

**Project Planning for Small and
Medium Scale Industries No.10**

Starch and Syrup

Manufacturing Plant

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This technical brochure was compiled to help in the drafting of a suitable plan for the construction of Starch and Syrup Manufacturing Plant.

The production scale and manufacturing process have been described in this brochure on the basis of a typical instance.

The profitability was estimated by fixing certain required conditions, which may differ from country to country.

We hope that the data contained in the brochure will help you to draw up the most suitable plan for the industrialization of your project.

In case a government or public organization requests the Japan Consulting Institute to conduct a feasibility study of the above industry for the purpose of establishing the most suitable plan, it is possible for us to carry this out free of charge.

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PART I Starch Manufacturing Plant

1. Outline of Product

Starch is being used in various fields. Among many kinds of starch, only about ten are being manufactured industrially. Typical materials are corn, potato, sweet potato, wheat, cassava, and rice. Depending on a region, a kind of raw material available is limited. What is most easily obtainable in the tropics is cassava. Starch, which is used for special purposes, is produced from beans, arrowroot, bracken, lotus, and water caltrop. In order to display the characteristics of each starch, it is essential to use it for the most appropriate purpose.

1.1 Use of Starch

As is indicated in Table 1-1, there are a great deal of purposes of starch. There may be more than 2,000 in all. The use of starch can generally be classified into three as below.

- (1) Fields where polymer characteristics of starch are used

The characteristics of starch are the temperature of gelatination, the degree of swelling, the stability of viscosity, and the stability of starch. These characteristics of starch are utilized in such fields as food, fish paste, adhesives, paper making, textile, etc.

- (2) Fields, where such constituent units of starch as glucose and maltose are resolved for use

In case glucose and glucose syrup are made by hydrolyzing starch, the kind of starch exerts a great influence on quality as a rule. Depending on the kind of raw material, the hydrolysis reaction with enzyme and acid becomes easy or difficult and the problem of manufacturing technique concerning filtration and refining arises.

- (3) Fields where starch is utilized as fermentation material

The use in (3) is similar to that of (2) above, where starch is hydrolyzed for use. In brewing beer, starch is used as it is, while in the glutam-

ic acid fermentation and pullulan synthesis starch is hydrolyzed and is used as glucose.

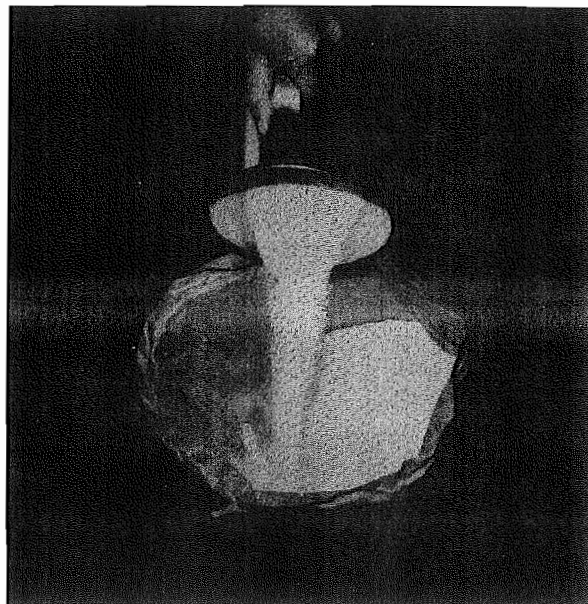


Photo 1 Starch

Table 1-1 A List of Uses of Starch

1. Glucose syrup	(1) Acid saccharified gluten (2) Malt gluten (3) Powdered glucose syrup	Caramel, drops, jam, jelly Caramel, sweets, medicine Sake, ice cream, sweets, sausage, soy, baby food
2. Grape sugar	(1) Refined grape sugar (2) Crystal grape sugar (3) Solid or powdered grape sugar	Bread, canned food, sweets, beverage, ice cake, jam, marmalade, fish paste, sweetening for domestic use, liquors Sweets, beverage, ice cake, canned food, liquors, medicine, chemical industry raw material Sake, bread, sweets, fish paste, hide tanning
3. Food production	(1) Direct food (2) Food industry (3) Confectionery (4) Beer	Cooking material, rice-cake meal Fish paste, vermicelli, wheat vermicelli Biscuit, cracker, ice cream, pudding-like arrowroot starch cake, oblaat, baking powder
4. Modified starch	(1) Soluble starch (2) Dextrin (3) British gum (4) Alkali starch	Textile starch (size), tablet shaping agent Textile starch (size), printing, tablet shaping agent, postage stamp adhesive, paper making, printing ink, tape adhesive Printing Venner board adhesive, sizing, colors
5. Starch material, adhesives	(1) Ordinary starch (2) Laundry starch (3) Industry	Sticking paste Paper making, silk making, book making, corrugated cardboard, dyeing, veneer board, molding charcoal
6. Medicine manufacture	(1) Tablet matric (2) Increasing and shaping agents of powdered medicine (3) Oblaat (4) Antibiotic culture medium	

1.2 Marketability of Starch

Table 1-2 shows the uses and the quantities of starch consumed in Japan. The annual consumption of starch in Japan is about 2,000,000 tons (in 1982), of which more than 60% is used in the form of starch sugar as sweetening, namely grape sugar, high fructose corn syrup and glucose syrup.

Table 1-3 indicates the estimated production of starch by kind in the world.

Table 1-2 Uses and Quantity of Starch Consumed in Japan

Unit: 1,000 tons

Year	1980						1981						1982					
	Sweet potato	Potato	Corn	Cassava	Wheat	Total	Sweet potato	Potato	Corn	Cassava	Wheat	Total	Sweet potato	Potato	Corn	Cassava	Wheat	Total
Glucose syrup, grape sugar, high fructose corn syrup	87	161	880	12		1,140	104	130	916	9		1,159	107	114	1,014	5		1,240
Fish paste		55	4		25	84		55	3		21	79		54	3		25	82
Textile, paper making, corrugated cardboard			101		4	105			113		5	118			127		7	134
Modified starch	2	17	146	34		199	1	13	157	41		212		12	164	45		221
Beer			68			68			73			73			84			84
Glutamic acid soda				18		18				23		23				28		28
Food and others	13	79	138	6	22	258	6	83	127	8	22	276	8	88	114	9	22	241
Total	102	312	1,337	70	51	1,872	111	281	1,389	81	48	1,910	115	268	1,506	87	54	2,030

Table 1-3 The World's Production of Starch by Kind

Unit: 10,000 tons

Raw material	Kind of starch	Major countries	Starch production in recent years	
Corn	Corn starch	U.S.A.	216	(1979)
		Japan	111	(1979)
		U.S.S.R.	31	(1965)
		Europe	250	(1977)
		South Korea	22	(1979)
Sweet potato	Sweet potato starch	Japan	10	(1979)
		South Korea	1.7	(1979)
		China		
Potato	Potato starch	Japan	25	(1979)
		U.S.S.R.	27	(1965)
		Europe	109.5	(1977)
Cassava	Tapioca starch	Thailand	30~35	(1978)
		Indonesia		
		Malaysia	4~5	(1973)
Wheat	Wheat starch	Japan	6	(1979)
		Europe	6~8	(1970)
		Australia		
		U.S.A.	6~8	(1970)
		South Korea	0	(1977)
Others				
Rice	Rice starch	Japan	600 ~ 1,000 tons	
Arrowroot	Arrowroot starch	Japan	150 ~ 300 tons	
Sago palm	Sago starch	Sarawak (Malaysia)	4 ~ 6	

Note: The starch production of the U.S.A. does not contain the quantity used for saccharification.

2. Raw Material

As stated in the preceding section, starch is made from corn, potato, sweet potato, wheat, cassava and rice, etc, but in this paper cassava, which is generally used worldwide, will be taken up. The starch made from cassava is either called tapioca starch or manioc starch. But industrially it is called tapioca flour.

There are two kinds of cassava cultivated, one is called *Manihot utilissima* and the other *Manihot palmata*. Cassava is cultivated in the tropics and the semitropical regions, where cassava is consumed as important food, and some is used for manufacturing starch, feed and fermentation.

From one cassava 18 to 22kg rootstock can be obtained. The ripe stalk usually contains 15 to 30% starch. The largest quantity of starch is obtainable at the most favorable harvest time. Before and after that time the obtainable quantity is less.

The component of roots stalk of cassava is quite similar to that of potato as is shown in Table 1-4, and a very equivalent method is employed for producing tapioca starch and potato starch. However, cassava has a thicker cell wall than potato and has a smaller starch grain size and its grinding efficiency is inferior.

When the texture of cassava stalk is broken, it produces a poisonous hydrocyanic acid by enzyme in the

rootstock. This varies depending on a kind, cultivated degree, latitude and climate. *Manihot utilissima* has less hydrocyanic acid, which is concentrated to the skin and less inside. Therefore, *Manihot utilissima* is fit for food after peeling the skin; while *Manihot palmata* has plenty of hydrocyanic acid inside and is unsuitable for food. Nevertheless, *Manihot palmata* is stronger, higher yield and contains much more starch than *Manihot utilissima*. Accordingly, *Manihot palmata* is suitable for the manufacture of starch. During the manufacture of starch hydrocyanic acid combines with an iron ion and forms ferrocyanide, and starch becomes blue. Therefore, it is necessary to pay attention to water and process (See Table 1-5).

Table 1-4 Comparison of Stalk Component between Cassava and Potato (wt %)

	<u>Cassava</u>	<u>Potato</u>
Water	70.25	75.80
Starch	21.45	19.90
Sugar	5.13	0.40
Protein	1.12	2.08
Fat	0.41	0.20
Fiber	1.11	1.10
Ash	0.54	0.92

Table 1-5 Hydrocyanic Acid Contained in Cassava Rootstock (wt%)

<u>Kind</u>	<u>Manihot utilissima</u>	<u>Manihot palmata</u>
Skin	0.020 – 0.092	0.012 – 0.056
Inside	0.013 – 0.014	0.002 – 0.037

3. Process and Production Scale

The tapioca starch manufacturing plant can be classified into three scales, large, medium and small. They differ not only in the quantity to be processed but also in the manufacturing method as is shown in Table 1-6. A large-scale plant is equipped with the latest facilities, produces more than 30 tons a day, and the quality of product is superior. A medium plant produces 3 to 15 tons a day, and its quality of product lies between those of the large and small scale plants.

3.1 Processing of Raw Material

The rootstock of cassava rapidly deteriorates in quality after have been harvested and results in reducing the yield of product. Accordingly, the rootstock must be processed on the day of harvest or within 48 hours at the latest. The quality of product is measured by specific gravity using the Reiman balance. The woody base of the rootstock is cut off. First the stalk is put into a concrete pit, and the mud sticking on the surface is taken off. The main washing and peeling are done in a horizontal stirring potato washer.

Table 1-6 Manufacturing Process of Cassava Starch

Scale Process	Large plant	Medium plant	Small plant
Raw material	Receiving by truck scale	Receiving by truck scale or by balance	By balance
Selection	By hand	By hand	By hand
Potato washing	Horizontal potato washer	By hand in concrete pit	By hand in concrete pit
Coarse grinding	When necessary	Unnecessary	Unnecessary
Grinding	Rasper with sawteeth	Rasper with sawteeth	Rasper with sawteeth
Sieving	Two-stage centrifuge sieving: Jet extractor, Sieve bend, etc.	Two-stage centrifuge sieving: Jet extractor, Sieve bend, etc.	By hand Flat 50~60 mesh sieve
Refining	By nozzle separator	By nozzle separator	100~200 meshes
Dehydration	Basket-type centrifuge: Decanter	Basket-type centrifuge: Decanter	Tank precipitation (or tapering) By hand lift
Drying	Flash dryer	Flash dryer	Solar drying or floor heating
Sieving	By machine	By machine	By hand
Packing	Automation	Semi-automation	Semi-automation or by hand

3.2 Grinding

The washed cassava is continuously put into a mill called a rasper. A rasper has 100 sawteeth on the drum, which rotates at over 40 meters per second.

3.3 Sieving

The ground rootstock first passes through the large meshes (40 to 60 meshes), and the filtrate passes through the small meshes (120 to 130 meshes). As a sieve, a flat sieve, jet extractor, sieve bend, and funnel sieve are used independently or in combination. In this paper a six-stage sieve bend has been adopted. For finishing, a jet refiner is used, which will prevent a trouble at the time of refining.

3.4 Refining

In separating the coarse starch slurry into starch and protein water, a centrifuge is used. Three centrifuges are connected in series. Starch is refined by repeating the concentration of starch slurry and thinning it with fresh water. In the first and second stage starch is prevented from the leakage into the drainage, and in the third stage starch is held there, and the drainage is sent back to the centrifuge in the first or second stage to prevent the loss of fine-grain starch and fine lees into the drainage.

3.5 Dehydration, Drying, Milling and Packing

The hydration of the refined starch slurry is done by a basket-type centrifugal dehydrator. The dehydrated starch is dried by pneumatic dryer. The hot air at the time is 130° to 160°C. Together with the air, starch passes through a drying duct. The water content becomes about 18% while passing through a cooling duct. The dried starch gets into a mill, and then weighed, and packed into a bag, whose mouth is sewn with a machine.

4. Outline of Model Plant

4.1 Production Scale

In this paper a medium-sized plant will be taken up as a model plant using modernized machines with a production capacity of 12 tons a day. Mechanization will initially require a large sum of investment. On the other hand, if not mechanized, the personnel expenses in the running cost will become higher. Which is to be adopted will be determined according to the personnel expenses. Here some description will be made on the case of slight mechanization. The mechanization scale can be reduced than what is cited here as an example. In a small-scale plant, only grinding is done by machine, sieving is made by a simple sieve, precipitation is done in a concrete pit for refining. The product is finished by solar drying.

Cassava contains 15 to 30% starch as was mentioned before. When the refining efficiency is assumed to be 80%, a 12-ton/day plant must process 50 to 100 tons of cassava.

4.2 Machinery and Equipment

The following shows the machinery and equipment required.

(Water treatment process)

1. Water pump	2.2kw	3
2. Water treatment device	17m ³	1 set
3. Tank	50m ³	1

(Raw material receiving process)

4. Belt conveyor	0.75kw	1
5. Balance	1,000kg	1
6. Horizontal stirring potato washer		1

(Grinding process)

7. Mill (rasper)	7.5kw	1
8. Ground milk pump	2.2kw	1
9. Pump for sending milk to mill	0.4kw	1

(Extraction process)

10. Sieve	1,500kg/hr	1 set
11. Sieve pump	2.2kw	5
12. Starch lees conveying pump	0.4kw	1
13. Lees dehydrator service tank	500 ℓ	1
14. Lees dehydrator	2.2kw	1
15. Dehydrated lees conveyor	1.0kw	1
16. Sieved milk pump	0.4kw	1

(Refining process)

17. Coarse starch milk tank	1.5kw	1
18. First-stage centrifuge feed pump	1.5kw	1
19. Filter	0.2kw	1
20. First-stage centrifuge	11.0kw	1
21. Concentrated liquid conveying pump	0.4kw	1
22. Starch milk stirrer	0.75kw	1
23. Refiner feed pump	2.2kw	1
24. Starch refiner	5.5kw + 1.5kw	1
25. Refiner washing water pump	0.75kw	1
26. Fine lees pump	0.4kw	1
27. Starch milk conveying pump	0.4kw	2
28. Centrifuge feed pump (for 2nd and 3rd stages)	0.75kg	2
29. Centrifuge for 2nd and 3rd stages	2.2kw	2
30. Concentrated starch milk conveying pump	0.2kw	2
31. Refined starch milk stirring tank	1.5m ³	1

(Dehydration process)					US\$
32. Dehydrator feed pump	0.4kw	1	Water treatment process	1 set	105,000
33. Starch dehydrator	9.75kw	1	Raw material receiving process	1 set	5,000
34. Filter return pump	0.2kw	1	Cutting and peeling process	1 set	20,000
35. Dehydrated starch conveyer	1.0kw	1	Grinding process	1 set	35,000
36. Constant feeder	2.2kw	1	Extraction process	1 set	75,000
37. Starch dryer 500kg/hr	31.0kw	1	Refining process	1 set	160,000
38. Refined flour bagging machine	2.2kw	1	Dehydration process	1 set	50,000
39. Product conveyer	1.0kw	1	Drying and bagging process	1 set	150,000
40. Boiler	500kg/hr	1	Other machines	1 set	170,000
41. Water softener	1,000kg/hr	1	Instruments for quality control	1 set	10,000
(Other machine parts)					
42. Piping materials (pipe, valve, coupling, flowmeter, etc.)		1			
(Instruments for quality control)					
43. Infrared moisture meter		1			
44. pH meter		1			
45. White degree meter		1			
46. Baumé meter		1			
47. Centrifugal sedimentation meter		1			
48. Glass instruments		1			
				Total	US\$780,000

4.3 Construction Cost

A plant having a starch refining capacity of 500kg/hr (12-ton/day) will roughly need the following cost for its facilities.

4.4 Plant Layout

Fig. 1-1 shows the plant layout.

4.5 Labor Required

The modernized facilities need less number of workers. In case the operation is made with a 3-shift system, it requires at least 1 engineer, 3 supervising foremen, 3 workers in the grinding process, 3 in the refining process, and 3 engagings in bagging the final product. In addition, 2 persons, who serve as substitutes or plant cleaners, are needed. As a whole, 16 persons are required including a factory manager.

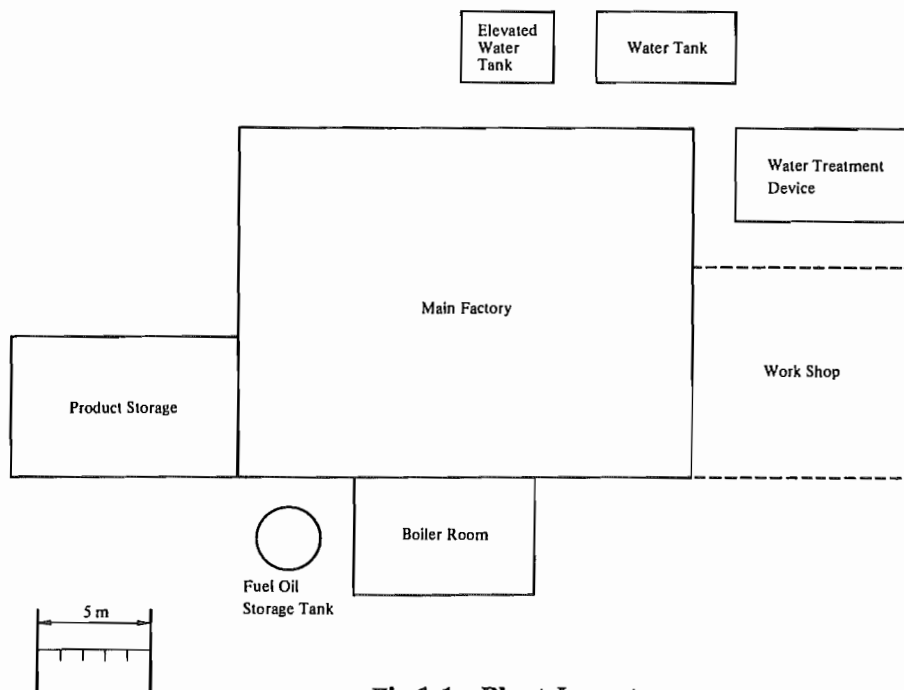


Fig.1-1 Plant Layout

5. Production Cost and Profitability

In order to estimate the profitability of a starch manufacturing plant, it is necessary to calculate the production cost. Because the raw material cost, personnel expenses, and other conditions differ from country to country, the production cost in this paper has been calculated on the following assumption.

5.1 Calculation Basis

(1) Fixed capital

- (a) Considering that the land price may be very low, it has been omitted from calculation. The bearing capacity of soil must be strong enough for the plant construction.
- (b) The plant consists of an office, a factory and a warehouse. Their unit construction cost is assumed to be US\$150/m².
- (c) Machinery and equipment cost is shown by FOB Japanese port. Import duties for machinery and equipment are exempted.
- (d) Spare part cost is assumed to be 8% of the FOB price of machinery and equipment.
- (e) Freight and insurance cost is assumed to be 5% of the FOB price of machinery and equipment. This includes the inland transport and insurance cost.
- (f) Erection cost is assumed to be 5% of the FOB price of machinery and equipment.
- (g) Civil engineering cost is assumed to be 10% of the FOB price of machinery and equipment.
- (h) Supervision cost is assumed to be 5% of the FOB price of machinery and equipment.
- (i) Commissioning cost is assumed to be 3% of the FOB price of machinery and equipment.
- (j) Training cost is assumed to be 3% of the FOB price of machinery and equipment.
- (k) Contingency is assumed to be 2% of the FOB price of machinery and equipment.

(2) Working capital

Raw material cost for one month.

(3) Production cost

(a) Raw material cost

Raw material cost is based on the international market price, which is assumed to be US\$30/ton.

(b) Unit price of utilities

Unit price of utilities is assumed as follows.

Electricity	US\$0.06/kWh
Industrial water	US\$0.2/ton
Fuel cost	US\$200/kl

(c) Labor cost

Direct labor cost is assumed to be as follows in terms of man-year.

Factory manager	US\$14,000
Engineer	US\$ 8,000
Skilled worker	US\$ 4,000
Unskilled worker	US\$ 2,000
Odd-job man	US\$ 500

(d) Maintenance cost

Maintenance cost is assumed to be 3% of the FOB price of machinery and equipment.

(e) Depreciation cost

Straight-line method will be adopted for depreciation. Depreciation of machinery and equipment has been made according to the following formula.

$$\begin{aligned} & (\text{Fixed capital} - \text{building construction cost}) \\ & \times 7\% \end{aligned}$$

Depreciation of buildings is assumed to be 3% of the building construction cost.

(f) Insurance cost

Insurance cost is assumed to be 0.5% of the fixed capital.

(g) Selling and administration cost

Selling and administration cost is assumed to be 1.0% of the annual sales.

(h) Interest

One-second of the necessary capital is to be covered by equity capital and the remaining half by a long-term loan, and its annual rate of interest is 10%.

Note: The exchange rate of the U.S. dollar to the Japanese yen is assumed to be US\$1.0 = ¥240.

5.2 Annual Sales

It is supposed here that 1,800 tons of nondried product, which is used for making glucose syrup, are sold a year at US\$260 per ton, and 1,800 tons of refined starch at US\$520 per ton, totaling US\$1,404,000.

5.3 Capital Required

(1) Fixed capital

	US\$
Plant area 2,000m ²	—
Factory buildings 400m ²	60,000
Machinery and equipment (FOB Japan)	780,000
Spare parts	62,400
Freight and insurance	39,000
Civil engineering	78,000
Erection	39,000
Supervision	39,000
Commissioning	23,400
Training	23,400
Contingency	15,600

Sub-total US\$1,159,800

(2) Working capital

Raw material cost for one month	
Raw material	
2,160 tons (US\$30/ton)	US\$64,800

(3) Capital required Total US\$1,224,600

5.4 Production Cost

Annual production cost is as follows.

(1) Raw material	US\$
Raw material	
US\$30/ton × 25,920 tons	777,600
(2) Utilities	US\$
Electricity	
US\$0.06/kWh × 1,080,000	64,800
Industrial water	
US\$0.2/ton × 111,600	22,320
Fuel US\$200/kl × 1 × 150	30,000

Sub-total US\$117,120

(3) Labor cost	
Factory manager	US\$14,000 × 1
Engineer	US\$ 8,000 × 1
Skilled worker	US\$ 4,000 × 3
Unskilled worker	US\$ 2,000 × 6
Odd-job man	US\$ 500 × 5

Sub-total US\$48,500

(4) Maintenance cost US\$23,400

(5) Depreciation cost US\$78,786

(6) Insurance US\$ 5,799

(7) Selling and administration cost US\$14,040

(8) Interest US\$57,990

Total US\$1,123,235

5.5 Profitability of Plant

It is supposed here that 1,800 tons of the product, which is used for making glucose syrup, are sold at US\$260/ton, and 1,800 tons of refined starch at US\$520/ton, the annual sales will become US\$1,404,000. The annual production cost being US\$1,123,235, the annual rough profit will be US\$280,765, which corresponds to 19.99% of the annual sales.

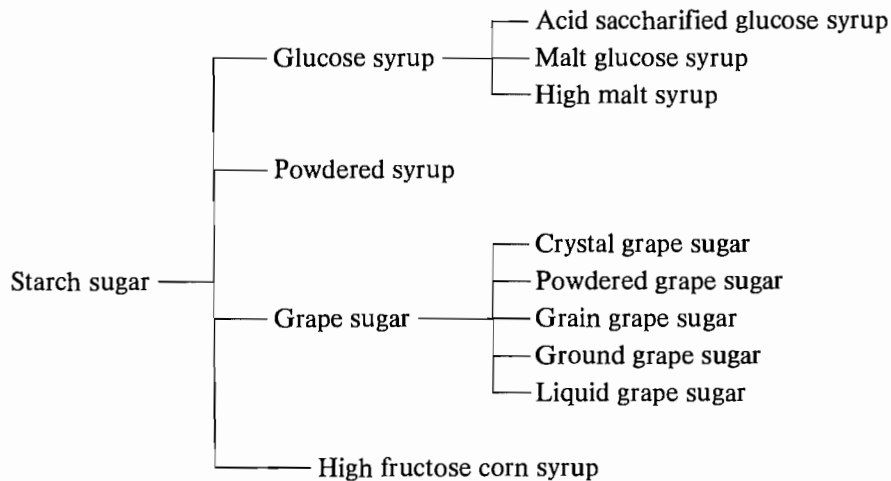
PART II Glucose Syrup Manufacturing Plant

1. Outline of Product

In case starch is hydrolyzed with acid or enzyme, a mixture of various intermediate products consisting of different components will be obtained depending on the hydrolyzing condition. The decomposed have such common properties as they dissolve in water and have sweetness. Accordingly, they are generally called

starch sugar. Table 2-1 shows the classification of starch sugar. Glucose syrup has the international standards, which prescribe that glucose syrup must have more than 70.0% solid, more than 20.0% reduced sugar, less than 1.0% sulfated ash, less than 40 mg/kg sulphurous acid, less than 1 mg/kg arsenic, and less than 2 mg/kg lead.

Table 2-1 Classification of Starch Sugar



1.1 Properties of Starch Sugar

As characteristics of starch sugar, greatly depending on the degree of hydrolysis, its solubility, viscosity, crystallinity, and hygroscopicity change continuously. The degree of hydrolysis of starch or that of saccharification is indicated with DE value, which is commonly used in the world.

Note: DE is short for “dextrose equivalent”, which is represented by the following formula.

$$DE = \text{direct reducing sugar} \times 100 / \text{total solid}$$

As Table 2-2 shows, the properties of each starch differ according to its DE value.

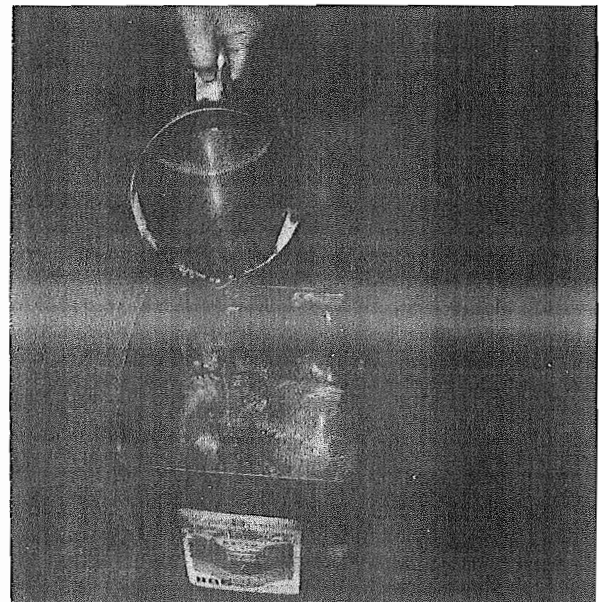


Photo 2 Glucose Syrup

Table 2-2 Starch Sugar, DE value, and Properties

Name	DE value	Sweetness	Viscosity	Hygroscopicity	Congealing point	Osmotic pressure	Mean molecular weight
Crystal grape sugar	99~100	Much	Less	Less	Low	High	Less
Powdered grape sugar	92~96	↓	↓	↓	↓	↓	↓
Ground grape sugar	80~85						
Liquid grape sugar	55~80						
Glucose syrup	35~50						
Powdered syrup	25~40	Less	Much	Much	High	Low	Much

1.2 Effective Use of Starch Sugar

What greatly characterizes starch sugar as a sweetener is to delicately help display the quality of raw material to be seasoned, especially the quality of color, flavor and taste. For instance, if grape sugar is added to fruit when processed or canned, the aroma, taste and color, which are peculiar to the raw material fruit, will remain as they are. Besides the preservation of flavor just stated, starch sugar will serve to help the food to be processed display the beauty of its external appearance, softness, luster, palatability and color. For example, dextrin, the component of glucose syrup, is viscous, and when it is used for candies or chewing gum, they become quite agreeable to the taste.

2. Raw Material

Glucose syrup is made from raw starch by using enzyme before starch is dried. To use raw starch prior to its becoming the final product starch will save the energy of drying of raw starch. Consequently, the use of raw starch will reduce the raw material cost than the use of dried raw starch.

3. Process

Glucose syrup consists mainly of acid saccharified glucose syrup and high malt syrup. In addition, there are malt glucose syrup which has long been manufactured for displaying the taste of malt, special glucose syrup which is directly made from cereals, and powdered glucose syrup. The enzyme saccharified glucose syrup, which is made from malt, was hitherto regarded as a low-grade glucose syrup because its refinement was impossible. However, recently the enzyme liquefaction technique has been developed, and it has become possible to filter and refine the syrup completely. This newly manufactured enzyme saccharified glucose syrup has been given the name of "high malt syrup". And various uses of it has been developed by taking advantage of its sugar component which differs from that of the acid saccharified glucose syrup, and has come to share half of the glucose syrup. Accordingly, in this paper the manufacturing process of glucose syrup using enzyme saccharification has been adopted.

Fig. 2-1 shows the flow diagram of a glucose syrup manufacturing plant.

The hydrolyzation process of starch with enzyme has two processes. One is to roughly cut the starch molecule and liquefy it into the water soluble dextrin, and the other is saccharification, in which the liquefied dextrin is dissolved to produce glucose syrup.

3.1 Liquefaction

In this liquefaction process starch molecule is completely emulsified and is concentrated as high as to about 40% so that liquefaction can be done. When liquefaction is completed, the temperature is raised to 85 to 86°C, and the liquefy enzyme is added.

3.2 Saccharification

Saccharification is the main reaction process when glucose syrup is made from starch. Depending on the saccharification condition, the saccharification rate and properties differ. The liquid is kept at 55 to 70°C, and β -amylase is applied, and then is dissolved for 5 to 6 hours before it becomes syrup.

3.3 Purification Process of the Liquefied

The purification of syrup is an important process, which decisively influences on the purity and the quality of product. The syrup is heated to deactivate

enzyme, whereby the solid protein and other insoluble protein as well as colloidal matter are removed by filtration. Then, active carbon is put to eliminate such impurities as inorganic matters like iron and metal ion, and such organic matter as high molecular coloring, and decoloring is performed. The electrolyte impurities, which cannot be removed with active carbon, are removed with anion exchange resin.

The removal of impurities with ion exchange resin can be achieved more efficiently when the concentration of syrup is high. Hence, intermediate concentration is performed before entering this process.

3.4 Concentration

Vacuum evaporator is used for the concentration of syrup. The degree of vacuum is fixed so that the temperature of syrup does not exceed 55°C. When the temperature rises, the syrup gets colored and caramelized. The final concentration is made to about 85 wt %. While syrup is warm enough to flow, it is packed into, say, a 25kg container.

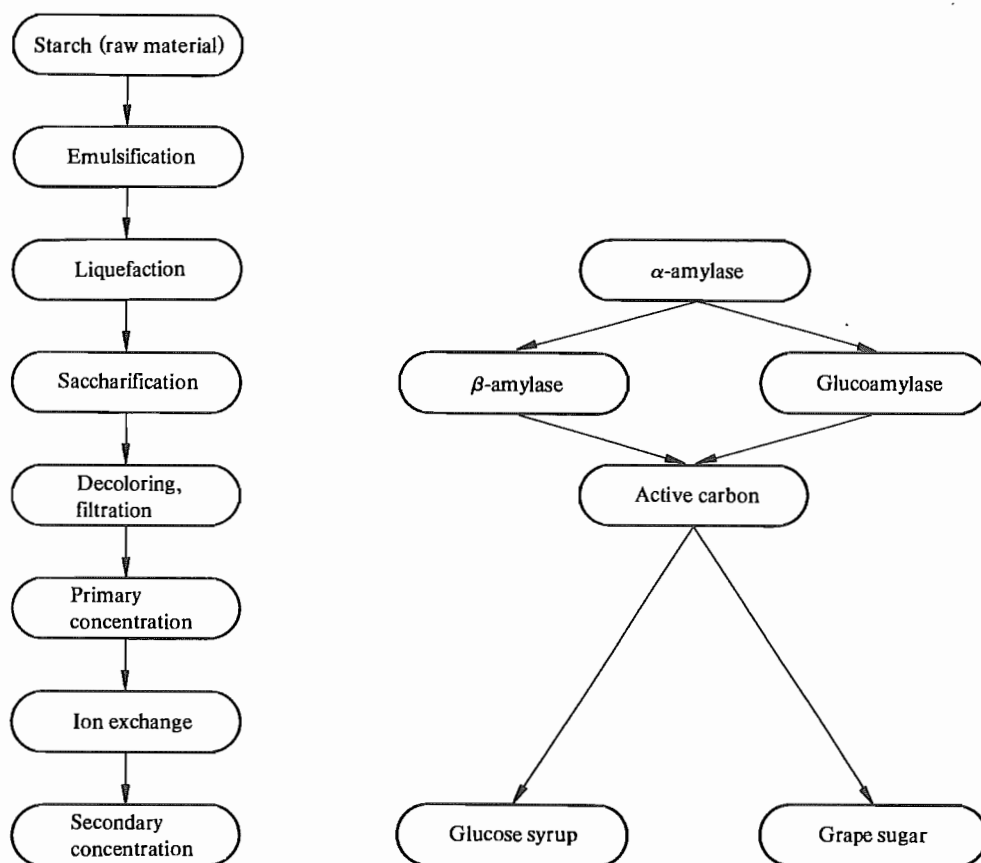


Fig. 2-1 Flow Diagram of Glucose Syrup Manufacturing Plant

4. Outline of Model Plant

4.1 Production Scale

Glucose syrup is manufactured, using half the quantity of starch prepared in the preceding section. From 6,000 kg of raw material, almost the same amount of product (85 wt %) can be obtained. In this paper a plant manufacturing 6 tons of product a day or 1,800 tons a year with a 300 day per year operation will be adopted.

4.2 Machinery and Equipment

The following shows the machinery and equipment required.

(For manufacture)

1. Starch slurry adjustment tank	4,000ℓ	3.7kW	1
2. Starch slurry pump		1.5kw	1
3. Liquefaction tank	4,000ℓ	3.7kw	2
4. Liquefied slurry pump		1.5kw	1
5. Saccharification tank		2.2kw	2
6. Saccharified liquid pump		1.5kw	1
7. Decoloring tank	4,000ℓ	2.2kw	1
8. Filter feed pump		5.5kw	1
9. Filter			1
10. Filtrate tank	4,000ℓ		1
11. Filtrate pump		1.5kw	1
12. Ion exchanger	4,000ℓ/hr		1
13. Refined syrup tank	2,000ℓ		1
14. Vacuum evaporator	300kg/hr		1
	(evaporating speed)		
15. Vacuum pump		2.2kw	1
(Auxiliary)			
16. pH meter			1
17. Pure water making device			1 set
18. Pure water tank			1
19. Boiler			1
20. Water softener			1 set
21. Platform scale			1
(Measures)			
22. Photoelectric colorimeter			1
23. Polarimeter			1
24. Refractometer			1

25. Balance	1
26. Dryer	1
27. Glass instruments	1 set
28. Reagent	1 set

4.3 Construction Cost

A plant having a glucose syrup manufacturing capacity of 250kg/hr or 6 tons per day will roughly need the following cost for its facilities.

		US\$
Emulsification and liquefaction process	1 set	20,000
Saccharification process	1 set	25,000
Refining process	1 set	15,000
Concentration process	1 set	80,000
Other machines	1 set	50,000
Instruments for quality control	1 set	10,000
Total		US\$200,000

4.4 Plant Layout

The plant layout of a glucose syrup manufacturing plant is shown in Fig. 2-2.

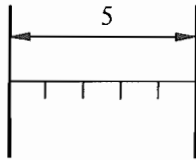
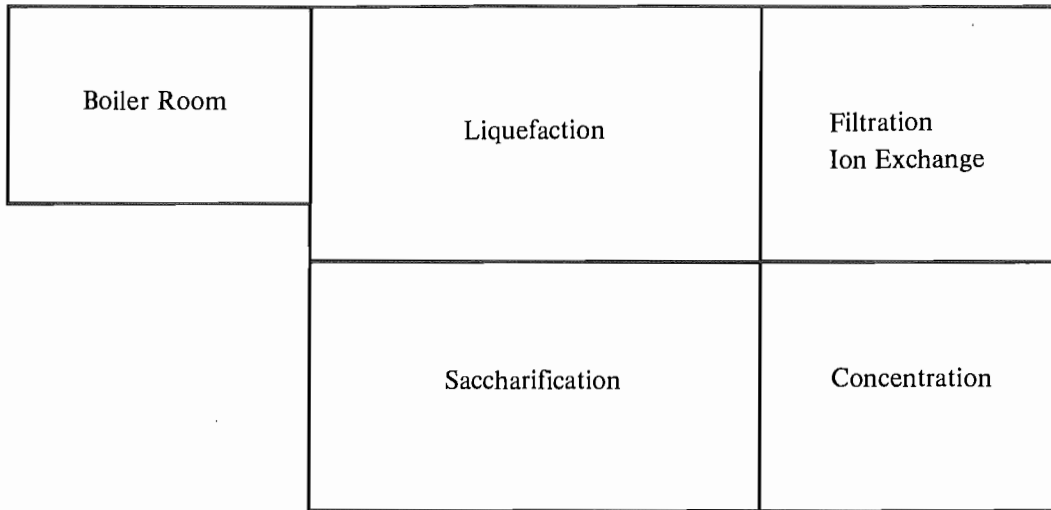


Fig. 2-2 Plant Layout

4.5 Labor Required

The modernized facilities need less number of workers. In case the operation is done with a 3-shift system, it requires at least 1 engineer, 3 supervising foremen, 3 workers engagings in the emulsification and liquefaction process, 3 workers in the refinings and concentration process, and 3 workers engagings in packing the product into a 25 kg can. In addition, 2 persons, who serve as substitutes or plant cleaners, are needed. As a whole, 16 persons are required including a factory manager.

5. Production Cost and Profitability

In order to estimate the profitability of a glucose syrup manufacturing plant, it is necessary to calculate the production cost. The raw material cost, personnel expenses, and other conditions are differ from country to country. The production cost in this paper has been calculated on the following assumption.

5.1 Calculation Basis

- (1) Fixed Capital
 - (a) The land price has been omitted from calculation because of being very cheap. The bearing capacity of soil must be strong enough for the plant construction.
 - (b) The plant consists of an office, a factory and a warehouse. Their unit construction cost is assumed to be US\$150/m².
 - (c) Machinery and equipment cost is shown by FOB Japanese port. Import duties for machinery and equipment are exempted.
 - (d) Spare part cost is assumed to be 8% of the FOB price of machinery and equipment.
 - (e) Freight and insurance cost is assumed to be 5% of the FOB price of machinery and equipment. This includes the inland transport and insurance cost.
 - (f) Erection cost is assumed to be 5% of the FOB price of machinery and equipment.

- (g) Civil engineering cost is assumed to be 10% of the FOB price of machinery and equipment.
- (h) Supervision cost is assumed to be 5% of the FOB price of machinery and equipment.
- (i) Commissioning cost is assumed to be 3% of the FOB price of machinery and equipment.
- (j) Training cost is assumed to be 3% of the FOB price of machinery and equipment.
- (k) Contingency is assumed to be 2% of the FOB price of machinery and equipment.

(2) Working Capital
Raw material cost for one month.

(3) Production Cost

(a) Raw material cost

Raw starch is used as raw material without passing through the drying process. Therefore, the raw material cost has been assumed here to be US\$260/ton, half of the international market price of starch. Enzyme and others, of which weight is one thousand of raw material, will be required at a price of US\$10,000 per ton.

(b) Unit price of utilities

Unit price of utilities is assumed as follows.

Electricity	US\$0.06/kWh
Industrial water	US\$0.2/ton
Fuel cost	US\$200/kl

(c) Labor cost

Direct labor cost is assumed to be as follows in terms of man-year.

Factory manager	US\$14,000
Engineer	US\$ 8,000
Skilled worker	US\$ 4,000
Unskilled worker	US\$ 2,000
Odd-job man	US\$ 500

(d) Maintenance cost

Maintenance cost is assumed to be 3% of the FOB price of machinery and equipment.

(e) Depreciation cost

Straight-line method will be adopted for depreciation. Depreciation of machinery and equipment has been made according to the following formula.

(Fixed capital — building construction cost) × 7%
Depreciation of building is assumed to be 3% of the building construction cost.

(f) Insurance cost

Insurance cost is assumed to be 0.5% of the fixed capital.

(g) Selling and administration cost

Selling and administration cost is assumed to be 1.0% of the annual sales.

(h) Interest

One-second of the necessary capital is to be covered by equity capital and the remaining half by a long-term loan, and its annual rate of interest is 10%.

Note: The exchange rate of the U.S. dollar to the Japanese yen is assumed to be US\$1.0 = ¥240.

5.2 Annual Sales

It is supposed here that 1,800 tons of product are sold a year at US\$450/ton, with the annual sales of US\$810,000.

5.3 Capital Required

(1) Fixed Capital		US\$
Plant area	2,000m ²	—
Factory buildings	300m ²	45,000
Machinery and equipment (FOB Japan)		200,000
Spare parts		16,000
Freight and insurance		10,000
Civil engineering		20,000
Erection		10,000
Supervision		10,000
Commissioning		6,000
Training		6,000
Contingency		4,000
	Sub-total	US\$327,000

(2) Working Capital		
Raw material cost for one month		
Raw material		
US\$260/ton × 150		US\$39,000
Enzyme and others		
US\$10,000/ton × 0.15		US\$ 1,500
	Sub-total	US\$40,500
(3) Capital Required Total		US\$367,500

5.4 Production Cost

Annual production cost is as follows.

(1) Raw material cost		US\$
Raw material		
US\$260/ton × 150 × 12		468,000
Enzyme and others		
US\$10,000/ton × 0.15 × 12		18,000
	Sub-total	US\$486,000
(2) Utilities		US\$
Electricity		
US\$0.06/kWh × 1,150 × 300		20,700
Industrial water		
US\$0.2/ton × 360 × 300		21,600
Fuel cost		
US\$200/kl × 1 × 300		60,000
	Sub-total	US\$102,300
(3) Labor Cost		
Factory manager	US\$14,000 × 1	
Engineer	US\$ 8,000 × 1	
Skilled worker	US\$ 4,000 × 3	
Unskilled worker	US\$ 2,000 × 6	
Odd-job man	US\$ 500 × 5	
	Sub-total	US\$48,500

(4) Maintenance Cost		US\$ 6,000
(5) Depreciation Cost		US\$21,090
(6) Insurance		US\$ 1,635
(7) Selling and Administration Cost		US\$ 8,100
(8) Interest		US\$16,350
	Total	US\$689,975

5.5 Profitability of Plant

When 1,800 tons of product are sold per year at US\$450 per ton, the annual sales will become US\$810,000. The annual production cost being US\$689,975, the annual rough profit will be US\$120,025, which corresponds to 14.8% of the annual sales.

Project Planning for Small and Medium Scale Industries

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- No.8 Fishing Net Manufacturing Plant
- No.9 Ice Making, Refrigeration and Cold Storage Plant
- No.10 Starch and Syrup Manufacturing Plant

Project Planning for Small and Medium Scale Industries No. 10

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