of their extensive use in large bakeries, they have been developed to a very high degree of efficiency. They are easily filled from the floor above, insure thorough mixing and kneading, and can be tipped forward to dump the kneaded dough into a tub rolled beneath the outlet or through a chute to a starch extractor on the floor below .

The kneaded dough is of such consistency that it can be stirred into cold water to yield lumps. It is also extruded or rolled into a flat ribbon and then cut into pieces and fed onto metal shaking sieves with perforated wooden separators to keep the pieces separate. Sprays of water wash out the starch. The separators and the shaking sieve also turn and roll the dough pieces to the discharge end of the sieve where they are practically freed of their starch. The starch slurry is then purified, separated from wash water, and dried as previously described. This is accomplished by a short fermentation of the small amount of gluten, induced by souring , and passage through refining sieves to remove a little fine fiber. An imperforate bowl centrifuge is sometimes used . In the original process , the dough mass was kneaded in strong porous bags, the starch washing through the bags, and the gluten retained . Various devices are also used for extraction of the starch. One such device is a steel table with corrugated surfaces of considerable area and corrugated or fluted stainless - steel rollers passing over the thin, flat lumps of gluten under sprays of water to facilitate extraction. The starch slurry passes off the tables through perforations in the gutters of the tables. In a relatively large wheat starch plant, several starch extraction devices or several units of one kind may be employed.

***Approximate percentage yields of wheat starch :***

	From Whole Grain	From Flour
First - grade starch	40 - 50	50 - 60
Second - grade starch	10 - 15	10 - 20
Gluten	4 - 6	8 - 15

With hard wheats , less starch and more gluten is obtained, hence the general practice of using a soft wheat . In the Fesca thin - mash process, the flour is not made into a dough but into a thin water mixture and then quickly centrifuged to obtain a crude starch. This is purified and dried as in the other methods described.

Waste vat and wash waters from wheat starch factories must be purified , usually by lime , before being run into rivers or lakes.

### **Other Procedures and Modified Wheat Starches :**

Many patents are new procedure for obtaining starches from cereal grains such as corn , wheat , sorghum, and rice . The extraction is accomplished by mixing a starch - gluten cereal flour with water to jellify the gluten to a flowing slurry. The slurry is then passed through a colloid mill to disperse the gluten gel to a solution; this liberates the starch granules which are then separated by centrifuging, and by washing and drying the starch. Methods of facilitating jellification and dispersion of the gluten with subsequent separation of the starch are given, and also the proper pH of each grain slurry. To inhibit bacterial growth during drying of the starch, an acid, preferably sulfurous, is added to bring the pH to between 3 and 5 before drying. Antioxidants may also be necessary to aid in processing; gum guaiac is suggested.

We could produce starch suitable for use as such or for conversion to a high quality syrup from regular., low - grade or damaged wheat flour ( or from rye , barley , or oat flours ) . For protein removal , the flour is treated with sodium hydroxide at a pH of 10.6 or a little higher , but not over 11.8 , and at temperatures not over 35°C , then tabled or centrifuged . Neutralization of the milk , screening. The tailings contain some starch that can be recovered for lower grade syrup. The first-run material is of high quality and can be sold as such or converted into a high quality syrup . Starch produced without tabling by use of a centrifuge yields a lower quality but a high yield . Proteins , partly changed by the alkaline treatment , can be recovered from the table or centrifuge liquors by acidification and can be used for sodium glutamate production.

### **Uses of Wheat Starch :**

Wheat starch has many of the same uses as corn, tapioca, rice, or

potato starches, to which the reader should refer. However, its higher cost usually limits its various uses to those for which it has superior characteristics. Wheat starch has better paste - forming properties than most other starches; therefore wheat starch and flour pastes are widely used for purposes such as bill posting, paper hanging, and bookbinding.

Wheat starch, modified wheat starches, wheat starch derivatives , and wheat gluten products are made in the United States . for the market monosodium glutamate. Wheat starch production by modifications of the Martin process is now of the order of 30 to 40 million pounds annually in the United States . Marketing of wheat starch, as well as the other common starches, is carried on largely through sales companies .

### **Special Wheat Starches :**

Many specially purified, modified, or chemically treated wheat starches are produced mostly under special trade names in America. Some are treated to obtain thinner or thicker boiling properties than untreated starch . Some are partly gelatinized; some have high water-absorption properties. Some with high thickening properties improve the quality of salad dressings to yield a soft, thin, smooth, buttery character and desirable appearance and can be used in smaller quantities with a given quantity of various oils or liquid fats when it is desired to keep carbohydrate quantity within small limits. Some improve stability in salad dressings and prevent breaking down or thinning. Under some adverse weather conditions, a modified starch yields better products than does the natural. Modified starches are also employed in many products including pie fillings, cream-style canned corn, baby foods , canned cream - style soups , ice cream cones, and confectionery. Some acid-modified starches improve the appearance and increase the shelf-life of certain kinds of confectionery as in the case of gum drops. Some pregelatinized starches find use as a binder for molding cores in metal and alloy foundries. Most commercial wall - paper pastes are wheat flour or wheat starch and an added chemical .

## Gluten :

In a well - operated wheat starch factory, the gluten is very largely recovered. It is introduced into cattle feeds, worked up as a diabetic food, or made into sodium glutamate, which is now used on a large scale in prepared foods, in making soup stock, as a soup flavoring material, etc. Gluten is very nutritious, being made up mostly of gliadin, a protein soluble in 70 per cent alcohol; glutenin, a protein insoluble in dilute alcohol but soluble in very dilute acid and dilute alkaline solutions; and a globulin or salt-soluble protein; Gliadin and glutenin make up about 80 per cent of the total proteins of wheat. Leucosin or water - soluble wheat albumin is present only in small quantity, about 0.3 to 0.4 % of the wheat kernel, and is lost in the starch extraction and wash waters. About 10 % of commercial "germ meal" is leucosin . and if the germ has been separated in making wheat flour, a smaller amount of leucosin is present. Foul odors at wheat starch plants are, therefore, due to fermentative decomposition of all proteins present, as well as of other components.

## Gluten as a Feed :

Where the gluten is obtained by the Alsatian or Martin process it is usually used in the wet state locally or dried , milled , and incorporated into mixed feeds if it is to be stored or shipped . For local feed use , it is usually stirred up in water and heated to about 70°C to gelatinize the remaining starch .

Gluten waste from wheat starch factories , has the following percentage composition :

	Fresh	Dried
Total solids or dry substance	30.0	92.3
Nitrogenous substances mostly protein	4.6	16.9
Crude fat	0.5	1.5
Non - nitrogenous matter	24.4	21.9
Crude fiber ( cellulose )	0.1	0.4
Ash ( mineral salts )	0.4	1.7



The small amount of mineral salts requires supplemental feeds to yield the minimum needs as a feed; therefore a salt, such as calcium phosphate, is added .

### **Gluten for Human Food :**

The gluten or mixture of proteins in the proportion found in bread, distributed intimately with the starch after gelatinization, is easily digested, the baked mixture being readily attacked by the enzymes of the saliva, stomach, and intestine. Alone , it is not readily digestible and must be combined with other materials such as fats., starch, and mineral salts, except for diabetics, in which case other non-starch material must be present to facilitate digestion . For cattle, bran can be fed with the gluten. For humans, gluten from wheat flour is desirable. If a coarse wheat meal is employed, it is customary to remove germs and hulls by washing the gluten masses or pieces in a perforated washing drum . Such a drum, fitted with a charging door, is rotated in a slow stream of water. Pins inside the drum break up the gluten mass which forms films about the pins, while the hulls and embryos are washed out.

Some starch remains with the gluten. Admixture with some additional starchy material, drying, and fine milling yield a flour from which a high gluten bread can be prepared. Such a bread has a darker color than ordinary wheat bread. The gluten may also be quick-dried and milled for use in enriching other bakery products.

Cereal and potato flours, the latter too low in glutinous material to form a dough, can be made into gluten bread. Potato breads, "so called," can be prepared by baking mixtures of wheat flour with potato starch or by mixing wheat gluten with potato starch or potato meal. Gluten breads are usually prepared by adding a small amount of sodium phosphate to replace the phosphate lost in the separation of wheat starch from wheat gluten .

For commercial purposes, wheat gluten, for making gluten bread, is first kneaded with some starch and sodium phosphate. The

resulting dough is extruded into thin sheets which are easily dried to a friable mass and milled to yield a flour. The gluten flour is a cream-colored product, is highly nutritious, and keeps well in dry storage.

The gluten separated in wheat starch factories can also be converted into grits by extruding the dough through a vermicelli plate in a dough extrusion cylinder having a rotating cutter close to the under side of the plate to limit the size of the thin short cylinders. These gluten cylinders are kept dusted with flour or powdered starch and can then be conveyed to a rotating drum or pill - forming or - coating machine wherein small spherical particles are formed. These particles can then be dried and sieved to size. They are used in a manner similar to corn grits .

### **Mono sodium Glutamate :**

Mono soditim glutamate , is now extensively used in food preparation to improve the flavor and palatability of certain types of foods , especially of meats . It is the neutral sodium salt of glutamic ( glutaminic ) acid which , with few exceptions , is present, in combined form, in proteins. It is prepared commercially in starch factories from wheat and corn gluten by hydrolysis in autoclaves with hydrochloric acid; separation of the crystalline amino acid; conversion to the monosodium salt by sodium hydroxide solution and to obtain pH of 7 ; and crystallization.

This mono sodium salt is a white crystalline compound of about 99 per cent purity and much like sugar or salt in appearance but with a different taste. Mono sodium glutamate is made from other protein materials also. It is used only in small amounts of the order of 0.05 to 0.5 per cent in food preparation ; hence its cost in a food product is low . Being a pure compound, like sugar, it does not undergo decomposition changes and resists high-temperature sterilization and long storage. It is marketed principally in 100-pound fiber drums. Many amino acids are known, of which 18 to 24 usually combine to form proteins. About eight of these are essential to man. Some of the other amino acids and peptids ( simpler combinations of amino acids

than proteins ) are produced by hydrolysis of wheat gluten (a protein mixture). In a few starch factories, some of these mixtures are worked up into liquid, paste , and powder preparations as food flavoring materials and food adjuncts . The final products include souj5s, chowders, cooking and table sauces , meat products, gravies, bouillon cubes , baked beans , oriental - type foods, stews, meat and vegetable mixtures, army rations, etc. Flavor solids often vary from about 40 to 90 per cent . Such products are sold in 6,000 - and 8,000 - gallon tank cars, in 50 - pound drums , 60 - pound steel pails , and 105 - pound fiber drums.

### **Wheat Germ :**

In some cases, wheat germs are separated in the making of wheat flour . They contain vitamins and nutrients approximately as follows :

<b>Milligrams per Ounce</b>	
Vitamin B 1 ( Thiamine )	0.50
Vitamin B 2 ( Riboflavin )	0,15
Vitamin E	11.50
Niacin	1.00
Iron	2.20
Phosphorus	275.00
Pantothenic acid	0.32
Choline	114.00
Inositol	201.00
Folic acid	0.13
Biotin	0.003
Pyridoxine	0.34

Approximate percentage analysis is about as follows :

Protein	3.30
Carbohydrate	45.50
Fat	11.50
Crude Fiber	1.70
Ash	5.00
Moisture	3.30

## CHAPTER - 7

### RICE STARCH

Rice ( *Oryza sativa* ) is the most extensively cultivated of grains and the principal food of more than one - third of the world's population. Although much like wheat , its seed - head or panicle is different. It consists of a number of fine stalks each bearing a single grain instead of a compact ear.

The rice kernel is enclosed in a hard hull with small riages, on the crest of which are sharp tooth-like projections. Under the hull, but separated from it and attached firmly to the starchy body of the kernel itself, is a light - brown seed coat with seven distinct bran layers visible under a microscope. The embryo (germ) is visible at one end of the kernel.

Rice is very nutritious, consisting mostly of carbohydrate. It contains some protein and a little fat, which occur mostly in the hull. The small - granule starch is easily digested and assimilated by humans. It is regarded .as a low-cost food, eaten mostly in cooked form and in puddings and cakes. Where it is eaten extensively, high-protein foods such as fish, meat, eggs, and milk are supplementary.

The long and medium and short grain are used in about equal quantities . The medium and short grain varieties usually yield the largest percentages of unbroken rice. In the southern states, short grain yields about 95 per cent unbroken grains ; medium, about 87 per cent; and long, about 80 per cent. The total yield of broken and unbroken rice is also greatest for the short grain rice.

During the growing season, most varieties of rice must be kept flooded, and it is therefore grown on level lowlands with a shallow soil covering a clay sub - soil. With irrigation, it can be grown in elevated places as on terraced hills and mountain sides by periodic flooding from reservoirs at higher altitudes . This is especially true in-Japan, and in the Philippines . Varieties such as " Upland rice " can be grown without flooding .

Rice is grown in warm , moist , tropical lands , especially in southeastern Asia, where it is the principal foodstuff. Burma, India, Malaya, Indochina, China, the Philippines, and other southeastern Asiatic islands are the principal production centers. Rice is also grown in Cuba, South and Central America, and in the United States.

Rice milling and polishing were crude , and the customary practice then was to use - the mortar and pestle and blow off the chaff with hand fans.

### **Rice Production :**

Rice is produced much as other Midwest grain crops, but must be kept under 4 to 8 inches of water from the time the plants are 6 to 10 inches in height until the heads are nearly ripe and the crop is ready to drain for drying and harvesting. The land is often plowed in late summer and fall and pulverized in the spring by harrows. The seeding is done by large grain drills and broadcast seeders. About 100 to 150 pounds of 5 - 10 - 5 fertilizer per acre is often applied at planting time. In California, seeding is done almost entirely on water from airplanes, although this requires about 30 per cent more seed. Normally, from 75 to 150 pounds of seed are used per acre. Airplane seeding requires only about one-tenth the time of other procedures. Dyking machines are used to control the depth of irrigation water. About one-half of the 30 to 60 inches of water needed for a rice crop is commonly obtained by rainfall; the remainder is provided by wells and streams., Salt water from tidal streams near the coast, during dry spells, must be kept to a minimum. Companies are often organized to provide about 36 inches of irrigation water per season, on a contract basis.

Rice is harvested, usually during August in the United States, by use of grain binders or combines. In fair weather, it dries, after draining the soil, in 10 to 14 days. The threshed, rough rice is bagged and hauled to mills, warehouses, or shipping points or is shipped loose, covered with tarpaulin, in large trucks with wide doors and

bottom gates, which can hold many tons. Much rice is shipped to mills in boxcars, or in gondola cars after being covered with tarpaulin. In some localities, it is dried in driers before storage. Rice is often stored in the common large type of grain elevator. Because of its high carbohydrate content, heat and moisture must be controlled in large bulk storage, and rice must sometimes be reconditioned before milling.

In the rice mill, dirt, sticks, stones, and other coarse and fine materials are first removed by "scalpers," screens, and suction fans. These operations, along with shrinkage, represent about a 2 per cent loss. The rice then goes to the clipper which removes the long beard and stems, and to a "monitor" which removes light or blighted grains by suction. The main product is now "cleaned rough rice" and is ready for milling.

In the milling of rice, first the hull and then the germ and all layers of bran are removed except a part of the last or aleurone layer. Thus, there is left the starch part and some of the inmost bran-coat layer which is very rich in protein. Only about 10 per cent of the protein of the rice kernel is removed by milling, together with about 85 per cent of the oil content, most of which is in the germ. The bran contains from 12 to 20 per cent of vitamin B which can be extracted with isopropanol immediately after milling to avoid deterioration and rancidity. Isopropanol, an alcohol, 91 per cent pure, was used as a solvent by Meinke, Holland, and Harris.<sup>8</sup> They also found that hexane could be used as a solvent if only oil was to be removed.

Some operational reports indicate a milling loss, usually of the order of 2 per cent. The hulls are sometimes used as a packing material. The rice products may be of the order of 67 per cent and the by-products of about 15 per cent. Therefore, about three units of rough rice yield about two units of clean rice.

A description of one rice - milling process. It may be divided into three parts :

(1) - The hull or husk is removed by flour mill " buhr stones ", one rotating, the other fixed, and spaced to cause the grains to assume a somewhat vertical position so that the pressure causes them to crack and the kernel to fall out. Many transverse cracks are present when the rice is received at the mill. The setting is controlled to obtain a minimum of broken kernels and a maximum of whole or head rice.

(2) - The product from the stones goes to a reel, a large revolving octagonal framework covered with square - mesh wire sieves or screens, usually fourteen mesh to a linear inch. The rice and hulls are then conducted to the " monitor " .

(3) - In the " monitor " , the hulls are removed by suction. The rice stream goes to the " paddy machine " . a shaking device for separation of lighter components, the "fines," from hulled or heavy rice .

The "fines" consist of broken hulls, germs, and true bran. The paddy rice escaping the first milling operation goes to a second pair of stones, set closer than the first, for crushing. The hulled product, often called "brown" rice, although it is more of a dark cream color, passes into the main rice stream going to the reel.

The bran or colored skin is removed from the "brown" rice stream by a machine which consists of a grooved, tapered cylinder, revolving within a concentric hollow cylinder, so spaced as to rub loose some of the bran coat. This mixture goes to a bran reel where the rice is separated from the bran. The rice stream then enters a second set of bran looseners and reels. In some mills, the rice with its bran coating goes to a machine known as a pearling cone. This machine consists of the frustum of a cone covered with a composition stone surrounded by a sieve mantel of heavy iron wire. The rice enters the top and is rubbed between the cone and the wire before passing out at the bottom. The cone can be adjusted for proper clearance. Frequently the cones are used in addition to the bran removers. The fine material from the "pearling cone" is sold as pearling cone or rice meal or is mixed with the other bran.

From the bran removers, the "white rice" emerges warm and must be cooled in bins. The rice is now rough and unsightly and it is therefore polished. It is also often conveyed to the top of vertical brushes, set within screens, in order to remove the remainder of the aleurone layer containing much of the minerals and vitamin B. Again the rice becomes heated, so a stream of cold air is blown in at the bottom. The air stream also removes some of the "polish" or fine bran dust. This is separated in a cyclone. Polishing is also carried out in padded revolving cylinders with felt or leather flappers.

Normally, much of the germ, which contains vitamin B, is lost in hulling. The Robinson Ideal huller reduces germ breakage. This huller consists of a toothed metal wheel that passes over and entrains rice kernels on an endless resilient rubber belt, 31.5 inches wide. The belt and toothed wheel movements exert a pressure which results in forces that crack open the hulls. The capacity of this machine is one ton of rough rice per hour. The hulls, split off from the ripe rice kernels, are thrown off the endless belt into a collecting chamber where they are sucked by a fan to one compartment while the rice collects in another. The Robinson Ideal whitener contains a specially grooved rotor, the movement of which causes the brown surface meal to be rubbed from rice kernels. Polishing is effected by a rapid pulsating movement. Pressure is kept low to reduce kernel breakage. Degree of polishing can be controlled. This machine, enclosed in a dust - proof metal casing, can handle about one-half of a ton of brown rice per hour.

Practically all white rice is now polished, although the process removes some of the nutrient, vitamins, and flavor. Demand for brown rice is negligible. Polished white rice is often coated with a thin layer of glucose, gypsum, kaolin, oil, glycerin, or talc. The operation is performed in rotating drums, giving the rice a high finish or glaze. Washing removes the coating.

The rice leaving the brushers or polishing machine may be sent to market as such or screened and graded by sieves into "rice," "head rice," "second head rice," "fancy head rice," sometimes "extra fancy head rice," and screenings. White rice should be bright and flinty in



appearance, and of a white or cream color. A "fancy" grade should be free of gray or colored grains and impurities and should contain only a very low percentage of broken grains. If old, white rice becomes yellow. Brown rice varies from light yellow to brown.

The sticks, beards, stems, and hulls removed in the process usually go to the furnace. Bran, pearling cone meal, brewer's rice, and rice polish are by - products. The rice bran and polish are incorporated into mixed stock feeds and the brewer's rice grains are employed in making beer.

The chemical composition of rice mill products is given in following Table :

	Paddy or Rough Rice with Hulls	Brown Rice after Hulling	White and Polished Rice	Broken Rice, Indonesian (Rchwald)"
Moisture	12.6	11 - 12	12 - 14	12.10 - 13.23
Protein	6.1	8 - 8.5	7 - 8	6.87 - 8.95
Fat	2.0	2.0	0.2 - 0.5	0.35 - 0.71
Starch , sugar, and gums	72 - 79	75 - 79	77 - 79	74.06 - 78.64
Fiber (crude)	4.0	1.0	0.1- 0.5	0.32 - 0.40
Ash	1.2	1.0 - 1.5	0.4 - 0.6	0.10 - 1.80

### **Rice Products :**

The most common rice product on the American market is puffed rice. It is made by placing rice in sealed containers and heating it for 60 minutes at 1,022°C . The heat converts the grain moisture to steam and when the pressure is suddenly released , the steam explodes or expands the grains ,puffing them to several times their original size.

Rice flour , like rice starch , is made chiefly from broken grains sieved out in preparing food rice . It is used by confectioners and ice

cream makers, in puddings and in pastry. It lacks the gluten needed to make bread. Rice polish is that part of the grain removed in polishing and is used industrially for the same purposes as rice meal.

Other rice products include rice macaroni , which is made like wheat macaroni; rice meal or bran removed in milling, which is an excellent cattle feed and when fresh and clean is also a good human food ; and rice sugar , which is rice glucose or dextrose.

In making " Minute Rice " , a precooked product, large volumes of waste are produced in soaking, cooking, and washing processes. Henkelekian \* studied these dissolved wastes which contain 1,460 ppm of total solids . Laboratory aeration and chemical treatment reduced the biological oxygen demand to about 10 per cent of the original requirement.

The amylopectin layer of rice starch contains a little fat. The bran contains much more. To increase the food value of rice, some efforts have been made to transfer some of the fat from the bran into the finished rice kernel .

Some rice oil or rice bran oil is extracted on a small scale from rice bran, especially in Europe. This, however, reduces the value of the extracted material as a feed. Such operations require chemical control. Rice oil is used for olein and stearin manufacture.

The first rice bran, continuous , solvent - extraction plant in the Far East started operations in 1952. Located in Taiwan, Formosa, it included roller and flaking mills, coolers, heaters, driers, extraction tube, pumps, and motors. This plant is also equipped to produce soybean oil.

### **Rice Starch Manufacture :**

Rice starch is characterized by the small size of its granules, usually being from 3 to 8 microns (  $\mu$  ) . The granules are polygonal. Characteristic markings . Occasionally , large masses of granules are clumped in an oval mass.

Rice starch was first manufactured about 1840. Its manufacture spread to all industrial countries during the next half century. Holland, Belgium, France and Germany were the principal exporting countries early in the twentieth century.

The large quantity of damaged or broken grains produced at rice mills, in the preparation of rice for food, usually constitutes the raw material for starch manufacture. This represents from about 20 to 50 per cent of the rough rice. This polished and broken rice has approximately the following percentage composition :

Moisture	10 to 14
Protein	6 to 9
Fat	0.2 to 0.8
Starch.	70 to 78
Sugar and gums	0.8 to 1.9
Fiber, etc.	0.1 to 0.5

- The absolute starch content . This includes the sugar and gum as starch.

- Total protein
- Soluble protein
- Quality of the starch.

The rice starch manufacture in some detail. Various steps in the process, products, by - products, and patents are described or referred to.

### **Alkali Steeping Process :**

The alkali steeping process and the essentials of rice starch manufacture in 1840, which were much as they are today. Because the small granules are tightly packed and held together by a coating of gluten and other proteins, chemical agents are needed to soften the hard horny envelope of the grain to liberate and purify the starch. Caustic soda is commonly employed. A layer of rice, about 12 to 18 inches thick, is soaked in about 5 parts of 0.3 to 0.5 per cent ( 0.5 to 1.0 °Be ) , sp. gr. 1.0035 to 1.007 , caustic soda solution

( corresponding to about 400 to 450 gallons of 0.4 per cent caustic soda per ton of rice ) for about 18 to 24 hours, with occasional stirring, in rectangular tanks or vats. These tanks or vats are of steel or concrete, with perforated false bottoms. They are often about 12 to 16 feet long, 3 to 5 feet wide, and 40 to 42 inches deep, and of about 100 to 160 cubic feet. ( 750 to 1200 gallons ) capacity. The stirring operation may be repeated three more times or about every six hours, or until the grains are soft enough to crush between thumb and finger and the rice has swollen to about twice its original volume. The first lye solution is often drained off and second steep liquor added for 12 hours, after which the solution is again drained, and the starchy residue washed once with water. Rice hulls cannot be readily softened by fermentation. Orlando Jones, in England, first used caustic soda about the year 1840.

For steeping, tall cylindrical steel tanks with conical bottoms and perforated draining plates, a starch discharge outlet, and means for air agitation and for liquor addition, circulation, and removal, are also employed. Centrifuges are sometimes used in the separation of the protein liquor and purified starch. For the best product and highest yields and also for the lowest costs, the trend is to complete the steeping in the shortest time and to avoid frothing and fermentation.

We regard continuous leaching with a caustic soda solution of sp. gr. 1.0105 ( 1.5 °Be ) and with artificial cooling , during warm periods, as preferable. The quality of the water is a factor because hard waters react to reduce the caustic soda concentration. Hard waters containing soluble carbonates should first be purified with quick lime. To prevent fermentation, the temperature, liquor volume, and caustic soda or sulfurous acid concentrations are varied and controlled . Temperature, especially, is an important factor. Some of the caustic soda ( alkali ) reacts with the protein. Enzymes form organic acids which react with some of the alkali. To eliminate some troubles of open - vat steeping , the Uhland ( Starcosa ) rice macerator , an enclosed steel vessel, can be used. In this macerator, compressed air provides circulation of the liquor.

This steeped and washed rice, with about 40 to 50 per cent moisture, is then easily fed to and ground between mill stones to a wet pulp of about 25 per cent total solids. The slurry is then sifted, sometimes using brush sieves, the residue on the sieves being reground to obtain a maximum yield. A dilute sodium hydroxide solution ( 0.3 to 0.5 per cent ) is usually added during milling at a rate of about 22 gallons per cwt of rice to keep the total solids of the slurry sufficiently wet and to aid in removing the gluten which holds the starch granules in the form of lumps. Stone mills usually have the dimensions: diameter 4 to 4.5 feet, thickness 8 to 16 inches, and operate at 120 to 140 rpm. Some tandem stone mills, as the Uhland duplex rice mill, having a distributing feed roller, thoroughly grind about 10 tons of rice in 24 hours. Often operated in pairs, 20 tons of rice per day are ground. Cone mills with fine adjustments are also used. A Uhland cone mill consists of a fluted chilled steel cone mounted on a horizontal shaft and operating at a high speed inside a fluted chilled steel casing of the same shape, somewhat like a Jordan in a paper mill. The steeped rice fed from a hopper with power-driven feed and the dilute alkali solution are thus rubbed together and between the fluted steel rotor and fluted shell. Such a mill requires little attention and relatively little power.

### **Separation of the Starch :**

The starch is then separated , using horizontal jig or shaker sieves or cylindrical reels or centrifugals . Revolving, long – paneled , inclined, cylindrical and hexagonal sieves or reels , about 15x3 feet, having a slight pitch , and fitted with fine mesh bolting silk, are extensively employed for sieving purposes . These reels have largely replaced shaking sieves . A hollow shaft with perforations permits introduction of wash water under a slight pressure against the bolting silk to keep it clean. The starch slurry is usually collected in a settling tank. The pulp waste passes out at the end of the drum or reel, beyond the casing, and is collected in a tank, pressed, and dried for use as a cattle feed.

Rice starch slurries are not tabled due to the very slow settling rate of the starch granules which is due to their small size (3 to 5  $\mu$ m). Hence, the starch is usually separated from the slurry by sedimentation, centrifugation, or filtering. When settling vats are used, the sieved slurry of about 25 per cent concentration can be further diluted to a specific gravity of about 1.01 to 1.05 (1.4 to 7.0°Be) using 0.3 per cent caustic soda solution. The heavy impurities will then settle in about an hour. The supernatant starch suspension or slurry can then be pumped or flowed to settling tanks where the starch separates completely in two to three days, leaving a cloudy supernatant protein water. This is drawn off to a tank, and the protein is precipitated by acid, filtered, and added to the pulp for pressing and drying.

In settling vats, similar to potato starch settling vats, the light impurities containing some protein, pectin, etc., settle last on top of the pure starch and can be scraped off. The once settled starch is then resuspended, washed, settled, and the wash water drawn off. The starch may be resuspended again, the slurry passed through sieves fitted with silk bolting cloth, and the starch allowed to settle for a third time. This thrice-settled starch is resuspended and centrifuged, or filtered, to obtain starch with about 45 per cent moisture, ready for drying. In small plants, it is removed from settling tanks by shoveling. In some factories, imperforate bowl centrifuges are used for classification or separation, and the layers, consisting of the starch, heavy impurities, and light impurities, are separated and the starch conveyed to wash tanks. Centrifugation of a screened rice starch causes it to pack hard on the wall of the imperforate bowl of a centrifuge. Imperforate bowl centrifuges are operated at about 1400 rpm. The slurry is adjusted and pumped to the centrifuge, and when a sufficient layer of starch has been built up, usually in about 20 minutes, the centrifuge is stopped, and the gluten and other fine impurities on the surface are scraped or brushed off. The starch is then discharged by a plow, resuspended, and recentrifuged to increase the purity. The starch layer can also be built up in fractions, the gluten layer being removed after each starch deposit. Starch can be recovered from the accumulated gluten. The once-separated starch can be resuspended in water, washed, centrifuged, and the process repeated until the desired

purity is obtained. Filter presses or perforate centrifuges can be used to separate the starch and gluten from dissolved impurities, but the gluten must be separated by classifying, imperforate centrifuges, or in settling vats.

Use of centrifugal purification, although representing a greater investment, reduces space, time, sieving operations, and cost of bolting silk. Silk is affected by dilute alkali to a considerable extent. Centrifugal separators also permit the use of stronger alkali solutions. Some factories use combinations of sieve, vat, and centrifugal separation and purification methods.

Most rice starch factories produce only one grade of starch; others produce two grades according to equipment, production costs, and market price of rich starch.

Where laws prohibit the disposal of protein tank liquors in streams or ponds, the protein can be coagulated by use of sulfuric acid, filtered, washed, pressed, and dried for feed or fertilizer use, as it contains about 15 per cent protein. Naturally, there are many patented processes connected with the production of rice starch. Sodium hydroxide, sulfur dioxide, and other chemicals are used to prevent or check fermentation in the starch slurries and to make a purer and whiter final starch. In some factories, bleaching or coloring is carried out.

### **Crystallizing and Drying of Rice Starch. :**

For rice starch " crystals ", the starch is drained or molded into cubes to about 40 per cent moisture in various types of filter boxes or presses, usually under increased pressure.

One method of draining, to produce " crystal " starch, is to place a heavy slurry in a draining box about 54 inches long, 9 inches wide, and 9 inches deep, with partitions to make or form cubes. These boxes are fitted with a perforated bottom and filter cloth. As the water is removed from the slurry, more thick slurry is added until the drainage boxes are filled with starch. The starch milk may have a density of

about 1.2 to 1.25 ( 24 to 29°Be ) , a consistency to permit flowage, for this type of filtration or separation. To facilitate "packing," the drainage boxes are sometimes mechanically jolted. This also eliminates air bubbles.

The drying of rice starch is a slow process and involves much care and temperature control to avoid fermentation, which may leave gas bubbles in the " blocks " . The starch in the form of filter or drained blocks is next placed in the crusting ovens, on porous earthenware tiles, and partially dried. When warmed or heated, the blocks expand and moisture leaves at the surface. In the evaporation, impurities are drawn to the surface of the blocks as a yellow crust. These impurities may extend to about half an inch into the block. In two days the moisture content in the first drying is reduced to about 26 to 30 per cent at a temperature of about 50 to 60°C (122 to 140°F). The crusting stage is then finished and the starch mass still holds together as a slightly damp cake or block. The crust is removed by scraping, planing, or cutting, which involves a loss of from about 20 to 30 per cent of the starch mass. The Uhland "scraper" is a machine which quickly slices off the crust. The starch in the crust can be recovered by working it up in succeeding batches. Draining in presses results in lower labor costs and crust losses.

The drying is then continued to about 12 per cent moisture. If "crystal" starch is desired, the blocks are wrapped in paper, in which the starch crystals are finally marketed, and slowly dried for a period of from two to three weeks in an oven with the temperature gradually increased from 30 to 50 °C . Cracks then extend from the surface of the blocks to the center. A slow rate of drying produces fewer and straighter cracks, yielding better "crystals," but too slow drying or too much variation in temperature yields irregular cracks. Too rapid drying yields many small cracks. Moisture in "new crystals" usually varies from about 9 per cent outside to about 14 per cent in the center. Hanemann<sup>3</sup> employed a procedure in which the starch is kept in an oven for a few days without heat, and is then subjected to a slow rise in temperature. Many other gradual drying procedures are employed.



Rice starch can be dried rapidly in many forms of mechanical driers at low temperatures, even when much moisture is present. Low initial drying temperatures avoid gelatinization. Final drying to a specified moisture content can then be carried out at higher temperatures. The ring-story turbo drier is most suitable for this purpose from the viewpoint of operating cost, efficiency, and quality of product. The dried starch is bolted, or milled and then bolted, especially for face and dusting powder.

A yield of rice starch is about 85 to 90 per cent of that present in the rice used. In some factories, about 75 per cent yield of a first grade and 15 per cent of a second grade is obtained .

### **The Hoffman Starch Factory :**

A general outline of operations at the Hoffman Fabrik in Germany, one of the oldest but most modernized starch factories in the world, is about as follows: Broken rice to the extent of a through put of 1500 to 1500 tons monthly is received in bags, dedusted, and cleaned in a shaker sieve to remove straw, paper, etc.; it is then passed through a slowly rotating reel with internal rotating helical blades or paddles. Small particles of dirt pass through, the reel; rice does not. Loss in such cleaning represents about 0.8 per cent. About 3000 pounds of rice are then placed in a concrete vat and covered with water, and dilute sodium hydroxide is added. After a soaking interval, the steep liquor is run off. This steeping is repeated three times and the rice kernels are then soft. Gluten waters go to the gluten recovery .

The rice is then conveyed to a hopper which feeds through vibrating chutes to six stone mills with stones about 4 feet in diameter and 9 inches thick turning at about 120 rpm. Each mill is operated by an individual motor and fitted with a dilute alkali feed. The ground rice slurry is then delivered to one of several tile-lined vats fitted with wooden agitators. The alkaline rice slurry is next pumped to the sieving section and passed through hexagonal reels mounted over concrete vats. The reel panels are covered with silk. Hot water spray is forced through a hollow shaft. The thin starch slurry passes through

the silk while the pulp flows to the end of the reel and falls into a tile-lined tank. The rice starch slurry is collected in a storage vat and is next pumped to glazed – tile - lined concrete tanks fitted with a pair of agitators turning at about 12 rpm , placed diagonally, one submerged, the other at the surface of the slurry.

The starch slurry is centrifuged in Wyss or Haubold horizontal centrifuges mounted on concrete bases, the purified starch delivery being to three white glazed-tile-lined tanks fitted with agitators. Starch milk and water are pumped through copper pipes. The centrifuge cycle involves the operations: fill, spin 10 minutes, discharge. The crude starch slurry input to the imperforate bowl centrifuges is separated or classified into three components: starch as the outer or wall layer, hard and soft fine fiber pulp for fodder in the middle layer, and gluten water as the inner layer. The gluten water and soft pulp mass are removed by movable suction scoops. More slurry is then added, the bowl spun, and a second layer of starch is impacted against the first outer starch layer and inner hard pulp layer. Thus. a second layer of starch, a hard and soft fiber pulp as a middle layer, and a protein or gluten inner layer are built up. The inner layer of gluten and the soft pulp layer are removed separately as before. The two hard masses of fiber and the two hard masses of starch are plowed out by automatic plows. The outlet valves are shifted by the operator as the color of the mass indicates whether it is pulp or starch. Each is separately discharged into vats under the centrifuges. The centrifuges are fitted with automatic operational time recorders. Starch from the centrifuges is resuspended in water, containing a very little sodium hydroxide and the slurry is sieved using reels of which there are two sets of three reels each, one set being in reserve. These reels are fitted with finer silk than on the first. The refined starch collects in a vat under the reels, and pulp goes to a fodder slurry tank.

The starch slurry from the sumps under the reels is collected in two tanks and slowly agitated, the trimmings from the outside of the partly dried starch blocks being added. The starch slurry is again centrifuged as before. The twice - centrifuged starch is resuspended in water with a trace of alkali in a neutralizing tank , and adjusted for

density and pH. The neutral starch slurry is then flowed to vacuum block presses yielding blocks with 40 to 42 per cent water. The presses have a perforated bottom with a sieve plate covered with a filter cloth. A compartment mold of phosphor bronze with hinged sides or sections, to fall flat when not in the press, makes a series of cubic compartments. With the compartment in place in the press, starch slurry is fed into these compartments with a vacuum of 500 to 600 mm under the filter cloth, until cubic blocks of starch with about 15-cm edges are built up. The press is then opened so that the mold can be pushed out; the starch blocks are then removed by hand and placed on paper-lined trays on a trolley. The trays with starch blocks are then moved into one of two tray driers and the moisture slowly reduced from about 42 to 28 per cent. The moisture moves to the surface of the blocks where impurities collect as a crust, enmeshing small crystals of sodium phosphate. The blocks with about 28 per cent moisture are still firm enough to handle and the crust is cut off on a trimming machine and returned to the last pre-centrifuge starch slurry vats.

For "crystals," some of the cleaned cubes are wrapped in paper and dried slowly, time varying with the size of crystal desired, at about 50 to 60°C. When removed from the drier, cooled, and tapped lightly, the starch blocks break into "crystals" containing about 12 to 15 per cent moisture. They are sold as such. Some of this "crystal" starch is milled and sieved to yield the powder.

### **Commercial Forms and Uses of Rice Starch :**

Rice starch appears on the market in the form of "crystals," lump, or powder, with usually about 12 to 15 per cent moisture.

Rice starch, like most starches, is used as a food, especially in puddings, ice cream, and custard powders. Due to the smallness of the granules, rice starch is employed in "cold starching". The ungelatinized starch can penetrate into the spaces in a fabric and then be gelatinized by heat, thus stiffening a fabric throughout. Such stiffening does not readily become limp in humid air. Its chief use, therefore, is as a special, fine, stiffening laundry starch, and for this

purpose it is frequently preferred. It is used in some textile plants as a finish on cloth. Traces of alkali, often 0.5 to 1.0 per cent, restrict its uses, and the boiled paste is unstable. Commercial rice starch is often colored with ultramarine to offset a cream color, due to a trace of protein, which appears after being treated with an alkali. It is sometime treated with other dyes or mixed with ingredients such as waxes and borax.

Rice starch is extensively used as a cosmetic in face and dusting powders . For such purposes it is colored and perfumed. It often appears on retail cosmetic counters, attractively packaged, as " Poudre de Riz " . As a laundry starch in America , where relatively little is used, the price is about 11 to 15 cents per pound (1950). As a face powder, it retails for a few dollars per pound.

Because of their small size and high absorptive and adsorptive capacity for colors, rice starch granules were dyed with the basic colors yellow, red, and blue and used in the Lumiere color photography process about a half century ago.

Some rice starch is used to make rice dextrin ; as a thickener in calico printing; and in the finishing of some bleached and printed textiles. Like some other starches, it is used in dusting molds in metal and alloy foundries. With about 2 per cent sodium hydroxide solution, a very tenacious paste can be obtained. Such a paste is used in mounting photographic prints .

Rice starch , as well as the lower cost starches — corn , potato , tapioca and wheat - according to production, surpluses, and prices, is used in gelatinized form for circulating drilling muds in oil well drilling, etc.<sup>9</sup> Naturally , a relatively poor quality of starch serves the purpose, although wheat and rice would be more susceptible to fermentation than potato starch .

## CHAPTER - 8

### OTHER STARCHES

#### **Canna Starch :**

Canna starch, Australian arrowroot or tous-les-mois starch, is prepared from tubers of plants of the genus *Canna*. *Canna edulis* is a native of Peru where it is eaten much like potatoes. It is cultivated instead of *Maranta*.. arrowroot in Australia as it yields more starch per acre.

Granules of canna starch are large in size (among the largest) with conspicuous oyster - shell - like striations and a prominent eccentric hilum near one end. Such granules are easily distinguished under the microscope. Equipment and processing are similar to that of arrowroot starch.

#### **Chest nut Starch :**

Small quantities of starch are some times made from chest nut tree nuts , especially from the horse chest nut tree { *Aesculus hippocastanum* ) which contains about 25 per cent starch. The nuts are,dried in a kiln until the husk can be separated by crushing between fluted steel rolls and removed by means of a coarse sieve. The nut meats are soaked in water, to which siifurous acid has been added, at 38 to 54 °C , and the starchy mass is then ground. Aesculin, a glucoside, dissolves in the water. The starch slurry is sieved, the starch settled, and the wash water removed The starch is next resuspended, resieved, washed, separated in a dewaterim centrifuge, and dried.

Because aesculin cannot be completely removed and because of its relalively high cost, the use of chestnut starch is limited to a few industries as in the dressing of some cotton goods to which it gives a soft " feel " .

## **Pea Starch :**

Pea flour from the common pea ( *Pisum sativum* ) containing odd - shape starch granules was observed by Griebell who stated that new and unusual forms of pea starch granules were found. The usual size of pea starch granules is about 35 microns and the form is kidney-shaped or irregularly oval .

Starches of the wrinkled and the smooth pea were studied by Peat, Bourne, and Nicholls<sup>4</sup> who extracted starch from pea flour with a hot 30 per cent alcohol hydrate. Wrinkled pea starch contained 98 per cent amylose and 2 per cent amylopectin. Starch from two types of smooth peas contained 29.4 and 30.2 per cent amylose and 65.8 and 66.1 per cent amylopectin.

## **Rye Starch :**

In the preparation of rye starch , Klopfer stirred rye meal with warm water , 1 per cent lactic acid, and 0.5 per cent ethyl acetate and then centrifuged the slurry to remove gluten. Foaming was prevented and viscosity reduced by this procedure. Power requirements and other costs have also been reduced.

Rye starch, as a substitute for rice and as a wartime food , was studied at the Hoffman Starke Fabrik. The company worked on rye for three years, and used the same equipment as for rice, except for changes needed in obtaining more fodder, and also in the extraction of vitamins. Rye flour represented 75 per cent of the original grain and was processed as follows :

(a) The flour was stored in silos, then distributed through a sieve, like rain , into water and agitated. Batches of the slurry were made with a pH of 2.0, by action of hydrochloric acid; this was pumped to a tank and stirred slowly for 3 to 4 hours. The acid was then neutralized to a pH of 5.0 by sodium hydroxide solution .

(b) The slurry was next pumped and fed to centrifuges, two fillings to make a full charge. The centrifugate was sent to the vitamin

extractor section and the fodder layer to the coarse fodder section .

(c) The starch fraction from the centrifuge contained 40 per cent water. It was diluted to 15°Be in a receiving tank, by the addition of about 1.5 times its weight of water, then to the second series of centrifugals. The resulting filtrate was used for gluten recovery; the fodder was conveyed to the fine fodder section. The starch from the centrifugals was sieved and purified in the same manner as wheat and rice starches.

One difference in the resulting starch blocks produced was in a thin top layer, 1.0 cm thick, which was darker than the rest of the block and contained appreciable coarse fodder. The starch amounted to about 50 per cent of the production of rice starch. The fodder section was a bottle-neck although this was a war operation to obtain food and fodder.

Fine fodder represented 8 per cent of the rye flour and contained 10 per cent water. It was principally starch. The fodder was used to make soup powders. The gluten recovered amounted to 0.4 to 0.5 per cent of the rye flour and contained 5 per cent water. Dry vitamin Bx, starch sugars, and albumin mixture were sold to pharmacies. The solutions from the centrifuges were first evaporated under diminished pressure and dried on steam-heated cylinders; the dry solids were then removed with knife scrapers. The dry extraction represented 10 to 12 per cent of the rye flour, and contained 6 to 8 per cent water.

### **Oats :**

Oats are widely cultivated in northern Europe and in northern America as a food for humans and as a feed for domestic animals, especially horses. White and yellow kinds are usually milled for human consumption. They are used in the form of "groats" or "grits," especially in preparation of cooked breakfast cereal foods. Oats are rich in protein and richer than most grains in fat.

Oat meal usually refers to both ground and rolled oats . Because

of its high protein and fat content, oatmeal does not keep well, acquiring a disagreeable taste; hence it must be well packaged. At the mill, oats for human use are sorted to size, kiln-dried to loosen the hull and develop a pleasing flavor, cleaned, hulled, and sterilized.

Rolled oats are prepared from hulled, sterilized grains by flattening the hulled grain into flakes and sometimes by additional processes to remove adhering flour, etc. Quick-cooking oats are partially cooked with steam so that only a few minutes' cooking is needed to prepare an oatmeal porridge. Oatmeal can be cut by passing through steel cutting machines or ground between corrugated steel rolls; the resulting product sieves to various sizes. Oatmeal is a hearty food used especially in Scotland.

Oat starch is very rarely produced except for experimental purposes. When needed, it can be obtained in the same manner as rye or barley starches.

### **Banana Starch :**

Banana starch is obtained from the green banana *Musa pardisiaca*. As the banana ripens, some of the starch is enzymatically converted into glucose, gluconic acid, etc.

The constitution of banana starch was studied by Hawkins. Jones, These investigators found that banana starch, from unripe fruit, has an optical rotation  $[\alpha]_D^{20} = 152^\circ$ ; hydrolysis with 2.0 per cent sulfuric acid yields 97 per cent glucose of which 88 per cent was isolated in crystalline state. They also obtained starch acetate in 88 per cent yield when banana starch was treated with acetic anhydride in pyridine, in the presence of chlorine and chlorine dioxide as catalysts.

### **Salep :**

Salep is a starch extracted from the nodular roots of several varieties of orchids ( *Orchidaceae* ) in subtropical sections of Asia Minor, where it is often sold in dry lumps threaded on a string. The extraction process consists of washing the roots, removing the skin,



cooking, grinding, and sieving the thinned, ground mass slurry. When mixed with boiling milk, it yields a semitransparent jelly which is regarded as an excellent invalid and infant food. It is often found as powdered salep in pharmacies. Its use is limited due to its small-scale production and high price.

## CHAPTER - 9

### SPECIAL FORMS & MODIFIED STARCHES

#### Starch Tablets or Molded Forms :

The vast bulk of starch is sold in powder form , some in pearl ( small miscellaneous lumps , graded as to size or mixed with the powder), and a very little in " crystal " and extruded forms. For some uses where a given weight of tablet is desired, it can be molded .

Some starch manufacturers make starch tablets with the company name , mark , or symbol clearly impressed on them . Various types of molds are in use. In some cases the wet starch is allowed to dry on hardened gypsum ( plaster ) molds formed from oiled wooden patterns with the design in relief. In other cases for smaller tablets, presses with multiple alloy molds bearing the design, and using considerable pressure, are employed. In such pressing, the starch with a limited moisture content is pressed directly or sometimes first moistened, with a trace of partly gelatinized starch to act as a binder and to prevent the tablet from breaking up readily in shipment or in handling. Automatic starch molding presses are made by many machine-building concerns such as Starcosa. The higher cost rice starch is pressed into tablets to a greater extent than other starches.

Various shapes are prepared from dry finished starch by making a very thick slurry, adding to it a hot 1 per cent starch paste, mixing, and extruding it. Cylindrical, square, and other shaping dies can be attached to the extruding machine so that rods can be obtained. The extrusion die can be followed with an automatic cutter to cut rods and prisms of definite length. Leaving the die, the cut extruded forms can be laid on a continuous belt which carries them through a drying tunnel or by a table where they can be transferred to drying racks.

#### Soluble Starch :

Soluble starch is a product which, while still made up of granules, is soluble in hot or warm water. Soluble starches can be

prepared in several ways, as by adding dilute mineral or organic acids and chlorine to the green or undried starch or to a starch slurry. The starch slurry or milk is treated in tanks with 0.1 to 0.3 per cent ( dry starch basis ) of nitric , hydro chloric , sulfuric , formic , oxalic , tartaric , or similar acids in dilute solution , and contains about 10 ounces of free chlorine per ton of commercialiy dried starch. If a dilute starch suspension is treated with an acid -chlorine mixture , the treated starch is centrifuged and then dried. If commercially dry starch is used, it can be treated with fine sprays or mists of the acid – chlorine - water mixture and dried at temperatures up to 79 °C until samples, first washed with cold water, are readily soluble in boiling water to yield a clear solution.

In one procedure , starch is allowed to remain in contact with 12 per cent hydrochloric acid for 24 hours and freed from acid by washing. The product dissolves in hot water without forming a viscid paste, and the solution deposits the soluble starch as a pasty mass on cooling. It has no action on Fehling's solution. Many other reagents have been employed at various temperatures to produce soluble starch. Most of these preparations, however, contain dextrose, dextrin, and maltose, as well as modified starch and starch esters. Starch can be heated with 1 per cent formic or acetic acids at 115°C for 5 to 6 hours to yield a soluble starch. The excess acid distills off so no neutralization is necessary. Starch heated with sodium hydroxide becomes pasty and when the sodium hydroxide is neutralized with sulfuric acid, the paste is miscible with water. Chlorine, sodium hypochlorite, calcium hypochlorite, persulfates, ozone, and many other chemicals have been tried or used to render starch soluble. Chlorinated starch sells for from 1 to 1.5 cents a pound above the same regular starch.

Starch , soluble in cold water, can be prepared by running the paste in a fine stream into an absolute alcohol (methanol or ethanol) or into acetone and then separating the starch and drying it at a low temperature.

Soluble starch reacts with iodine solution to yield a blue - violet color, almost that of a dextrin made with a minimum amount of acid and heat. It has no odor. It can be washed with cold water, although soluble in warm water, and then dried, or dried without washing. Chlorine, as an oxidizing agent, modifies starch slightly. Soluble starch can be used directly or converted into various derivatives.

Starch, in suspension in an agitator tank, can be treated simultaneously with a stream of ozone and chlorine to yield a colorless, odorless, pale, water-soluble gum. Starch suspended in water, or a homogenized starch suspension, saturated with chlorine, then treated with ozone, and dried, yields a soluble starch. Such ozonized starches, similar in appearance to untreated starches but with a very slight yellow color, dissolve in boiling water to yield a thin, transparent solution. Unlike common commercial starches, ozonized starch yields no appreciable odor when boiled with acids. It is used for dressing fabrics, as it penetrates fibers, hairs, and filaments much more readily than starch pastes, and thus improves the "feel" and also the amount of dressing absorbed without a hard or brittle effect.

There have been a great many patents issued for soluble and modified starches and the processes for making them. Many have expired. Others, however, take their place.

Some of these soluble ozonized starches, on going out of solution as the hot solution cools, have a white color and the consistency of a paste or butter. Such pastes are soluble in hot water, insoluble in cold, and have a cementing action for articles on glass. According to the degree of action, starches, or starch products, can be made with varying solubilities from soluble in boiling water to soluble in cold water. Solubility involves the breakdown of the starch molecule to a mixture of starch and dextrin, or of starch, dextrin, and sugar. The cold water-soluble products usually have a slightly sweet taste. These soluble starches are related to dextrans and yield similar colors with iodine solution.

Starch slurry can be treated and made soluble with dilute caustic alkalies, the alkali just neutralized with hydrochloric acid, and the starch precipitated with enough magnesium sulfate, washed thoroughly with water to remove all salts, dried, and milled to yield a soluble starch. Although the chemical properties are unchanged, the starch is soluble in 10 parts of boiling water to yield a thin solution and a thin paste suitable as an adhesive for highly glazed paper.

Starch, after being stirred with an equal weight of water, dried on a drum until gelatinized, and then ground, is soluble in cold water.

Starch heated to 150 °C with water under pressure forms a product which is soluble in hot water and insoluble in alcohol and other neutral solvents. With alcohol, this soluble starch forms an amorphous flocculent precipitate. A number of other chemical compounds such as dilute acids ( e.g. hydrochloric acid ), dilute bases ( e.g. dilute sodium hydroxide ), some hot higher alcohols, hot glycerin ( glycerol ), and maltase solution act on native starch to make it soluble. Soluble starch has a specific rotation of  $D - f 202^\circ$  at 15°C in a 2.5 to 4.5 per cent solution. Further chemical and enzymatic action occurs with an increase of temperature, time, and pressure. The starch molecule is then broken up gradually into dextrin, maltose ( a di saccharide ), and finally dextrose ( a mono saccharide ). which is relatively resistant.

### **Thin - boiling Starch :**

Since 1907, practically all laundries have used thin - boiling starches. Such starches are made by stirring starch ( in the damp unfinished state ) with water into a thick milk. Hydrochloric or sulfuric acid, at the rate of 0.5 pound acid per 100 pounds of starch, is diluted about 1 to 10, or 1 to 20 parts, and then added slowly to the starch mass, which is kept agitated. Stirring is continued for 6 to 24 hours. The starch is then allowed to settle, and after the acid is drained off, thoroughly washed and dried. The acid converts some of the starch into a soluble modification ( amyloextrin ) which dissolves in warm water without forming a paste.

Thin - boiling starches penetrate textile goods better and do not adhere as much to the surface . The price is about 0.4 cent per pound above that of the regular or common starch.

Hansen patented a starch modification process for producing a thin - boiling starch. A corn starch suspension of 22.5 to 52°Be is heated with 4.48 parts sulfuric acid in 12.7 parts water and 2.0 parts chromic oxide in 4.5 parts water. After treatment for 1 hour, the pH is adjusted to 8.5 with sodium carbonate, then lowered to 5.5. The starch is recovered by filtration and drying. Less than 1 per cent of the starch becomes soluble by this procedure.

### **Gelatinized Starches :**

Heat and water cause the cell walls of starch to rupture, liberating the starch granules as a paste. The temperature at which this rupture occurs varies with the kind of starch. Apparently the wall thickness of cells containing starch granules varies in its resistance, due perhaps to physical structure or chemical composition. The temperatures for cell wall rupture, in water, vary from 55 to 85°C but are quite constant for a specific kind of starch. Starch behaves not as a pure compound but as a mixture of two principal components - amylose or carbohydrate , and amylopectin , a phosphorous carbohydrate ester . The proportion of these two components varies .

with the kind of starch, there being a greater proportion of amylopectin in potato starch than in corn starch. The amylopectin can be separated from the amylose by use of various chemicals under certain conditions. The separated amylopectin yields a purple color with iodine solution, whereas the amylose yields a pure blue color.

gelatinized starch can be prepared in the presence of much water and starch conversion solids. Water is used at least in the ratio of 6 to 1 by weight to form a free - flowing slurry. When gelatinization starts, a free - flowing liquid results. Transparency and specific volume are increased relative to the older gelatinizing procedures . Conventional times and temperatures are used in the process .

## **Special Starches :**

There is an ever - increasing number of special starches which are mixtures containing small quantities of other products; starches which are modified slightly , to a considerable extent, or completely; and pure and mixed starch derivatives . Such products , according to the present procedure, are given designating numbers , letters , or words and are almost always patented in the country of origin and in the competitive market countries.

Among the starches sold under special names are poudre de riz ( powdered rice starch ) and artificial sago ( semi gelatinized potato or corn starch).

Purified stearic acid, added to starches in quantities of about 4 per cent, sometimes also with a small quantity of boric acid, imparts a glaze which is desired in many laundries. With a melting temperature of about 60 °C , this mixture cannot be powdered readily unless cold. The mixing in finely powdered form with starch may cause some melting and formation of irregular lumps. Therefore, it is cooled, grated, and gently mixed in a rotating drum for several hours or in a mixer with a cold water jacket for a short period. Excessively high temperatures used in laundering irons, rolls, or presses may cause a slight brown coloration in the finish if stearic acid is used.

## **Toilet Starches :**

Many powdered starches are colored and perfumed , especially rice starch , due to its small angular granules; also small-granule potato starch, which is separated by classifiers from the large-granule starch. Use of a toilet starch ( dusting or face powder ) is based on its purity and on its high absorptive and adsorptive capacity for moisture, perfumes , and dyes .

There are many such perfumes and harmless dyes available. These are usually prepared in a dilute alcoholic solution, mixed in a circulating cold - water jacketed mixer to obtain maximum uniformity, and then dried.

Because the more desirable odors or perfumes are usually the most volatile, it is necessary or desirable to package such face and dusting powders in metal or moisture-tight containers, either as loose powder or in cake form. The packages must be as attractive as possible to furnish the necessary eye appeal of articles on a cosmetic counter. The perfumes ( attar of roses , violet , bergamot oil , rose geranium , etc ) , can be obtained from the perfume supply concerns (the dyes likewise) or from a fine chemical supply company.

For flesh - colored face powders, carmine is a color frequently used in different concentrations to produce a large number of flesh to pink shades. Cream colors are obtainable by use of small quantities of yellow dyes.

To bring about the desired high uniformity in mixing and matching to a specified color shade, and the kind and degree of odor, various types of stainless - steel rotary drum mixers are employed.

### **Bleached Starches :**

Various kinds of starches are bleached to obtain a higher degree of whiteness than results from normal processing. Either sulfurous or hypo - chlorous acid can be used at some stage of the process to bleach the coloring matter adhering to the starch granules, and a filial starch may be produced which has a degree of whiteness (reflectance) equal to that of pure magnesium oxide obtained from chemical solution by precipitation and ignition. These acids act also as purifying agents , destroying organisms such as those of the B . coliform group.

For use in the bleaching process, sulfurous acid can be obtained from sulfur dioxide gas or from sodium bisulfite. Sulfur dioxide, purchased in compressed form in steel cylinders, is introduced in a controlled stream through a rotameter ( which measures it ) into potato grater sumps, streams of starch slurry, or into the vats during processing. It dissolves to form sulfurous acid. To avoid the cost of the compressed gas and the transportation charges on steel cylinders, sulfur dioxide can be obtained by burning sulfur in a small sulfur



burner in a controlled stream of air. The gas is then dissolved in a stream of water or in one of a pair of tanks of water to yield sulfurous acid. In some cases the water is flowed countercurrent over silicate stones or coke in a small absorption tower, and after the gas is dissolved, the sulfurous acid solution is conducted by acid-resistant pipe or by pipes of rubber or plastic tubing into storage , into streams of starch slurry, or into wash vats fitted with agitators . When sodium bisulfite is used to obtain sulfurous acid for this purpose , it is fed into a wash vat through a power - driven dry feeder.

Starcosa builds small sulfur furnaces of cast iron, about 300 mm in diameter and 1,235 mm long with sulfur filling pocket and water - cooling device. This burner or furnace is supplied with compressed air up to 1.5 atmospheres from a rotary compressor with oil and water separator, air filter, and flexible coupling for a 2 - hp motor. This size is suitable for a starch factory producing one ton of finished starch per hour.

Hypo chlorous acid for the bleaching process is obtained from chlorine gas. Like sulfur dioxide, compressed chlorine from a steel cylinder is flowed in a controlled stream through a rotameter, or into a controlling device such as a Wallace-Tiernan chlorinator, and conducted through pipes or tubes resistant to chlorine and acid. On a small scale, active bleaching powder ( calcium hypo chlorite ) or sodium hypo chlorite from tight, well-sealed metal containers can be added, together with a little hydro chloric or other inorganic or organic acid to decompose the chlorine compound. The freed chlorine can then be conducted into a starch slurry in a vat fitted with an agitator.

Chemicals such as sulfurous acid or hypochlorous acid cause no reduction in yields. They actually increase yields by improving extraction, separation, and purification processes. Used in proper quantities, free or combined sulfur or chlorine never appear in. the finished starch. Starch can be chlorinated but this requires a relatively high concentration under carefully controlled special conditions.

Obviously , starch , once dried, is sold as such . If yellowish or off color, it is sold as an inferior grade. Reslurrying and treatment with chemicals to remove associated coloring material, etc., dewatering by a centrifuge or filter, and drying would involve prohibitive costs.

Whea , rice , and corn starch which have been in contact with gluten and its associated compounds are sometimes found to have a yellowish tint . This can be overcome near the end of the processing by the use of bluish - colored compounds, such as are commonly used in offsetting cream yellow , or brown colors. Some are the blue colors used to whiten materials in a laundry .

## CHAPTER - 10

### APPLICATIONS OF STARCH

Starch was used principally in industries making textiles, paper, foods, confectionery, dextrans, rayons, and adhesives. It has a large number of miscellaneous small-scale uses. Potato starch is the most important starch in Europe ; corn starch in the United States.

Common uses of potato starch are those of starch.in general, as potato starch has characteristics which make it suitable, either directly or when modified, for almost all purposes for which a starch is used, as well as some of the characteristics of a commercial starch which particularly qualify it for use in certain processes, suck as in textile sizing and printing, in fine textile finishing, and in sizing fine paper.

Potato and corn starches are used extensively in the home as a food, and in the home and in commercial laundries as a fine textile finishing and stiffening agent. As a food material, potato starch is used for thickening soups and puddings, and in pastries, confectionery, unleavened bread, pie fillings, ice cream, sausages, etc. Potato starch is also made into imitation sago for common tapioca and sago puddings. It has greater swelling and firming characteristics than other starches. Often corn and tapioca (manioc, cassava) starches are somewhat lower priced in the United States; hence potato starch is a marginal use material for many purposes. Some starch, especially rice starch, finds use as a face and dusting powder. Starch is extensively used in making potato dextrin and many other special adhe-sives, including library and wall - paper pastes. Starches are used to some extent as oil-well drilling "fluids" when suspended in water. They are sometimes included in soaps to reduce "sweating." Some starch, preferably cold water starch, is used in chemical laboratories as a reagent in iodine analyses.

Some potato or corn starch with low moisture content is used for dusting potato chips and salted nuts to absorb moisture and reduce rancidity. Oat flour is also used for this purpose. Small quantities of

such dry starch find use in baking powders to absorb moisture preferentially and to prevent reaction of the acid-producing component on the sodium bicarbonate. It is used similarly in other substances to prevent caking due to moisture absorption from the air, as in the case of table salt.

Potato starch, in slurry form, is often hydrolyzed on a large scale in Europe (corn starch in the Americas), in units adjacent to starch factories to yield glucose syrup and dextrose. Some potato starch finds use as an adhesive in making plywood. The lowest grades are sometimes employed as a binder in making coal briquettes from coal "fines" at a coal "breaker" plant, and for dusting molds in foundries.

In general, the greatest development and consumption of starches have been in the most highly industrialized countries. To protect the potato starch industry with its much higher cost of labor in the United States, there have been or are import duties on some starches.

Uses for specific starches have been stated or listed at the ends of the chapters devoted to them. Uses for the important commercial starches are described in more detail in the following paragraphs.

### **Laundry Starch :**

In laundry work in homes or in commercial laundries, and in finishing clothing and other textiles, starch is used as a stiffening agent to form a smooth surface which does not become soiled readily; as a gelatinized finish which improves the appearance and brightens colors; and, in some cases, as a filler. The heat applied to a gelatinized starch dextrinizes it to some extent. Rice starch, because of its ratio of amylose and amylopectin and its small granule size, is especially suited for textile finishes and may be used as a cold water suspension. By various chemical treatments, one starch may be made to behave more like another starch of higher cost.

Starching washed clothes is a means of replacing the original finish of the cloth which was partly or completely removed by

laundering. This finish, whether applied at the factory or in the home or laundry, leaves the textile material smoother, brighter, and more pliable, and holds down surface fibers; much starch, however, will stiffen the textile goods. Soft water yields a thicker paste than hard water for the same concentration. The cooking time required for producing the thickest paste varies with the kind of starch. Potato starch paste is thickest after boiling a starch-water slurry for 5 minutes, and then becomes thinner with continued boiling. Corn starch forms a thinner paste than potato starch but makes the cloth which has been starched, stiffer. Wheat starch yields a still thinner paste but stiffer finish.

### **Starch in the Paper Industry :**

Starch is used in the paper industry as a size or bonding material. Stretch, tensile strength, folding endurance, ink penetration, printing ink surface absorption, etc., are all greatly improved by starches.

In modern paper mills, amylolytic enzymes are added to cold-water starch suspensions. These enzymes, which are liquefying, reduce the viscosity and convert some of the starch into dextrans and sugar. Only a small quantity of enzyme, about 0.2 to 0.5 per cent, is required, the exact amount depending on the kind of starch, the concentration, the viscosity desired, and the cooking equipment. The optimum pH varies, since different enzymes act best between certain ranges, usually 6.5 to 6.9. The temperature treatment or cycle involves heating above the gelatinization temperature (to about 160° F) until the desired viscosity is obtained, and then inactivation of the enzyme by heating to about 200° F or even to boiling, or by heating with solutions of salts of heavy metals or with hydrochloric or sulfuric acids.

Cold - water dispersible potato and tapioca starches, made by cooking a starch slurry on a heated cylinder where it swells and dries in one operation, are sometimes used. This product, added in the beater, swells again and partly disperses. Unmodified starch is also added in the beater, either in a raw form or after cooking with water.

Retention of the raw starch is greater than that of the boiled. It is then gelatinized while passing over the drier rolls. For effective use, granules must be swollen during the sizing process.

Papers coated with enzyme-modified starches are relatively more flexible than those on which unmodified starch is used. Before the use of enzymes, most paper mills in the United States used tapioca and corn starches, about 80 per cent in cooked form. Modified starches, as they became available, were usually in oxidized form. One and one-half per cent of the starch does not develop sufficient strength in a paper, while over 4 per cent may cost too much for the additional strength imparted. Now, when cellulose cost is greater than that of starch, larger quantities of the latter are used. With 10 per cent of starch in a paper stock or furnish, percentage retention with hand-made sheets has been found to be highest for potato starch—about 76 per cent if raw, 46 per cent if cooked. Retention is less in machine than in hand - sheet sizing. Potato starch is best retained when applied cold, as compared with wheat or rice. The Mullen bursting test is highest when 1 per cent of converting enzyme is used. Maximum Mullen test is obtained with a limited retention of the starch. Degree of hydration of cellulose is a factor in beater, tub, and calender sizing.

In a study of applications of starch viscosity to the paper industry, Bechtel and Kesler observed that identical instruments for viscosity must be used with the same orifice type, viscosimeter, etc. Details of cooking were of great importance and single viscosity tests were not found to give complete information about starch flow. The Corn Industries viscosimeter makes a continuous record during cooking and cooling, and is automatically controlled.

For colored coatings, any clay, pigment, or dye is first dispersed in water, with vigorous agitation. Partly hydrolyzed starch is prepared separately and then added. In some procedures, heat is applied after the starch is added to the pigment - water mixture. The enzyme converts starch up to about a 50 per cent concentration. The adhesiveness of the coating is finally measured by the Dennison wax test in many mills.

Starch is employed in writing, drawing, book, and cigarette papers. There are various prepared starches in use made by treating ordinary starch with alkaline and acid solutions, chlorinating agents, etc. These modified starches are also of use in making high-grade papers.

Corn, tapioca, and potato starch usually compete for use in the paper industry. Potato starch is used mostly in Europe; corn starch in the United States. As the industry uses large quantities of starch, availability and certainty of continued supply at a stabilized price, quality and uniformity of quality, and price differentials become factors of considerable economic importance. Because of some of its characteristics, only about three-fourths as much potato starch as corn starch is needed for sizing paper to meet certain ink penetration tests, and only about one - half the quantity of enzymes is needed to modify it .

### **Starch in the Textile Industry :**

The purpose of a starch or gelatin size in the textile industry is to bind together loose filaments, hairs, or fibers; to give strength to the warp threads; and to prevent breakage under the variations in tension during weaving in low - or high - speed looms. Chemicals may be added to the starch in a size tank to alter the hardness or stiffness of the warp threads. All of the starch can be removed from the cloth after weaving by continuous or batch treatment with animal or plant enzymes such as 2 per cent "Ac - tivin" which converts starch to sugar in the desizing machine, jigg , or padder.

Because of its high viscosity, potato starch has no substitute for sizing fine - count threads or filaments; because of its thin-boiling character, it is a fine textile finish. It is also an excellent (and perhaps the best) textile printing paste component. When mixed with borax, it forms a starch glaze. It is also mixed with powdered stearic acid or paraffin for this purpose.

It has been known for over a century that starch forms difficultly soluble compounds with chromium dyes. Such dyes used in calico printing hold very fast to the fabric and can be removed only with difficulty — as a rule, not completely. It is not known whether some of the OH groups of the starch react with the chromium salts as mordants to hold the dye or whether the phosphoric acid of the amylopectin component, which yields the paste and is a phosphoric acid ester ( an inorganic salt of an organic compound ) , reacts with mordant or dye. Chromic acetate is one of the most extensively used chromium salts in textile printing and dyeing .

For identification of commercial starch sizes, iodine in the form of potassium iodide was used; for albumin-containing sizes, the biuret or ninhydrin tests. The finisher could easily remove these sizes by treatment of the goods with diastatic desizing agents.

Although wool is regarded as an irreplaceable fiber, much has been done to impart wooly characteristics to other textiles and synthetic filaments.

An innovation in textile sizing during the past decade has been the use of homogenized, gelatinized starch. Starch, representing about 5 to 10 per cent of the warp yarn, by weight, is mixed with water and a softening compound, if needed, in a conventional cooking kettle. The temperature of the starch slurry is then raised through the gel or swelling point to about 170°F in case of potato or tapioca starch or to about 180 to 200°F in case of pearl corn starch. The heat is next shut off and the mixture agitated for approximately 5 minutes to insure complete gelation of the starch. The viscous gel is pumped at once through the homogenizer at pressures varying between 500 and 2,000 psi to yield the desired viscosity. Potato and tapioca starch pastes are usually homogenized at between 500 and 700 and pearl corn starch pastes between 1,500 and 2,000 psi.

For use, the paste is then flowed by gravity to the size boxes, whenever possible , through about a 2 - inch pipeline. Pumping, as is the case with much agitation, reduces the viscosity of starch pastes.



Size box temperatures for cotton warps usually vary between 180 and 200°F, depending on the concentration of the size. Worsted yarns are sized at somewhat lower temperatures.

The homogenizer, of necessity, must be a very sturdy piece of equipment, compact, and with a forced oil lubrication system, the oil pressure being indicated on a gage. Materials of construction include considerable stainless-steel and bronze. Three-way valves prevent damage which might be caused by the closing of a shut-off valve and the building up of a very high pressure. A special rotary pump delivers the thick paste to the homogenizer. The valve assembly is so arranged that the size is subjected to a high pressure, indicated on a gage, and to a high velocity, in passing through a very small opening. This breaks down the starch granules by a hydraulic shearing action. The valves and orifices must, of necessity, be kept thoroughly clean. Continuous operation is made possible by the use of two preparation kettles.

Chemically modified or thin-boiling starches require less steam for cooking. Enzyme modification of starches is also employed in preparing slash sizes, although regarded as a delicate process. Homogenizers based on the colloid mill principle are also in use, to reduce viscosity.

The efficiency of sizing warp yarns, threads, or filaments is usually measured by determination of strength and elongation; penetration as compared to coating; percentage of added size; degree of fiber lay; moisture content; and flexibility. Fine to coarse yarns are referred to number as 60s, 40s, 28s, etc.

Some reference is made to homogenization in warp sizing . an example of this is chemically treated spun rayon. Wool is often extended by the use of zein, the alcohol-soluble protein of corn, to produce a cashmere effect and to improve the feel.

Under present conditions, there is an ever increasing number of chemical products, synthetic resins, starch derivatives, new synthetic textile filaments, etc., thus providing the textile chemist and textile

operator with many new opportunities and problems. The use of new materials has required new sizes and new equipment including jacketed, stainless - steel size kettles with closer and even automatic temperature controls ; thorough slow - speed stirrers ; size circulation; storage kettles; stainless-steel size boxes with two sets of heavy rubber-covered squeeze slasher rolls; and drying cylinders also with good temperature control. Potato starch in some of this newer equipment, at about 190°F, can yield uniform well-sized warp threads which work well in looms and have high flexibility and strength.

### **Adhesives :**

The artistic, beautiful mummy cases and furniture of the Egyptians about 2,000 to 3,000 a.d. were made possible by the use of animal glue for holding parts together and affixing beautiful, costly, and rare veneers to low-cost but strong woods. Glue was also used to attach decorations of gold, silver, ivory, and precious stones to various objects of art. Many centuries before 2,000 a.d. were required for the development of adhesives such as starch, and of glues made from animal waste, fish waste, white of eggs, and casein. Starches and glues, being organic material, have not readily withstood the ravages of time unless the articles to which they were applied were well protected, as were the mummy cases, due to their careful preservation as receptacles for the dead who were to enjoy a spiritual life after physical death, and to their later being lost and buried under stones and the dry sands of the desert.

The Greeks and the Romans had objects of art which were made of beautiful veneers and other rare materials held together by glue. Although fine craftsmanship in working with rare materials and glue disappeared almost completely at times, a little always survived, ready to develop when conditions were again favorable. Marquetry, or the art of inlaying furniture or pictures with materials such as precious stones and various woods, was a development in the period following the Italian Renaissance. It was much further developed in France about 1675.

The increasing use of glues spread to other parts of Europe and to America. Simple water - wheel - driven machinery and new types of saws made possible larger and better pieces of veneer. Workmanship in fine furniture in England and in the American Colonies developed as sailing ships entering ports in all parts of the world brought woods to be glued as a veneer to domestic woods. Not only did the American colonists, as they produced and acquired wealth, import beautiful inlaid furniture, but American cabinetmakers began to change from making heavy pieces, often with fine carvings, to more delicate pieces with mahogany and satinwood veneer finish.

Animal glue is undoubtedly the oldest adhesive known. Present animal glues are of two kinds: hide glue and bone glues. Hide glue is made mostly from tanners' hide trimmings, and bone glues from dry or "green" bones. Hide glue is regarded as the best, followed by dry and then by "green" bone glue. The high cost and irregular supply of these glues led to the development of vegetable glues early during the twentieth century. All animal glues swell in cold water, dissolve in hot water, and form a jelly on cooling.

With the advances in colloid chemistry, the animal glues are now better adhesives than formerly. Their ability to liquefy when heated and solidify when cooled makes them important for bonding and packaging operations. Evaluation of animal glues is based on characteristics such as jelly strength, viscosity, melting point, and setting point. As a packaging adhesive, clarity, odor, and chemical content are important.

In the making of cellophane bags and the lamination of cellophane to various surfaces, resin - starch emulsion-type adhesives came into use. These involve a resin - starch base mixture dispersed in water, a plasticizer, and often a solvent. By changing the ratio of resin-starch base and plasticizer, such adhesives can be made faster or slower, stiffer or more flexible. Solvents aid by penetrating cellophane or cellulose acetate or lacquer coatings on paper. Emulsions set fast on contact with a cellophane-like surface. Starches, dextrans, and animal glues without added chemicals tend to dry out

while resin - starch emulsions remain flexible and do not soften under high humidities or temperatures. Hot-melt type adhesives serve well for many purposes, especially for packaging, preserving, and sealing foods and miscellaneous products against dust, bacteria, and moisture. Moisture may be retained in meats, fruits, and vegetables by the sealing process. Easily operated electrical heaters, with temperature control, facilitate the packaging operation.

The starch adhesive chemist has the task of meeting this competition from improved glues and new resins, by producing new mixtures of starches and resins or by modifying the starches. Small percentages of alkali setting resins have been incorporated into starch adhesives especially for regular and waterproof corrugated boards. The tremendous developments during the past few decades offer a challenge to the starch chemist.

Both flexible and nonwarping glues can be prepared by addition of plasticizers. Essential oils, preservatives, and defoaming agents are often blended into such modified adhesives and the maker endeavors to produce the best adhesive for the buyer's packaging and labeling equipment and the materials employed. Film thickness, flexibility, minimum absorption into material, and freedom from brittleness and crystallization are factors considered.

Unmodified animal glues, which are usually quite variable in quality due to their source, have the disadvantages that they must be applied hot, and do not hold to paraffined or waxed, varnished or pyroxylin - coated surfaces or where there is much moisture or refrigeration. The glues to which plasticizers and resins are added overcome much of this difficulty. Bonding strength may be high for the specific purposes. Sodium silicate is an excellent adhesive for some purposes, but its use is limited to a few articles. For gluing furniture, vegetable glues made from thick starch slurries are pumped to tanks, after which chemicals are added and the reaction mixture is stirred for various periods of time.

Chemical treatments , of necessity , are controlled by frequent tests. iMany vegetable glues are subjected to strength tests after application. In most" cases, a well - prepared vegetable glue used on woods and veneers is strong enough so that breakage does not occur at the glue-line but in the wood itself.

Vegetable glues have replaced animal glues because of lower cost, greater versatility, and simpler application. Besides being used as veneer and wood glues, vegetable glues are used as linoleum cements, core fillers in foundries, sheet metal glues, etc. Vegetable glues can be prepared to resist temperature and moisture changes better than can animal glues, although there will continue to be uses for the latter.

Glues are used most frequently for woods in furniture of many descriptions; for pianos, radios, television cabinets, game boards, toys, and sewing machine covers; and for cabinets made of several layers of plywood, veneered doors, panelling, etc.

Case liner adhesives have been used in continually increasing quantities as the population of the world has increased and as wood has been almost entirely displaced as a container by paperboard. Adhesives are available to meet various strength requirements; specifications for seam - sealing tapes and closures have been written. Some adhesives are used for mold, fungi, and water resistance. These are applicable to asphalt-coated, creped, pleated, and coated papers and paperboards. Synthetic resins in large number have been mixed with starch to yield well - bonded paper and paperboard containers and bags. Solid fiber and laminated paperboards are being continually improved.

Starch and resin plywood bonding materials have been developed. The plywood business has been growing rapidly and new bonding materials, especially those based on starch, dextrin, and synthetic resins, have appeared on the market very frequently.

Starch and dextrin base adhesives, wood cellulose adhesives, cellulose derivatives, etc., are produced by many concerns in Europe.

Starch or dextrin, adhesive production in one plant is as follows. Starch or dextrin in bags is raised to the second floor and the raw material is fed by gravity to equipment on the first floor, mixed to a stiff paste, and dropped on roller driers. The mixers are heavy wooden vats with agitators about 5 feet in diameter, there being two mixers to one drier so as to provide for continuous drying. The mixers are of heavy wooden construction banded with steel bands or rods, fitted with bottom discharge doors, heavy steel agitator arms, and cast steel bevel gears, each pair operated by a 50 hp motor. Water is kept to a minimum. The roller or drum driers are furnished with two cast steel rolls with small adjustable knives. Distribution to the drying rolls is by three small feed rollers with spring contact, each roller supplying some of the mixture to obtain an even layer of adhesive on the drum.

A flexible feed pipe carries the mixture to the feed rolls, one operator controlling the feed for each drum. The thickness of the mixture on the drums is determined by the pressure. The knives or scrapers are of the flexible type used on paper mill driers, and are staggered to remove all dried adhesive and keeps the drums clean and smooth. Any adhesive left on the drying drum would become burnt, spoiling the color and viscosity of the batch.

The products of this plant include paper hangers' pastes; painters' glue; dry and wet "glue" mixtures; bookbinders' pastes; pastes or glues for paper to wood, paper to paper, and paper to real and artificial leather; office paste; envelope paste; textile size; textile printing and stiffening pastes; pastes for binding leather to steel or alloys as in cameras; and pastes for binding rubber to leather. Although potato starch is used normally, corn starch, wheat flour, rye flour, and tapioca are also used when price permits and potato starch supply is insufficient.

Adhesives are made most commonly from starch ( raw , modified , already mixed with some chemicals ) by action of heat , by caustic soda, or by caustic soda and heat . The quantity of caustic soda in solution is about 3 per cent but can be varied . Temperatures of the order of 150°F are used .

The equipment is often a stainless-steel or stainless-steel-lined, steam - heated, water - jacketed, kettle with an agitator . Processing involves running water into the kettle, adding the starch and mixing to a uniform slurry, then adding caustic soda in about 33 per cent solution slowly with continued agitation, and applying heat gradually until the mixture is at about 150 °F . The starch changes to an amber-colored, stringy paste. Heating is then discontinued and the reaction stopped by running cold water through the jacket. Satisfactory and uniform application of such an adhesive requires the use of mechanical spreaders. The bonded materials must then be pressed. After about 8 hours , bonded ply wood can be machined.

## CHAPTER - 11

### DEXTRIN

Associated closely with the starch industry is the dextrin industry. Much starch is converted into dextrin. From the economic viewpoint, it is desirable to convert the starch to dextrin in a building unit attached to a starch factory, thus avoiding some bagging, handling, and shipping costs. Many plants, however, make dextrans from potato, corn, and tapioca starches, all of which are produced in widely diversified geographical locations. For this reason, dextrin factories are often located near centers of dextrin consumption.

Dextrin may appear on the market in various grades, as "dextrin" is not a single product but a complex mixture. Among the components, the bulk being dextrin ( a modified starch product ) , are small quantities of sugars and brown - colored products of a peculiar odor.

According to published reports, dextrin was first observed when starch was accidentally heated in a British factory fire; this water-soluble, adhesive material was called British "gum" Dextrin corresponds to the chemical formula (  $C_6 H_{10} O_3$  ) , and is generally considered to be chemically intermediate between starch and dextrose. It is a gum - like substance, probably a mixture related to maltose, derived by heat or chemical action on starch. Dextrin is soluble in cold water and the solution, when treated with alcohol, yields an amorphous precipitate of dextrin. Chemical solutions, such as calcium and barium hydroxide, also cause a precipitate when added to a water solution of dextrin. Dextrin, like dextrose, yields water solutions which are optically active and dextrorotatory. It is a yellow or white amorphous solid in powder or granular form, insoluble in alcohol and in other neutral solvents . Its specific ( optical ) rotation is  $[\alpha] = + 195$ . It forms a thick , viscous solution which has strong adhesive properties .



## **Dextrin Production :**

Although starch is insoluble in water and in common solvents such as benzene, ethyl alcohol, diethyl ether, chloroform, etc., it can be partly broken down to yield completely soluble products in cold water. Heated alone under atmospheric pressure to about 204°C, or to a lower temperature in the presence of acid vapors, other chemicals, or enzymes, different degrees of degradation occur, varying with the kind and concentration of the reagent or mixture, and with the time and temperature roasting. Heated alone, starch becomes soluble due to the bursting of the granules as is evident under a microscope; further heating causes structural degradation, yielding various dextrans, which are water-soluble. Still further heating breaks down the dextrin molecules to the simple sugar, glucose, as discovered over a century ago by Kirchoff. With continued heating the glucose finally decomposes into gases and carbon.

Heated alone to about 140°C in an autoclave to about five atmospheres pressure, dextrans are formed and a little glucose. On cooling, a brown-colored, firm jelly is obtained. In an acid solution, as hydrochloric acid, a water-starch slurry directly yields the end product, glucose. Starch treated with the enzyme, malt diastase, breaks down only to the C<sub>v</sub>2 sugar, maltose.

The terms British gum, roasted gum, starch gum, and, of course, dextrin, have been applied to the primary starch decomposition products produced by heat without catalytic reagents. There is little chance in the fine spray of water at a rate which controls the final moisture and prevents any dextrin from being dissolved.

The advantages of the acid treatment over the dry-roasting method are that lower temperatures, of the order of 100 to 120°C can be employed and a lighter colored and more uniform product is obtained. A higher temperature permits shorter heating time.

Data and Chatterjee examined the preparation of dextrans on a laboratory and semi commercial scale by heating starches in free

access of air in a copper pan with an iron jacket filled with a sodium and potassium salt mixture which melted at 142°C. Hand stirring was used. For potato starch dextrin, the starch was heated with 0.225 ml concentrated nitric acid of sp. gr. 1.40, and magnesium chloride equivalent to 0.02 gram manganese per 100 grams of starch. The mixture was dried at not over 32 °C and passed through a 40 - mesh sieve; the starch was then dextrinized by heating to 170°C for 45 minutes. A yield of about 83 % of pale dextrin was obtained. With maize ( corn ) starch, 0.15 ml of nitric acid was used and the mixture dried and then heated at 210°C for 50 minutes to yield 85.6 per cent corn dextrin. For rice dextrin, starch was mixed with 0.625 ml of the nitric acid at 215 °C for 55 minutes for a yield of 80 per cent.

### **Dextrin Specifications :**

Specifications for dextrans are usually relatively few and simple. The common ones include moisture, solubility in water, color, viscosity, sugar content, and hydrogen ion concentration ( pH ). Variation in the starch used may require modification of the dextrin-making process or a blending of dextrans in order to produce a product which will meet certain specifications and have a definite adhesive strength. However, to produce dextrans with specific characteristics, the dextrin manufacturer seeks starches which are themselves relatively uniform. For example, high quality tapioca starch from a limited number of Indonesian starch factories was used in making almost all of the tapioca.dextrin until 1942. Then, shut off from the American and European markets, the improvement in Brazilian tapioca made it available for producing a good quality dextrin.

Dextrans made from corn, potato, and tapioca starches have somewhat different characteristics. Potato dextrin usually has an odor somewhat like that of cucumbers, due to a minute trace of potato oil. This odor develops during the roasting. It can be greatly reduced or eliminated by vacuum-drying the potato starch to about 7 or 8 per cent moisture. Such an odor and a taste are noticeable in adhesives applied to stamps, etc. Corn and tapioca starches yield adhesives with tasteless and odorless characteristics when applied to stamps and the Bureau of

Engraving and Printing of the United States Government, specifications for which are given below, require that tapioca starch ( flour ) or a proved substitute made from domestic raw material be used in making adhesives for stamps and envelopes for government use. In some cases, potato starch is treated with chemicals to give the adhesives made from it a sweet taste and pleasant odor. Thus the potato oil odor and taste, although slight, are masked. In the dextrination of starch, some sugar is often formed and this imparts a slight sweet taste.

Corn dextrin has about the same adhesive strength as potato or tapioca dextrans. However, they are cloudy instead of clear which reduces their value for some purposes. This cloudiness may be due to traces of protein and fat ( oil ) which are difficult to eliminate completely from corn starch, or to the small granule size.

Potato dextrin usually commands a higher price than corn or tapioca dextrin. In 1914, it was about 6 to 7 cents per pound, corn dextrin and British gum being at about one - half this price although the tariff at that time was only 0.75 cent per pound. The prices for domestic dextrans from potato starch have risen to as high as 20 cents per pound when potato starch was in short supply during periods of short duration since 1918.

United States Bureau of Engraving and Printing Specifications for Dextrin :

(a) - A dextrin not inferior to the material of which analysis is given below will be required :

Dextrin by polarization. . . . .	88.6
Reducing substance, as dextrose. . . . .	2.4
Volatile at 105°C . . . . .	1 - 8
Ash . . . . .	0.12
Material insoluble in cold water . . . . .	0.30
Polariscope reading, Ventzke scale, 10 grams in 100 cc	96.
Viscosity, three hours after solution in hot water, not less than 200 seconds nor more than 250 seconds	

Viscosity to be determined by Engier viscosimeter, after solution in hot water and cooling to 20°C, using 125 grams dextrin ( including moisture ) and 250 grams of water . The water time of the Engler viscosimeter now in use in this Bureau is 51.4 at 20°C.

(b) - Form - must be furnished as required without deviation from accepted sample, in powdered form and especially adapted for use in gumming postage and internal - revenue stamps, and free from grit or any foreign matter. After being dissolved and supplied to and dried on the sheets, it must be light in color, flexible, transparent, and of superior adhesive quality. It must be neutral, or only of slightly acid reaction.

(c) – Formula —The gum used as the adhesive on postage stamps is made according to the following formula: dextrin 750 pounds, boiling water 412 pounds. The product so made has a Beaume reading of 35.5° at 80°F. When cooled and allowed to stand for five days in an open vessel it must not show any appreciable thickening. Sample made according to this formula will be given a practical trial and rated on color , flexibility , and adhesive quality .

(d) - Sample - A sample of fifty pounds, free of expense to the Government, must be furnished of the exact article proposed to be supplied under contract.

### **Marketing and Uses of Dextrin :**

Dextrin appears on the market as the technical, yellow, white, granulated, or precipitated – by - alcohol grades. It is sold in cloth and paper bags and in wooden barrels.

Dextrin is used in brewing ; baking ; polishing coffee ; decoration of pottery and porcelain; process engraving; preparing some dry bandages ; making emulsions; thickening dye pastes and mordants in textile printing ; sizing some papers and fabrics; polishing cereal grains such as rice ; making glues, mucilage, and stamp, label,- paper, and envelope gums ; thickening tanning extracts ; and felting wool. It is also used in glass silvering compositions ; black

lithographic inks; some distilled liquors; textile bleaching, sizing, and finishing preparations; shoemakers' paste; some paper glazes and finish effects; some horticultural sprays; some printing inks; and in some confectionery ( especially whipped or beaten ) . It serves as a diluant and binder for dry extracts , tablets, and pills; a substitute for natural gums in pharmaceuticals ; a carrier and adhesive in laundry blues; a binder or adhesive in fireworks, explosives, and matches; a wetting-out agent ; an emulsifying agent; and occasionally as a chemical reagent.

Starch pastes have a stronger adhesive action than dextrans. Indeed, some papers, for example, those with a high rag content, will seal better with starch pastes than with dextrin gums. However, the water-soluble nature of dextrans makes them more desirable for admixture with other substances, especially simplifying their application to paper. Dextrin gums are well suited for use on stamps and envelope flaps, the surface of which only needs to be wetted for adhesive action.

With rapidly increasing costs of raw material and labor in the United States, the various industries making and using gums or gummed products are constantly under pressure to provide higher-strength adhesives and faster gumming machines. Sealing machines are being developed to seal ever - increasing quantities of packages of foods, etc., per minute. This requires gums or adhesives which are readily applied and which dry very quickly.

### **Analysis of Dextrin :**

Determinations of a dextrin usually include the following: water or moisture, ash, odor, taste, feel, microscopic appearance, sugar, cold water solubles, cold water insolubles, hot water solubles, and unchanged starch.

### **Moisture :**

Dry a 5 - gram sample in a quartz dish to constant weight at 105°C. Cool in a desiccator for about 20 minutes, and weigh.

**Ash :**

ignite the residue from the moisture determination to a white or gray ash , cool in a desiccator , and weigh .

**Insoluble matter in cold water :**

Stir 25 grams of the sample into 250 ml cold water and wash the mixture into a 500 - ml volumetric flask. Shake occasionally for several hours, dilute to volume, and let stand overnight. Pipette out 50 ml of the clear supernatant liquor ( equivalent to 2.5 grams ) , evaporate in a weighed dish on a boiling water or steam bath, and dry to constant weight at 105°C. Divide this residue by 2.5, then multiply by 100 (or shift decimal point two places to the right) to obtain the per cent of soluble solids. Add to this the per cent of water, and subtract the sum from 100 per cent. This gives the insoluble matter ( un converted starch ) .

**Dextrose :**

Mix a 10 - gram sample with water, stir thoroughly, and wash into a 250 -ml volumetric flask. Add 5 ml of lead subacetate solution, dilute to volume, mix, let settle, and filter through a dry filter. Do not wash. Add a few crystals of anhydrous potassium oxalate to remove lead and again filter through a dry filter, without washing. Determine dextrose in a 50 - ml portion of the clear solution (equivalent to 2.0 grams) by the regular Fehling - Allihn method , boiling for 2 minutes, and compute the percentage of free dextrose .

**Dextrin :**

Pipette 100 ml of the clear solution prepared for the dextrose determination into a 250 - ml flask, add 20 ml of 1:1 hydrochloric acid and 100 ml of water , boil gently 2.5 hours , cool , and neutralize to litmus with sodium hydroxide. Dilute to 500 ml in a volumetric flask, pipette out 50 ml , and determine dextrose after hydrolysis. This represents dextrose plus dextrin . Subtract from this figure the dextrose obtained above, to obtain dextrin .

## **Viscosity :**

Use a Dudley pipette surrounded by water at 25°C. Standardize the pipette with a sugar solution made by dissolving 120 grams of pure cane sugar in 100 ml of water at 25°C. This should give a viscosity of about 100 seconds. Fill the pipette..Release solution, with stop watch in other hand. Determine the number of seconds for a 100-ml flow. Make several runs, recording the average. Mix 40 grams of dextrin with about 150 ml of distilled water, heat to boiling, and boil exactly one minute, stirring thoroughly; then transfer to a 200-ml volumetric flask, cool, make to volume at 25°C, and determine the viscosity. The viscosity is much influenced by the time of heating. Therefore, in making the dextrin solution, stir the material with a little warm water and then pour it into a beaker containing the rest of the water which should be at or near the boiling point.

## CHAPTER - 12

### GLUCOSE AND CARMEL

One of the principal uses of starch is for making glucose. Starch heated with much dilute acid undergoes hydrolysis or breakdown, yielding in turn several grades of dextrin, maltose, and finally glucose.

Glucose ( dextrose ) is a  $C_6$  ( 6 - carbon atom ) sugar extensively found in sweet fruits such as grapes, etc. Honey is made up almost entirely of glucose. Because of the presence of glucose in grapes and fruits it is often called grape or fruit sugar. Glucose, in a water solution, is dextrorotatory, meaning that it rotates polarized light moving in one plane to the right; it is also called dextrose (right-rotatory sugar). Glucose is the common name for the syrups; dextrose for the solid sugar. Since dextrose is produced on a large scale from potatoes in Europe and from corn in America, it is also called potato sugar or corn sugar. It is less sweet than sucrose (cane or beet sugar) and also less soluble in cold water. Its crystals are smaller. Glucose is the normal sugar found in the blood as an energy-producing material, and pure, sterile dextrose sugar solutions are often introduced into the bloodstream intravenously after surgery. It has a lower market value than sucrose and can thus be used on a large scale as a sweetening agent . Cane syrup can not compete with glucose ( corn or potato syrup ) on a cost basis

Glucose was first produced by Kirchoff in 1811 from potato starch. It was then produced from other starches and starch - containing materials. The configuration of glucose was discovered by Emil Fischer .

#### **Glucose Production :**

The following steps are involved in glucose production: conversion of starch into sugar by acid ( hydrolysis ); neutralization of the acid; purification; clarification; vacuum concentration of the syrup .



The starch, if in solid form, is suspended in water to make about a 20°Be slurry for syrup and one of 10°Be for crystalline solids. It is then flowed by gravity or pumped into a pressure cooker. In some operations, a definite quantity of water is run into the cooker; the previously diluted acid is added, and then the starch milk. Vigorous boiling must be maintained. With live ( direct ) steam , the dilution due to condensed steam , usually about one - fifth of the total volume of water, must be taken into account.

When solid grape sugar is to be made, the weak liquor consists almost entirely of glucose ( dextrose ) in solution with only small quantities of other products, especially dextrans. Crystallization is made very difficult by dextrans . For this reason, the process is usually carried on quite differently according to the final product desired. A solid sugar has little or no dextrin, and a syrup has relatively much (about 30 to 40 per cent), along with maltose and other partial hydrolysis products of starch. Such a degree of molecular breakdown of the starch can be brought about by stopping the action of the acid at the proper point. The water used in the process is of ordinary drinking water grade.

Both sulfuric and hydrochloric acid can be used in the conversion of starch into glucose. These acids are purchased in concentrated form and diluted. Water must never be added to concentrated sulfuric acid due to the very marked heat evolution; the acid is always added to the water. Thus, when concentrated sulfuric acid is used in this process, a slight stream of acid is flowed into a wooden tank containing about four volumes of agitated water. The diluted sulfuric acid or diluted, higher cost hydrochloric acid (pH 1.9 for syrup) can be run into hot water in the cooker. Acid to the extent of 3 to 4 per cent of the weight of starch is often used to obtain solid corn sugar, and about 2 per cent if a syrup is desired.

Corn syrup can be made in open kettles, but the product is regarded as inferior and less uniform than that made much more quickly in pressure cookers at relatively high temperatures and in about one - sixth of the time. The cookers are strongly built of copper

or of steel with a copper lining when hydrochloric acid is used, or of steel with a lead lining when sulfuric acid is used. They are often about 5 or 6 feet in diameter and 20 feet deep, or even larger.

A wooden tank cooker is some times used in small plants for treating 1.5 tons of green starch. It is about 8 feet deep, 5.5 feet wide at the base, and 5 feet at the top. It is provided with a tightly fitting cover and equipped with a flue for removing vapors to the open air. Heat is transferred to the starch mixture by a heating coil (5 to 6 turns) of 2.5 - inch copper tubing, the coil being about 4.5 feet outside diameter. Steam is admitted at the top of the coil; condensate is discharged at the bottom through a 1 - inch pipe . If live steam is desired for the cooking, the bottom of such a coil can be closed off and the coil perforated.

Pressure is of the order of about 2.5 - 3 atmospheres for crystals, the equipment having been tested for twice the working pressure. Like steam boilers or other pressure equipment, pressure cookers are usually insured and inspected by both insurance company and government inspectors. Both cylindrical and tapered cookers are used. Water, acid, and starch milk are added through one or two valves at the side or near or in the top. They are added slowly and in the order indicated to obtain a smooth gelatinized paste without lumps. The glucose with the diluted acid is run off through a valve at the bottom. A safety valve and pressure gage are provided in the top. One or more sampling valves are located in the side. A manhole in the top makes entrance possible for cleaning and inspection. The cooker is usually set into a strong floor with legs or angle bars attached to the side of the shell to support it. The top is often about 3 feet above the upper floor at a convenient working level.

The process of converting starch in Europe is described by Bersch in his comprehensive book on glucose. Whalley has compiled much useful information on glucose manufacture.

## **Hydrolysis of Starch for Syrups :**

Except for the kind of starch used, European and American glucose - producing practices are quite similar. In the common American procedure using hydrochloric acid, a starch slurry of about 21°Be is acidified with enough acid to obtain a pH of about 1.9 and is pumped into pressure converters while live steam is being admitted at a rate so that the starch will gelatinize smoothly and so that no large lumps will be formed. Steam pressure is then built up to about 30 pounds and the hydrolysis is completed in about 0.5 hour.

## **Neutralization of the Acid :**

The liquid mass is then blown through a pipeline into a tank or vat which is often located on an upper floor. Here it is neutralized with sodium carbonate to remove the free acid and to obtain a pH of from 5.0 to 7.0. Sodium chloride is formed in the syrup as a result of the neutralization of the hydrochloric acid by the sodium carbonate. This salt, in the small quantity in which it is present, is not undesirable and remains in solution. When the solid sugar is to be made, it is left in the mother liquor when the dextrose crystallizes out. When sulfuric acid is used instead of hydrochloric acid as the hydrolyzing agent, slaked lime ( calcium hydroxide ), or sodium carbonate can be used to neutralize it. With the former, calcium sulfate is formed, which is practically insoluble in hot water and only slightly soluble in cold. Settling tanks or filter presses are needed for its removal, and the glucose requires much washing. When sodium carbonate is used to neutralize the sulfuric acid, sodium sulfate is formed. This salt is soluble and remains in the syrup. It should be added that when the neutralizer is sodium carbonate, carbon dioxide gas is produced which must be allowed to escape to prevent froth - over and loss of some glucose. Therefore, neutralization is carried out slowly or in steps to a pH of 5 to 7, in agitator tanks much larger than the converter. Only a small quantity of the alkali by weight is introduced, -in solution or suspension, at the bottom of the tank, until the free acid is completely neutralized. Only a slight excess of the computed neutralizer is ever used.

## **Purification :**

Some impurities may separate as solids. These can be removed by skimming from the surface in the neutralizing tank, or by centrifugal separation. Impurities will depend on the starch used and its purity. The solution is then passed through filters. The clear brown filtrate is decolorized by passing it through bone-char filters. These filters are usually long and narrow to permit a long period of contact with the glucose solution. In large plants, a series of char filters is used, the glucose solution being circulated through each filter in the series, finally passing through the freshest char. The char removes colors and some other impurities from the solution by surface adsorption and has no effect on the sugar. To make its use economical, the sugar must be thoroughly washed out with hot water. When the most used char no longer removes enough color, the char unit is "cut out" of circulation and the char revived or reactivated by burning off impurities in refractory-lined shelf furnaces. After being sieved to remove the very fine particles of carbon, the fresh, revived char is returned to a filter which then becomes the last in a purification series.

It has been stated<sup>2</sup> that the new Duzarit-Asmit process for cleaning and decolorizing glucose by a combination of ion exchange and adsorption appears more economical than the use of bone char, although ion exchange equipment and installation costs are reported as being high.

## **Concentration of the Syrup :**

The density of the purified and decolorized solution is about 30°Be. It is next concentrated in vacuum evaporators to a dextrose equivalent of 25 to 55 per cent and a density of about 42° Be.

One vacuum evaporator made by "Starcosa" has the main section bolted to the jacketed bowl. The upper part is provided with an outlet for vapors which have passed through a trap designed to catch suspended particles of sugar. Fittings include a three-way charging valve for admitting the sugar solution; a steam admission pipe with

one valve to admit steam to the heating coil and another to admit steam to the jacket of the bowl; a valve for discharging condensed water from the jacket; a thermometer; vacuum gauge; air valve; gauge glass; and a testing funnel to permit the drawing of samples from the concentrating mass to test its density without stopping the evaporation. A small window diametrically opposite a strong light is used for viewing the boiling sugar mass. The concentrated syrup is run off through a pipe, controlled by-a plug valve, which passes through the bottom of the steam jacket. Cylindrical evaporators are also used.

In the first evaporator unit there is only a slight vacuum. In the succeeding evaporator units the vacuum may be about 21 to 27 inches. Therefore, the steam evaporated in the first effect can be used to boil the solution in the second effect, under greater vacuum, thus preventing overheating of the more concentrated solution which could cause discoloration and scorching. A large, saving of steam also results. A third effect operating on the same principle is also used.

Films of glucose solution in a modern film-type tubular evaporator are in contact with the steam-heated tubes for only very short periods. Naturally, the tubes must be kept clean and free from deposits of calcium sulfate and decolorizing carbon when sulfuric acid has been used as the hydrolysing agent and lime for neutralization. Some evaporators are especially built to facilitate the cleaning of the heat transfer tubes.

The behavior of the mass in the vacuum evaporator is indicative of the concentration, although blocking off and drawing a sample from the gauge glass is commonly employed. The capacity of a large triple effect evaporator may be about 60 barrels of syrup per hour. As the hot syrup undergoes some oxidation, it is always cooled rapidly after leaving the vacuum evaporators, sometimes by being pumped through a refrigeration unit. In some factories, the concentrated syrup of about 45° Be is flowed to the finished syrup storage tanks from which it is drawn into 60 - pound cans , barrels , or drums of about 680 pounds net weight or into tank cars holding about 50 tons.

## **Crystallization :**

Crystal formation is controlled largely by the quantity of dextrans left with the glucose. It is much more difficult to obtain pure dextrose crystals than those of sucrose (common cane or beet- sugar) , and the manufacturer seeks an end - product of quality and the desired characteristics, as well as the maximum economic yield.

Dextrose crystallizes in two modifications: one having one molecule of water and forming hexagonal tablets in the crystallized mass, and the other having no water of crystallization and forming very fine needles. Granular, nodular, and other hard masses are also formed. Newkirk :!discusses the preparation of dextrose monohydrate crystals, refined anhydrous dextrose (  $\alpha$  - D - glucose), and  $\beta$  - dextrose (  $\beta$  - D - glucose ) . ami gives a method for converting the monohydrate to anhydrous crystals.

To obtain solid crystalline glucose which is extensively used in industry, the hot thick syrup from an evaporator, having a concentration of 70 to 80 per cent dextrose, is run into crystallizing pans or onto a crystallizing floor. The solid dextrose can then be broken up by sledges, then into small pieces by crushers or chippers and loaded into box cars for shipment. Slabs or molded masses often weigh about 150 pounds. Such commercial sugar is used by tanners, rayon manufacturers, and manufacturers of vinegar, "soft" or carbonated - water drinks, etc. For such uses, glucose in the brown form, without decolorization, is satisfactory.

For refined white dextrose crystals, the purest starch must be used, the purest glucose solution produced, and the production through crystallization carefully controlled at each step. Using essentially the same procedure as for syrup production but obtaining a thin starch slurry of about 10° Be and using 45 pounds pressure and a higher temperature, more dextrose is formed and less dextrin, etc. When about 91 % dextrose is present in the cooker, the hydrolysis is stopped, the acid neutralized, the pH adjusted, and the solution clarified and evaporated under a vacuum to a density at which clear

crystals form on cooling. If concentrated to about 40°Be, cooled to about 40 °C , and slowly agitated and seeded with dextrose monohydrate, the purified clear solution yields a mass of the monohydrate dextrose crystals . This crystalline slurry ( massecuite ) is then flowed or pumped to centrifugals which separate the crystals from the syrup, or it may be converted into the anhydrous dextrose. Seeding with anhydrous dextrose yields the anhydrous product. The mother liquid from which the crystals were separated is added to a successive batch. Recrystallization of dextrose crystals, produced as described above , yields practically 100 per cent pure dextrose, a pharmaceutical - grade sugar.

Crystalline dextrose is dried in rotary hot-air driers. It is usually bagged in 100 - pound paper - lined cotton or paper bags, often by use of automatic bag fillers , and closed by machine sewing .

### **Marketing of Glucose :**

In the American market , glucose can be obtained as brown - colored syrup of different densities; white; syrup ; brown crystalline masses of various or sifted sizes; molded blocks of definite weights; pure white monohydrate crystals; and pure white anhydrous crystals.

American glucose manufacturers operate evaporators to obtain certain percentages of dextrose ( dextrose equivalents , DE ). At a purity of 60, a syrup may yield crystals. Thus, production must be controlled to assure the consumer that the product will not be a mixture of syrup and crystals. In some cases the blending of syrups from two or more storage tanks in a glucose plant may be resorted to in - order to meet specific requirements of certain customers. Some syrups for table use are blended with sucrose syrup.

Large quantities of glucose syrups are used in the canning of fruits. Large fruit canners obtain glucose in tank - car lots, often specifying one of four grades, based on the percentage of dextrose. These grades are as follows :

(1) - low conversion , ( DE ) of 28 – 33 , 79.5 % total solids . (43°Be )

- (2) - Medium or average conversion DE 40 – 42 , 80.3 % solids .
- (3) - High acid conversion , DE 52 – 57 , 81 % solids .
- (4) - High enzymatic conversion , DE 62 – 65 , 81.8 % solids.

The low or 28 - 33 grade is not as sweet as the others and has a relatively high viscosity. The medium conversion grade is suitable for most uses in a fruit canning plant. The high acid conversion grade is also suitable for most cannery uses but under some conditions may have a slight bitter taste and also the possibility of crystallization out of some dextrose. The high enzymatic conversion grade possesses the highest degree of sweetness, and when mixed with 25 per cent of cane syrup, it yields an excellent syrup for preserving fruits of all kinds

### **Caramel :**

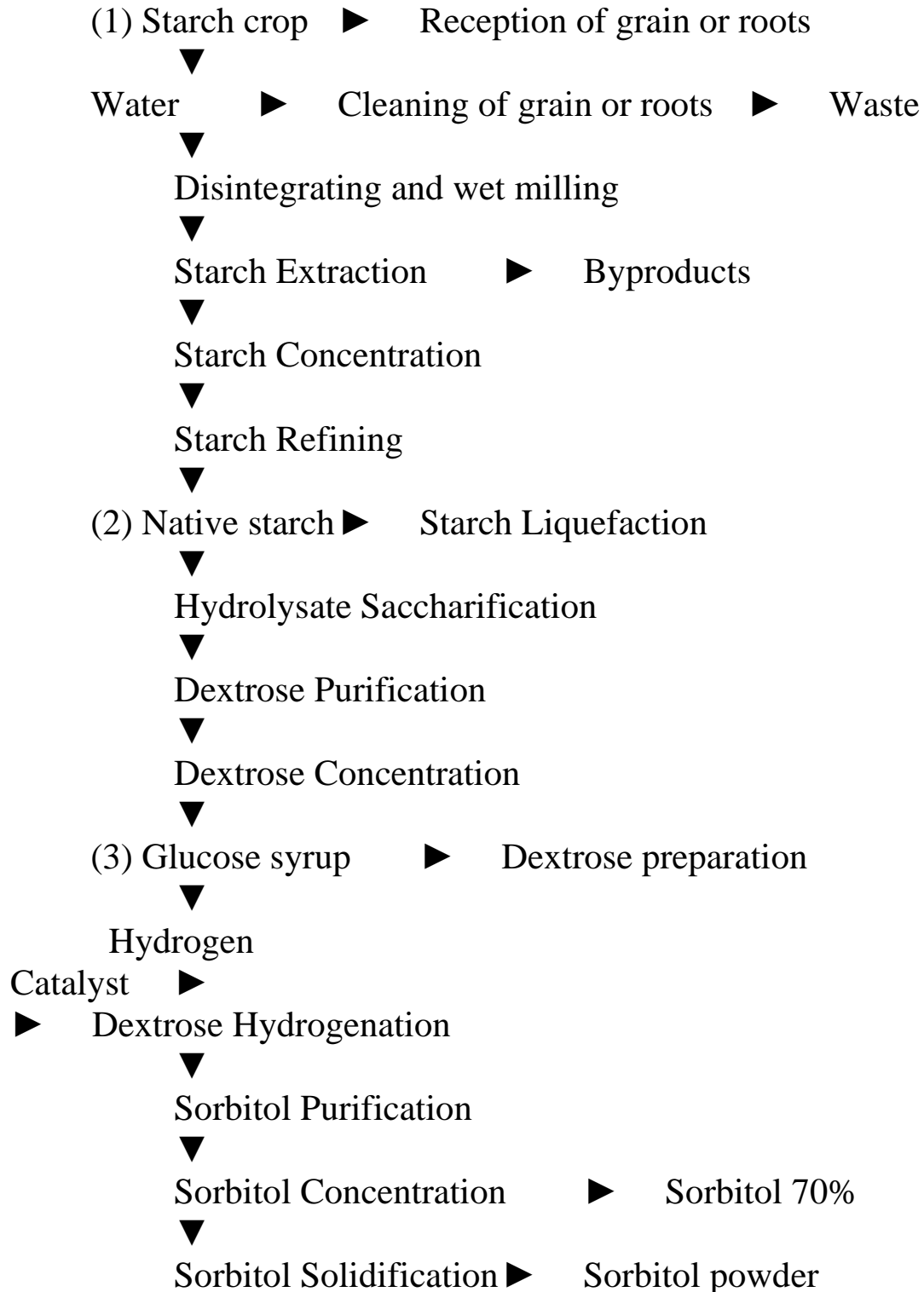
Caramel, as a coloring agent for foods, confectionery, liquors, etc., is extensively made from corn or potato glucose, rather than from sucrose, because of its lower cost. Caramel coloring does not produce any turbidity and does not affect the brilliance of a solid or liquid. Since dextrans are insoluble in alcohol, the glucose caramel used for alcoholic liquids must be devoid of such material.

The essential feature of caramel production is carrying the caramelization to the point where all sugar has been destroyed and carbon has not been liberated, or where decomposition products with a sharp, bitter, irritating taste have not yet been formed. A small quantity of sodium carbonate reacts with some of the acid which forms. Uniform and controlled heating to between 177 and 204° C and uniform agitation are necessary. No material must be left at the bottom of the pan of the caramelizing apparatus. Hence, these pans must be broad and shallow with agitators to keep the bottoms clean. To care for the frothing and gas formation for a given weight charge, expansion space and a hood with flue must be provided. The removal of acrid fumes is aided by means of a suction blower or a chimney stack with a good draft. Hinged covers which fit well permit the pan to be loaded and also cleaned. Taps are present for drawing off the thick,



dark-brown liquid whose density is about 1.35. Flues conduct the hot gases so as to impart a uniform heat to the bottom of the pan. The agitators, gently scraping the bottom of the pan, are driven by cone-pinion gears connected to a horizontal drive shaft. A small water tank, also heated by the hot flue gases, can be used to supply hot water, to dilute and to aid in the removal of the syrupy caramel from the pan outlet, or to reduce frothing and boiling - over of the hot caramelizing mass.

Caramelization is completed when a thin layer of a sample flows from an inserted test rod to yield a dark - brown, lustrous, brittle, glass-like mass. Small drops thrown into cold water should float to the surface and break up, as a result of the surface's cooling to a brittle mass before the interior hot liquid can solidify. A sample should have a pleasant but slightly bitter taste, some sweetness resulting from the presence of a little undeecom - posed sugar. When the sugar has caramelized to the proper extent, the contents of the pan is dissolved in about one-half its weight of hot water and drawn off through a cloth filter into storage tanks. Caramel coloring has a density or specific gravity of about 1.35. It must be entirely soluble in 90 per cent (volume) ethyl alcohol , also in dilute ethyl alcohol, indicating the absence of dextrin, and it must be very soluble in water to yield a clear solution. Caramel is soluble in most organic solvents. For coloring high alcoholic beverages, caramelization is checked to obtain lower tinctorial characteristics and more stability.

**CHAPTER - 13****Sorbitol****Process Route**

Input to the process may be either  
 (1) a starchy crop like cassava, corn and wheat,  
 (2) a native starch of any origin or  
 (3) pure dextrose monohydrate or glucose syrup of a suitable DE dependent on sorbitol specifications.

<b>Some Polyols</b>	<b>Sweetness ( Sucrose = 1 )</b>	<b>Calories kcal / g</b>
Arabitol	0.7	0.2
Erythritol	0.8	0.2
Glycerol	0.6	4.3
HSH	0.2 - 0.5	3.0
Isomalt	0.5	2.0
Lactitol	0.4	2.0
Maltitol	0.9	2.1
Mannitol	0.6	1.6
Sorbitol	0.6	2.6
Xylitol	1.0	2.4

Vitamin C may be manufactured by the Reichstein - synthesis with the following steps :

Sorbitol ► sorbose ► di acetone sorbose ► di acetone keto gulonsyre ► and final rearrangement as vitamin C .

Sorbitol is a sugar alcohol,  $C_6 H_{14} O_6$  found in nature as the sweet constituent of many berries and fruits best known from *Sorbus aucuparia* (Rowan or European Rowan) from which it was isolated for the first time in 1872.

Mid 1950s, sorbitol large scale manufacture began due to new applications, such as humectant in cosmetology and sugar substitute in non cariogenic confectionery. Sorbitol is today commercially produced from starch by enzymatic hydrolysis and catalytic hydrogenation. It has wide applications as a sweetener and humectant.

## **SYNONYMS :**

Sorbitol  
Glucitol  
D - glucitol  
D - Sorbitol  
Sorbite  
Hydrogenated Starch Hydrolysate ( HSH )



## **HSH**

Hydrogenated starch hydrolysates ( HSH ) , - poly glycol syrups - are found in a variety of foods . They serve as bulk sweeteners , viscosity or bodying agents, humectants ( moisture retaining ingredient ) , crystallization modifiers etc. just like sorbitol.

HSH and sorbitol are made the same way, but from starch hydrolysates of different Dextrose Equivalent ( DE ) and different composition. Sorbitol is the result of hydrogenation of dextrose or starch syrup with a high DE equivalent to pure dextrose , while a hydrogenation of low DE hydrolysate will lead to a mixture of sorbitol , maltitol , and longer chain hydrogenated saccharides (maltitritol a.o.) With no single dominant polyol the generic name Hydrogenated Starch Hydrolysate is used . If 50 % or more of the polyols are of one

type, it can be labelled as "sorbitol syrup", or "maltitol syrup", etc. A special variety is manufactured by hydrogenation of the mother liqueur ( hydrol ) after first dextrose monohydrate crystallization.

Hydrogenated starch hydrolysates are 20% to 50% as sweet as sugar depending on its particular composition. The HSH family of polyols is an approved food ingredient in Canada, Japan and Australia. U.S. food manufacturers may use HSH while FDA reviews the petition seeking approval for its use in foods.

### **CRYSTALLINE PROPERTIES :**

Sorbitol has four crystal structures - four anhydrous crystalline phases plus the hydrate. It may be crystallized from an aqueous solution or low moisture melt or even spray dried / spray crystallized. Gamma polymorph is the most stable of the anhydrous crystalline forms confirmed by its high melting point and low hygroscopicity and is the only form of significance for the confectionery and pharmaceutical industries.

Density : 1.489 g / cm

Melting point : 95 C

Boiling point : 296 C

### **RAW MATERIALS :**

Starch crops grain or roots are the basic raw materials. Also purified starch of any origin corn, wheat, potato or cassava can be used. The hydrogenation can of course begin with dextrose liquid or dry but in real life the process begins with basic raw materials like cassava, corn or wheat.

### **PROCESS :**

The front end design depends on the selected agro commodity. The attached diagram shows briefly the process route. The various designs are described in greater detail in respective Technical

## Memoranda.

The basic raw materials are cleaned and the starch is extracted in a wet milling process and then purified and concentrated to 21° Be pure starch milk. So far the process is identical to the one used for the manufacturing of native starch as the end product.

Instead of drying the starch, the concentrated pure starch milk is liquefied by cooking with acid or alpha-amylase. The cooking is carried out continuously in a converter by injecting steam. A rather low DE hydrolysate is the resulting intermediate of this conversion. The hydrolysate is hydrolyzed to the very end as the monosaccharide dextrose and purified. The purified fully saccharified starch solution is concentrated and is now identical to standard high DE dextrose syrup.

The clear dextrose solution is hydrogenated in the presence of a catalyst in vigorously stirred reactors at specified pressure and temperature. It is necessary to safe-guard the process carefully, because of the hydrogen applied. Head space of the autoclave is flushed with nitrogen to remove air and its oxygen completely. Hydrogen is made on site. The hydrogenation is carried out intermittently in few hours cycles. The hydrogenated solution is decanted and subsequently subjected to carbon treatment and ion exchange. The catalyst is recycled and reused.

The purified solution is evaporated to 70% dry matter - the most usual concentration of Liquid Sorbitol. The syrup may be spray dried or crystallized to obtain a powder .

## **MARKET :**

A review on sorbitol safety as been assessed by the Joint FAO / WHO Expert Committee on Food Additives concludes that it is not necessary to limit the dietary intake of sorbitol and related sugars. Nor has the Committee specified an Acceptable Daily Intake for Sorbitol. In the Code of Federal Regulations, FDA notes that sorbitol is used in food at levels not to exceed good manufacturing practices. These regulations further require that any sorbitol - containing foods whose

consumption would add 50 grams of sorbitol to a persons diet must be labelled with the statement, Excess consumption may have a laxative effect . In USA use is regulated by FDA. A maximum level of 99 % of sorbitol may be used in hard candy and cough drops, 98 % in soft candy, 30 % in commercial jams and jellies, 30 % in baked goods and baking mixes, 17 % in frozen dairy desserts and mixes and 12% in all other foods.

Sorbitol has a smooth mouth feel with a sweet , cool and pleasant taste. It shares many applications with propylene glycol and glycerine and glycerine provides hard competition in the market for humectants. Sorbitol acts as a crystallization modifier or inhibitor; it can prevent syrups from forming crystals of sugar. It is used to add body and viscosity to mixtures, and can protect against damage from freezing (cryoprotectant) and drying.

Liquid sorbitol itself has a tendency to crystallize at room temperature. A product of choice for most applications is non - crystallizing sorbitol ( NCS ) - a 70 % solution with approximately 50 % sorbitol and smaller amounts of other polyols ( maltitol a.o. ) .

## **POLYOLS :**

Global production of sorbitol has reached approximately 800.000 MT per year.

Sorbitol being the most commonly used polyol (it is the least costly) held the biggest market share among similar polyols.

Sorbitol	800,000 MT
Xylitol	200,000 MT
Mannitol	180,000 MT
Maltol	160,000 MT

Roquette Freres is the world's biggest sorbitol producer. Together with Cargill and SPI Polyols they hold a market share of over 70 %. Roquette has set up several production bases worldwide and is also constructing a large sorbitol plant in the east of China.

## **INDUSTRIAL TECHNICAL APPLICATIONS :**

Sorbitol, together with other polyhydric alcohols such as glycerol, is one of the ingredients in alkyl resins and rigid polyurethane foams manufacturing.

In tobacco industries, sorbitol may give mild effect in sniff, good humectant agent, and avoid acrolein formation which formed in burned glycerine. Sorbitol is used as softener and colour stabiliser in textiles and as softener in leather industries.

The manufacture of vitamin C consumes approximately 15% of world sorbitol production. *Gluconobacter oxydans* are used for the oxidative conversion of D - sorbitol to L - sorbose an important intermediate in de manufacture of L - ascorbic acid ( Vitamin C ) .

## **DIABETIC AND SLIMMING FOODS :**

A possible pathway of sorbitol metabolism is via fructose and glycogen to glucose. This process is slow. In trials no significant increase in blood sugar were observed after intake of ice cream with 35 g sorbitol. The low glucemic index explains the interest for sorbitol in diabetic foods.

Sorbitol is actually a nutritive sweetener with 2.6 calories per gram. Table sugar has 4 calories per gram. Slimming foods take advantage of this difference in calories and add artificial sweeteners to compensate for the lower sweetness of sorbitol.

## **ORAL CARE :**

Sorbitol does not promote tooth decay ; it is resistant to metabolism by oral bacteria which break down sugars and starches to release acids that may lead to caries. In toothpaste around 20 % of the sorbitol market - it serves as a humectant, bodying agent, sweetener, shelf - life extender, crystallization inhibitor. It competes with the sweeter xylitol, but in many recipes, they act together.

Sorbitol is an obvious choice for chewing gums and non-cariogenic confectionery. It is far better than table sugar. It adds sweetness with no risk of tooth decay.

Oral - care is in fact an important market with toothpaste, chewing gums, mouthwash and breath fresheners as top sellers.



## **SKIN CARE :**

Sorbitol retains moisture on the skin and leaves it feeling soft. Up to 5 % is used in creams , lotions , gels , lipsticks , masks , shaving cream , after shave lotions , shampoos and hair conditioners .

Sorbitol is also number one, when it comes to clarity and translucency as in transparent bar soaps and translucent gels.

## CHAPTER - 14

### Other Polyols

Non – nutritive , or high - intensity sweeteners:

- Saccharin
- Aspartame
- Acesulfame K
- Sucralose

**Polyols** or sugar alcohols are low-caloric, sugar-free, alternative sweeteners used to replace traditional sweeteners.

Some Polyols	Sweetness ( Sucrose = 1 )	Calories kcal / g	Origin
Arabitol	0.7	0.2	Arabinose
Erythritol	0.8	0.2	Starch
Glycerol	0.6	4.3	Fat
HSH	0.2-0.5	3.0	Starch
Isomalt	0.5	2.0	Sucrose
Lactitol	0.4	2.0	Whey
Maltitol	0.9	2.1	Starch
Mannitol	0.6	1.6	Starch
Sorbitol	0.6	2.6	Starch
Xylitol	1.0	2.4	Hemicellulose

#### **rabitol :**

or arabinitol or lyxitol is a sugar alcohol. It can be formed by the reduction of either arabinose or lyxose.

$\text{CH}_2\text{OH}(\text{CHOH})_3\text{CH}_2\text{OH}$  a sweet , colorless crystalline material present in D and L forms ; soluble in water; melts at 103C. Also known as arabite . CAS nummer 2152 - 56 – 9 .

#### **Erythritol :**

$\text{C}_4\text{H}_{10}\text{O}_4$  122 g mol<sup>-1</sup> , Density 1.45 g / cm Melting point 121 C . Boiling point 329 - 331 C.

Erythritol is a natural sugar alcohol , which has been approved for use throughout much of the world. It occurs naturally in fruits and fermented foods. At industrial level, it is produced from glucose by fermentation with a yeast, *Moniliella pollinis*. It is 60 -70 % as sweet as table sugar and almost non - caloric. Glucemic index is zero and it does not cause tooth decay. It is absorbed in the small intestine and then for the most part excreted unchanged in the urine. Therefore does not cause gastric side effects unlike other sugar alcohols. According to FDA labeling requirements, it has a caloric value of 0.2 calories per gram . In the European Union regulations currently label it and all other sugar alcohols at 2.4 kcal/g. As a whole, erythritol is generally free of side - effects in regular use.

Erythritol has a strong cooling effect ( positive heat of solution ) very similar to that of xylitol when it dissolves in water.

Erythritol has been certified as tooth-friendly. The sugar alcohol cannot be metabolized by oral bacteria, and so does not contribute to tooth decay. Interestingly, erythritol exhibits some, but not all, of xylitol's tendency to "starve" harmful bacteria.

### **Glycerol :**

Glycerol or glycerine forms the backbone of fat ( triglycerides ) , it is produced on saponification or trans esterification .

In foods and beverages, glycerol serves as a humectant, solvent and sweetener, and as a thickening agent. As a sugar substitute, it is 60 percent as sweet as sucrose. Although it has about the same food energy as table sugar, it is non - glycemic and non-cariogenic.

### **HSH :**

Hydrogenated starch hydrolysates ( HSH ) , - poly glycol syrups - are found in a variety of foods. They serve as bulk sweeteners, viscosity or bodying agents, humectants (moisture retaining ingredient), crystallization modifiers etc. just like sorbitol.

HSH and sorbitol are made the same way, but from starch hydrolysates of different Dextrose Equivalent ( DE ) and different composition. Sorbitol is the result of hydrogenation of dextrose or starch syrup with a high DE equivalent to pure dextrose, while a hydrogenation of low DE hydrolysate will lead to a mixture of

sorbitol, maltitol, and longer chain hydrogenated saccharides (maltitritol a.o.) With no single dominant polyol the generic name Hydrogenated Starch Hydrolysate is used. If 50 % or more of the polyols are of one type, it can be labelled as "sorbitol syrup", or "maltitol syrup", etc. A special variety is manufactured by hydrogenation of the mother liqueur (hydrol) after first dextrose monohydrate crystallization.

Hydrogenated starch hydrolysates are 20% to 50% as sweet as sugar depending on its particular composition. The HSH family of polyols is an approved food ingredient in Canada, Japan and Australia. U.S. food manufacturers may use HSH while FDA reviews the petition seeking approval for its use in foods.

#### **Isomalt :**

Isomalt is a sugar alcohol used for its sugar - like physical properties. Its glucemix index is low and it does not promote tooth decay. Like most sugar alcohols, it may cause gastric distress, including flatulence and diarrhoea, when consumed in large quantities and should not be consumed in quantities larger than about 50g per day for adults.

Isomalt is a disaccharide composed of the two sugars glucose and mannitol. It is odourless, white and crystalline. Isomalt has a low cooling effect, lower than many other sugar alcohols, particularly xylitol and erythritol. Isomalt is a natural sugar alcohol and may be produced from beets.

Isomalt is manufactured in a two-stage process in which sugar is first transformed into isomaltulose and then hydrogenated, using a Raney metal catalytic converter.

Isomalt has been approved for use in the United States since 1990 and in several other countries.

#### **Lactitol :**

Lactitol is manufactured from whey. Lactitol is a sugar alcohol used in low calorie foods with approximately 40 % of the sweetness of sugar. It is used in sugar-free candies, cookies, chocolate, and ice cream. Lactitol, sorbitol, xylitol, mannitol, and maltitol are all sugar alcohols. The United States Food and Drug Administration ( FDA ) classifies sugar alcohols as "generally recognized as safe" ( GRAS ) .

They are approved as food additives, and are recognized as not contributing to tooth decay or causing increases in blood glucose. Lactitol is also approved for use in foods in most countries around the world.

### **Maltitol :**

Maltitol is a sugar alcohol with 75 - 90 % of the sweetness of sucrose and nearly identical properties, except for browning. It is used to replace table sugar because it has fewer calories, does not promote tooth decay and has a somewhat lesser effect on blood glucose. Commercially, it is known under trade names such as Maltisorb and Maltisweet.

Maltitol is made by hydrogenation of maltose obtained from starch. Its high sweetness allows it to be used without being mixed with other sweeteners, and exhibits negligible cooling effect in comparison with other sugar alcohols, and is very similar to the subtle cooling effect of sucrose. It is used especially in production of sweets: sugarless hard candies, chewing gum, chocolates, baked goods, and ice cream.

Maltitol does not brown and caramelize after liquifying by exposure to intense heat. It does not promote tooth decay. It is somewhat more slowly absorbed than sucrose which makes it somewhat more suitable for people with diabetes than sucrose.

In some countries it carries a mandatory warning such as "*Excessive consumption may have a laxative effect.*" In the United States, it is a Generally recognized as safe ( GRAS ) substance, with a recommendation of a warning about its laxative potential when consumed at levels of 100 grams per day or more.

### **Mannitol :**

This polyol is used as an osmotic diuretic agent and a weak renal vasodilator. It was originally isolated from the secretions of the flowering ash, called manna after their resemblance to the Biblical food, and is also be referred to as mannite and manna sugar.

Mannitol is a sugar alcohol, that is, it is derived from a sugar by reduction. Aqueous solutions of mannitol are mildly acidic and sometimes such solutions are treated to raise the pH.

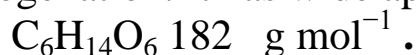
In oral doses larger than 20 g, mannitol acts as an osmotic laxative.

Mannitol is also used as a sweetener for people with diabetes. Since mannitol has a positive heat of solution, it is used as a sweetener in "breath - freshening" candies, the cooling effect contributing to the fresh feel.

### **Sorbitol :**

Sorbitol is a sugar alcohol,  $C_6H_{14}O_6$  found in nature as the sweet constituent of many berries and fruits best known from *Sorbus aucuparia* (Rowan or European Rowan) from which it was isolated for the first time in 1872.

Mid 1950s, sorbitol large scale manufacture began due to new applications, such as humectant in cosmetology and sugar substitute in non cariogenic confectionery. Sorbitol is today commercially produced from starch by enzymatic hydrolysis and catalytic hydrogenation. It has wide applications as a sweetener and humectant.



### **Xylitol :**

Xylitol is roughly as sweet as sucrose with only two-thirds the food energy. As with most sugar alcohols, consumption can result in bloating, diarrhea, and flatulence, although generally rather less so than other sugar alcohols like sorbitol. Xylitol was first derived from birch trees in Finland in the 20th century and was first popularised in Europe as a safe sweetener for people with diabetes that would not impact insulin levels. The largest manufacturer globally is the Danish company Danisco. Xylitol is produced by hydrogenation of xylose. Xylitol has virtually no aftertaste, and is advertised as "safe for diabetics and individuals with hyperglycemia." This tolerance is attributed to the lower impact of xylitol on a person's blood sugar, compared to that of regular sugars. Xylitol is widely used in Finland, its "home country." Many Finnish confectioneries employ xylitol, or have a xylitol version available. Virtually all chewing gum sold in Finland is sweetened with xylitol. Xylitol is a "tooth friendly" non-fermentable sugar alcohol.

Xylitol - based products are allowed by the U.S. Food and Drug Administration to make the medical claim that they do not promote dental cavities. A recent study demonstrated that as a water additive for animals, xylitol was effective in reducing plaque and calculus accumulation in cats . Possessing approximately 40% less food energy, xylitol is a low - calorie alternative to table sugar. Absorbed more slowly than sugar, it does not contribute to high blood sugar levels or the resulting hyperglycemia caused by insufficient insulin response. Xylitol also has potential as a treatment for osteoporosis.

**Part Two**

**Starch & Glucose**

**Glossary**



<u>A</u>	
Acid conversion	Starch hydrolysis with acid as the catalyst
Acid treated starch or Acid - thinned starch	Granular starch slightly hydrolyzed with acid at low temperature.
Acetylated distarch adipate	Acetylated starch cross linked by adipate groups.
Acetylated distarch phosphate	Cross linked starch esterified with acetyl groups.
Acetyl value	Acetyl value of a modified starch is % of acetyl groups calculated on starch dry matter . Method : <b>ISI 14</b> Acetyl Content Determination .
Acetylated starch	Granular starch ester with a $\text{CH}_3\text{CO}$ - group introduced at low temperature
Adjunct	Malt substitute. Adjunct syrup is used as a brewing supplement and booster - see wort syrup.
Alkali lability	Substituents of a modified starch removable by hydrolysis with alkali is titrated. Method : <b>ISI 23</b> Determination of Alkali Lability.
Alkali number	Is a measure of the average molecular weight of the starch and expressed as ml 0.1N sodium hydroxide, consumed under test conditions.
Amaranth	A common name used for plants with blossoms that do not readily fade when picked.
Amphoterich starch	is modified starch which both cationic and anionic substituents . f.e. cationic potato starch.
Amylase	is an enzyme breaking down starch at random. For the liquefaction an $\alpha$ - amylase of bacterial origin is used. For high maltose syrups $\alpha$ - amylase is applied for saccharification

Amylo glucosidase ( AMG )	Enzyme cutting off glucose from the non-reducing end of starch. AMG cuts both 1-4 and 1-6 bonds and enables the manufacture of up to 98 DE syrups, acting optimal on molecules that are 4 - 5 glucose units long
Amylo pectin	For most starches amylo pectin is the major component, and amylose the minor component. Amylo pectin is a branched glucose polymer with typically one 1-6 glucosidic bonds for every 12 glucose units. Amylopectin consists of several 100.000 glucose units.
Amylose	The minor constituent of starch is amylose - a linear glucose polymer with alpha 1-4 glucosidic bonds only. Amylose may contain 200-2000 anhydro glucose units.
Anhydro glucose unit	The glucose unit of amylose and amylo pectin minus one molecule of water.
Anhydrous dextrose	The crystalline form of pure <b>a-D-glucose</b> .
Arrow root	Belong to the family Marantaceae. The true arrowroot plant is classified as <i>Maranta arundinacea</i> .
<b><u>B</u></b>	
BAN.	Brand name of bacterial $\alpha$ - amylase hydrolysing 1,4 - $\alpha$ - glucosidic linkages at random.
Banana.	Genus <i>Musa</i> of the family Musaceae . The plantain, or cooking banana, is classified as <i>Musa x paradisiaca</i> .
Barley	common name for any of a genus of cereal grasses, native to north temperate regions, and one of the most ancient of cultivated plants.
Barley malt	is processed from grain, and retains about 40 % of its complex carbohydrates. The

	remaining sugar composition is 42 % maltose, 6 % glucose, and about 1 % fructose.
Baum (°Be) .	Density is measured in Baum : °Be = 145 - 145/specific gravity at 60 °F. The commercial Baum = °Be + 1 is used within the glucose industry .
Bio ethanol	( Ethyl alcohol , ethanol , etanol , alcohol ) is made by yeast fermentation of starch or starch crops . A second generation of bio ethanol is made from agricultural cellulosic byproducts.
Black pearl Black spheres	Made of tapioca starch and used as a chewy constituent of bubble tea.
Bra bender	Bra bender Viscograph is the industry standard in determination og starch viscoisty.
Brix (°Bx )	Percentage ( w / w ) of a sucrose solution. Dry matter of Glucose Syrups.
Brown rice syrup	Is an extremely versatile and relatively healthy sweetener which is derived by culturing rice with enzymes to break down the starches.
<b><u>C</u></b>	
Carbohydrate Mono saccharide	or natural organic substance giving mono saccharide by hydrolysis e.g. starch, sugars, cellulose, glucose, fructose, maltose.
Carbon treatment	Activated carbon is used for decolorization and purification of hydrolysates.
Cassava	Belong to the family Euphorbiaceae
Cationic starch	Granular cationic starch ether used in papermaking due to its affinity to cellulose fibres and thereby reducing BOD.
Chemical gain	The increase of dry substance by hydrolysatation of starch. Molecular weight

	of dextrose = 180. Molecular weight of Anhydrous Glucose Unit ( AGU ) of starch = 162 . By converting one AGU into dextrose a chemical gain of 18 is achieved equivalent to 11.1 %.
Chips.	Sliced and dried cassava roots.
Chiral Means " handedness "	A chiral or asymmetric molecule is one which can be distinguished from its mirror image.
Chromatography	Method for industrial separation of glucose and fructose on a resin-filled column.
Concentrated fruit juice.	Is a relatively new sweetener. It is highly refined, decolorized and at 68 % soluble sugar, is relatively concentrated.
Conversion	Synonym of conversion hydrolysis or hydrolysis.
Converter	Apparatus for the hydrolysis of starch.
Corn gluten feed	Is a medium protein by-product, along with fiber and residual starch
Corn gluten meal	Is a high – protein , high - energy ingredient consisting of protein ( gluten ) and yellow pigments separated in the corn wet - milling process.
Corn oil	Is widely used as a cooking oil and for margarine.
Crystallisation	In concentrated high DE syrups glucose crystals are formed and precipitate.
Curdlan	A fermentation - produced poly saccharide as is Xanthan , and Gellan.
CWS Starch	Cold Water Soluble Starch are made by cooking and spray drying or by alkali / alcohol technology to allow for hydration without cooking. Starches labeled instant, granular or cold water - swelling are made that way.

<b><u>D</u></b>	
D E	Dextrose Equivalent expresses the number of aldehyde groups - reducing ends - relative to pure glucose of same concentration
Derivative	Another term for chemically modified starch e.g. oxidized starch.
Dextrin	Industrial dextrin is granular starch with molecules reorganized by roasting causing the granules to be cold water soluble. Depending on the degree of roasting dextrins are grouped as White Dextrin, Yellow Dextrin and British gum.
Dextrose	Synonym for <b>glucose</b> . Within the industry dextrose is used to describe 100 % pure glucose. Both the anhydrous and the monohydrate form is used.
Dextrose mono hydrate	The crystalline form of pure $\alpha$ -D-glucose containing one molecule of water of crystallization. Produced from high DE syrup by crystallization under controlled cooling . The continuous vertical crystallizer has advantages, but not completely outdid the classic horizontal batch crystallizer.
Dextrose anhydrous	The crystalline form of pure $\alpha$ -D-glucose. Produced from high DE syrup by crystallization above 60 ° C .
Dextrozyme	Brand name of a pullulanase and AMG mixture
D P	Degree of Poly merization is the average number of mono saccharides in a polymer.
Di saccharide	Carbohydrate with two mono saccharides per molecule, e.g. sucrose , maltose. Sucrose is a di saccharide with one glucose and one fructose per molecule.

D S	(1) Dry Substance = Dry Matter ( DM ) . (2) Degree of Substitution.
DX	Dextrose
<b><u>E</u></b>	
Enzyme	Three groups of enzyme catalysts are used in the glucose industry : (1) Alpha- amylase for liquefaction, (2) Amylo glucosidase for saccharification (3) iso merase for conversion of glucose to fructose.
Enzyme conversion	A two step hydrolysis : (1) Liquefaction with a - amylase (2) Saccharification with amylo glucosidase.
Ethylated starch	Starch , 2- hydroxyethyl ether improves coating and ink holdout. It has good film - forming and produces superior printing paper
<b><u>F</u></b>	
Fructose	Alpha – D - fructose is an isomer of alpha – D – glucose . Standard fructose syrup contains as much as 42 % fructose and enriched syrups as much as 55 % . High concentration of fructose is achieved by chromatography.
Fung amyl	Brand name of fungal amylase hydrolyzing 1,4 - a - glucosidic linkages in formation of substantial amounts of maltose .
<b><u>G</u></b>	
Gari	Is a processed fermented cassava food.
Gelatinization.	Cooking starch.
Gellan Gum	is a water - soluble poly saccharide produced by Sphingomonas elodea . It is

	used as a food thickener , emulsifier , and stabilizer . It has E number E418.
Glucose	Is a mono saccharide , $C_6 H_{12} O_6$ existing as a - and - glucose with an optical rotation of $+105.20$ respectively $+ 20,30$ . The synonym dextrose refers to the positive direction of rotation ( dextra = right )
Glucose Syrup.	Is a liquid starch hydrolysate of mono - di- and higher saccharides .
Granular starch	Starch are formed in plants as tiny granules preserved in starches modified at low temperatures.
<b><u>H</u></b>	
High Fructose Syrup.	Is a liquid starch hydrolysate with a high content of fructose - typically 42 , 55 or 90 % fructose
HFCS	<b>H</b> igh <b>F</b> ructose <b>C</b> orn <b>S</b> yrup is identical to <b>H</b> FSS .
HFSS	<b>H</b> igh <b>F</b> ructose <b>S</b> tarch <b>S</b> yrup . HFSS - 42 contains 42 % fructose and is an all - purpose sweetener. HFSS - 55 contains 55 % fructose and substitutes sucrose. HFSS - 90 contains 90 % fructose.
Honey	Is a natural invert sugar. It is estimated to be approximately 25 % sweeter than table sugar
HSH	Hydrogenated starch hydrolysates , are poly glycol syrups - are found in a variety of foods . They serve as bulk sweeteners , viscosity or bodying agents, humectants (moisture retaining ingredient) , crystallization modifiers etc. just like sorbitol . HSH and sorbitol are made the same way, but from starch hydrolysates of different

	Dextrose Equivalent ( DE ) and different composition.
Hydrol	Mother liquor left by crystallization of dextrose from glucose syrup.
Hydrolysis	Break down of starch to glucose and smaller polymers by cutting glucosidic bonds with simultaneously uptake of water. Industrial hydrolysis is a two step operation : liquefaction and saccharification.
<b><u>I</u></b>	
Invert sugar	Hydrolyzed sucrose
Ion exchange	Deionization of the hydrolysate in columns of ion exchange resins.
Iso merase	Enzyme rearranging glucose into fructose. The process reaches a feasible equilibrium with 42 % fructose, 53 % glucose and 5 % higher sugars.
Iso merisation	Restructuring of glucose to fructose
<b><u>J</u></b>	
Jet cooker	Apparatus for continues gelatinization of starch by direct steam injection
<b><u>K</u></b>	
Karl Kroyer	Is the Danish inventor of the continuous glucose process.
<b><u>L</u></b>	
Liquefaction	Partial hydrolysis of cooked starch followed by a viscosity reduction. Depending on the catalyst the DE of the liquefied starch is 15 - 25.
Liquid sugar	Commercial syrup made by hydrolyzing sucrose ( invert sugar ) or by inverting glucose enzymatically.



Lysine	Is an essential amino acid made by fermentation of starch sugars.
<b><u>M</u></b>	
Maize or Corn	common name for a cereal grass widely grown for food and live stock fodder
Maltitol	Is a polyol like sorbitol.
Maltodextrin	Liquefied starch below 20 DE . Food applications as a carrier and extender.
Maltose	A disaccharide of glucose . - amylase is used for maltose rich syrups.
Maltose syrup	Starch syrup high in maltose, typically 45 - 50 % in ordinary conversion syrup and 65 – 80 % in high maltose syrup.
Mannitol	Isomer of sorbitol
Maple syrup	concentrated from the sap of maple trees, is a uniquely American product.
Millet.	Belongs to the genera Echinochloa, Milium , Panicum , Pennisetum , and Setana all within the family Poaceae ( or Gramineae ) .
Modification	Is a process , in which native starch is modified by physical and chemical means to suit various industrial applications, e.g. esterification.
Molasses	If manufactured as an end product and not as a by - product of commercial sugar production, can be a good choice of sweeteners .
Mono saccharide	The smallest unit obtained by hydrolysis of carbohydrates, e. g. glucose, and fructose. Glucose is the monosaccharide obtained by hydrolysis of starch.
MSG.	Monosodium Glutamate , is made by fermentation of starch sugars. It is also known as the " third spice " .
Mung bean starch	has 37 % amylose and produces a strong

	gel . Mung bean starch is the prime material for making clear starch noodles , how ever , it is much more expensive than tapioca starch often used as a replacement.
<b><u>N</u></b>	
Native starch	Designate starch in its natural unmodified form no modification, e.g. native starch from potato , cassava , maize , rice , wheat.
<b><u>O</u></b>	
Oat	Belongs to the genus Avena of the family Poaceae ( or Gramineae )
Oligo saccharide	Carbohydrate giving 2 - 6 mono saccharides by hydrolysis .
Oxidized starch.	Granular starch with carboxyl groups introduced by oxygenation. Its performance in paper is proven, reduces linting and Improves short-fiber bonding.
<b><u>P</u></b>	
Polyol or polyglycitol	Is a family of sugar alcohols such as sorbitol, mannitol etc . Like sorbitol , they have a wide range at applications.
Poly saccharide	Carbohydrate giving more than 6 mono saccharides by hydrolysis, e.g. amylopectin , amylose , cellulose .
Potato	Are produced by plants of the genus Solanum , of the family Solanaceae .
Precoat filtration	Hydrolysate filtration on a filter precoated with filter aid and activated carbon.
Pregelatinised Starch	cooked and dried starch.
Promozyyme	Brand name of pullulanase reducing oligo saccharides after liquefaction
Pullulanase	Pullulan 6 - glucano hyrolase catalyzing the hydrolysis of 1 , 6 - alpha linkages in pullulan and amylo pectin and only acts on

	molecules with at least two 1,4 bonds.
Pulp	The wet residue of tuber and roots after starch extraction . Pulp from potato and cassava is excellent cattle feed.
<b><u>R</u></b>	
Retrogradation	Starch crystallization . Linear chains of starch are able to form crystalline structures - crystallites - causing staling in bread and milky appearance or syneresis in starch gels.
Rice	Makes up the genus <i>Oryza</i> of the family Poaceae ( or Gramineae ) .
Rice syrup , brown.	Brown rice syrup is an extremely versatile and relatively healthy sweetener which is derived by culturing rice with enzymes to break down the starches
Rye	Belongs to the family Poaceae ( or Gramineae ) . It is classified as <i>Secale</i> cereal .
<b><u>S</u></b>	
Saccharification	Hydrolysis of starch into higher DE syrups after liquefaction.
Sago Starch	Is prepared from the pith of several genera of palms .
Sorbitol	A sugar alcohol - obtained by hydrogenation of glucose .
Sorghum	Makes up the genus <i>Sorghum</i> in the family Poaceae ( or Gramineae ) .
Starch	Is a polymer of glucose found as a reserve in most plants. Another glucose polymer found in plants is cellulose. Compared to cellulose, starch is made up of alpha glucosidic bonds, which cause helix-shaped molecules, while cellulose build with beta glucosidic bonds giving straight

	molecules and a fibrous structure. In plants starch is organized in 1-140 m granules.
Starch ester	Modified starch with ester groupings like acetylated starch and starch mono phosphate . Potato starch is a natural starch phosphate ester .
Starch ether	Modified starch with ether groupings like hydroxy propyl – starch , cationic starch and carboxy methyl starch
Starch succinate	Anionic starch esterified by succinate groups . The starch may also be cross linking.
Starch xanthate	Starch esterified by xanthate groups .
Stein - Hall	In the Stein - Hall corrugating process a carrier is prepared by gelatinizing 10 – 20 % of the starch using heat and caustic soda The paste is diluted with water and native granular starch is then added .
Sucanat	( <i>SUGAR CAne NATural</i> ) is a brand name for organically grown , dehydrated cane juice .
Sucrose	Ordinary sugar from cane or beet is a disaccharide of glucose and fructose. Synonyms : Saccharose , sugar .
Sugar	White table sugar is pure sucrose.
Sweet potato	Belongs to the family Convolvulaceae. It is classified as <i>Ipomoea batatas</i>
Sweetzyme	Brand name of immobilized glucose isomerase
Syneresis.	The free setting of water from a starch gel caused by retro gradation.
<b><u>T</u></b>	
Termamyl	Brand name of heat - stable $\alpha$ - amylase hydrolysing 1,4- $\alpha$ - glucosidic linkages at random.
Thin boiling starch	Acid treated and oxidized starches with

	low paste viscosity used in paper and textile
Total Sugar	Is high DE - dextrose syrup solidified by evaporation and subsequent instant crystallization .
<b><u>W</u></b>	
Wheat	Makes up the genus Triticum of the family Gramineae
Wheat Starch	Starch from Wheat , In EU wheat starch is an important starch.
White dextrin	Produced by gentle roasting of acidified starch
Wort syrup	Glucose or maltose syrup used as a carbohydrate source (adjunct) in breweries for increasing capacity , adjusting protein content , taste , mouth feel etc .
<b><u>X</u></b>	
Xanthan gum	A fermentation - produced polysaccharide. Xanthan is used as a viscous food additive. It is made by fermentation of glucose by Xanthomonas campestris bacterium .
Xylitol	With five hydroxyl groups . Its relative sweetness compared to sucrose is between 80 and 100.
<b><u>Y</u></b>	
Yam	Make up the genus Dioscorea of the family Dioscoreaceae.
Yellow dextrin or Canary dextrin.	Produced by roasting acidified starch. It is cold water soluble. Used as a glue and has a good tack.

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