<Appendix – II> Cornstarch Production and Its Uses

<Appendix–II>
Cornstarch Production and Its Uses

(1) Maize

Cornstarch is made from maize. Table 7–2 in section 7–3–1 shows analyses of maizes produced in Zimbabwe, and comparison with figures in the Standard Tables of Food Composition in Japan. Apparently Zimbabwean maize contains more carbohydrates than the standard maize used in Japan. When the water content of the yellow maize is corrected by 3.3% and adjusted to 14.5%, the carbohydrate content becomes 75.6/1.033 = 73.2 (%), which is 3.7% more than the Japanese standard content.

A cross section of a grain of maize is shown schematically in Figure II-1. The endosperms and scutellum are filled with starch granules packed in thin protein rich membranes. The pericarp consists of fiber, and the germ is mostly protein and lipid.

Zimbabwean maize has a large grain size and contains more starch in its endosperms and scutellum. The analysis method used in the laboratory does not actually measure the carbohydrate content which is obtained from the residual of the other analyzed items. Of the carbohydrates, 2% is assumed to be fiber and the rest starch.

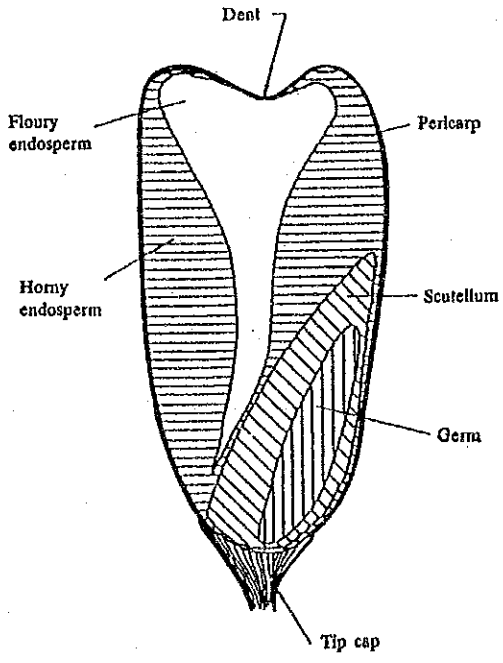

Figure II–1 Sectional View of Maize

(2) Production of cornstarch

There are two methods of producing cornstarch, namely wet milling and dry milling. However the recent tendency has overwhelmingly turned to wet milling except in Zimbabwe. Although there are many variations among existing wet milling processes, a typical process which is adopted in large scale factories is shown in Figure II–2. An outline of the process is described below.

Wet milling basically means to mill maize grains in a wet condition after dipping in 0.1% dilute sulfurous acid. After dipping in the acid for 30–40 hours at a temperature of 48–52°C, the acid penetrates into the endosperms and scutellum and the grain swells to 155–165% in volume. Then, the germ separates from the other parts and the pericarp also separates from the endosperms. Also the bond between the cell membranes and starch granules becomes loose.

This process is called steeping and the operation requires very careful attention.

Steeping is normally carried out using several tanks in parallel and the steeping liquid is circulated through them in counter flow. That is, the steeping water enters the tank at the last stage of the process, circulates through the tanks and flows out from the tank which contains maize newly added to the process.

After the steeping operation is completed, the tank is drained and the maize is taken out. The maize is dewatered by a screen and sent to the mill. This mall is an attrition mill and the gap of the mill surfaces is adjusted so as to avoid damage to the germ. Germ is lighter than the other parts of maize, so it can be separated in a hydrocyclone.

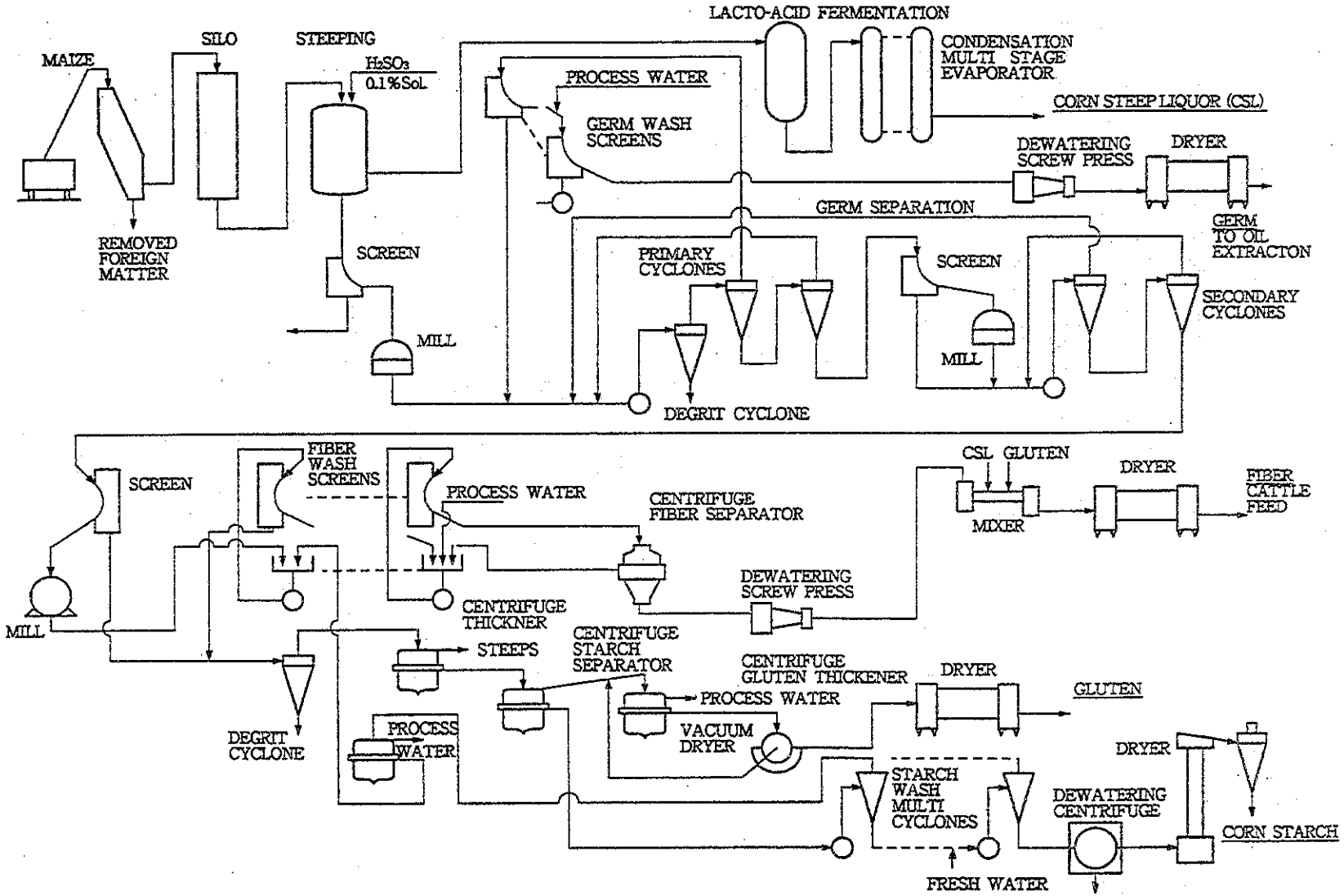

Figure II–2 Wet Mill Cornstarch Producing Process (Source: DORR-Oliver Bulletin)

As shown in Figure II–3, in the hudrocyclone heavy particles are driven to the outside wall by centrifugal force and then flow to the lower outlet by gravity. Light particles are carried upwards by the flow, and in this way the germ is discharged from the upper part of the hydrocyclone. This process can be performed by a two stage cyclone. However, two sets of two stage cyclone are used in most of the modern factories to prevent damaging the germ, because once germ is damaged and oil leaks from the damaged germ, it is very difficult to remove the oil by the downflow processes. The germ is washed by process water after it has been separated from the starch milk. This process recovers starch as well as preventing the starch being included in the germ. After the separation of germ, the crushed maize is milled by an impact mill with double rotating disks and is made into a milk mixed with fiber particles.

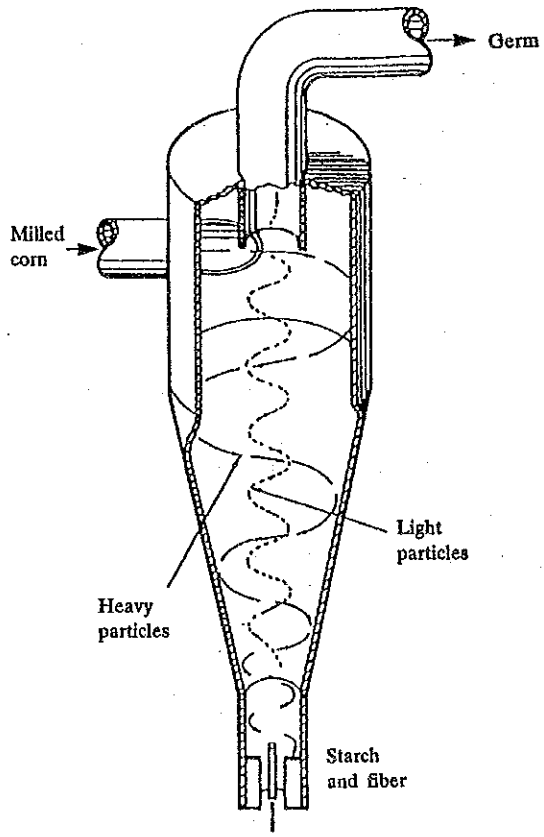

Figure II–3 Hydrocyclone

The fiber particles are removed by screens and repeatedly washed by a counter flow of water. That is new process water enters into the last stage and goes out from the first stage of the fiber washing screen.

The resulting starch milk is thickened by a centrifuge and then the protein contents are separated by another centrifuge, because the protein is slightly lighter then starch.

After centrifuging, elements other than starch have mainly been removed. The milk is then sent to multi-hydrocyclones for a refining wash. 9 to 14 stage cyclones are used, and each stage consists of many small cyclones made of plastic. The cyclones separate foreign elements by slight differences of specific weight. The washing water flows through the cyclones in a counter current direction to the milk, in other words fresh water is supplied to the last stage of the cyclones.

Cornstarch milk is sent to a centrifuge and dewatered after washing, and is then dried by hot air. An air cyclone catches the cornstarch powder at the outlet of the drier. The powder is measured and packed in bags for delivery to other factories or to storage.

The drying process consumes a large amount of energy for evaporating the water, so that it is more economical to send starch milk or starch paste directly to next process without drying, if the distance is not too great, because water has to be added to cornstarch powder for most applications such as fermentation for citric acid or hydrolysis to corn syrup.

The screens used in the above mentioned processes are usually made of stainless steel wedge bars as shown in Figure II–4. This type of screen assures smooth filtering without clogging.

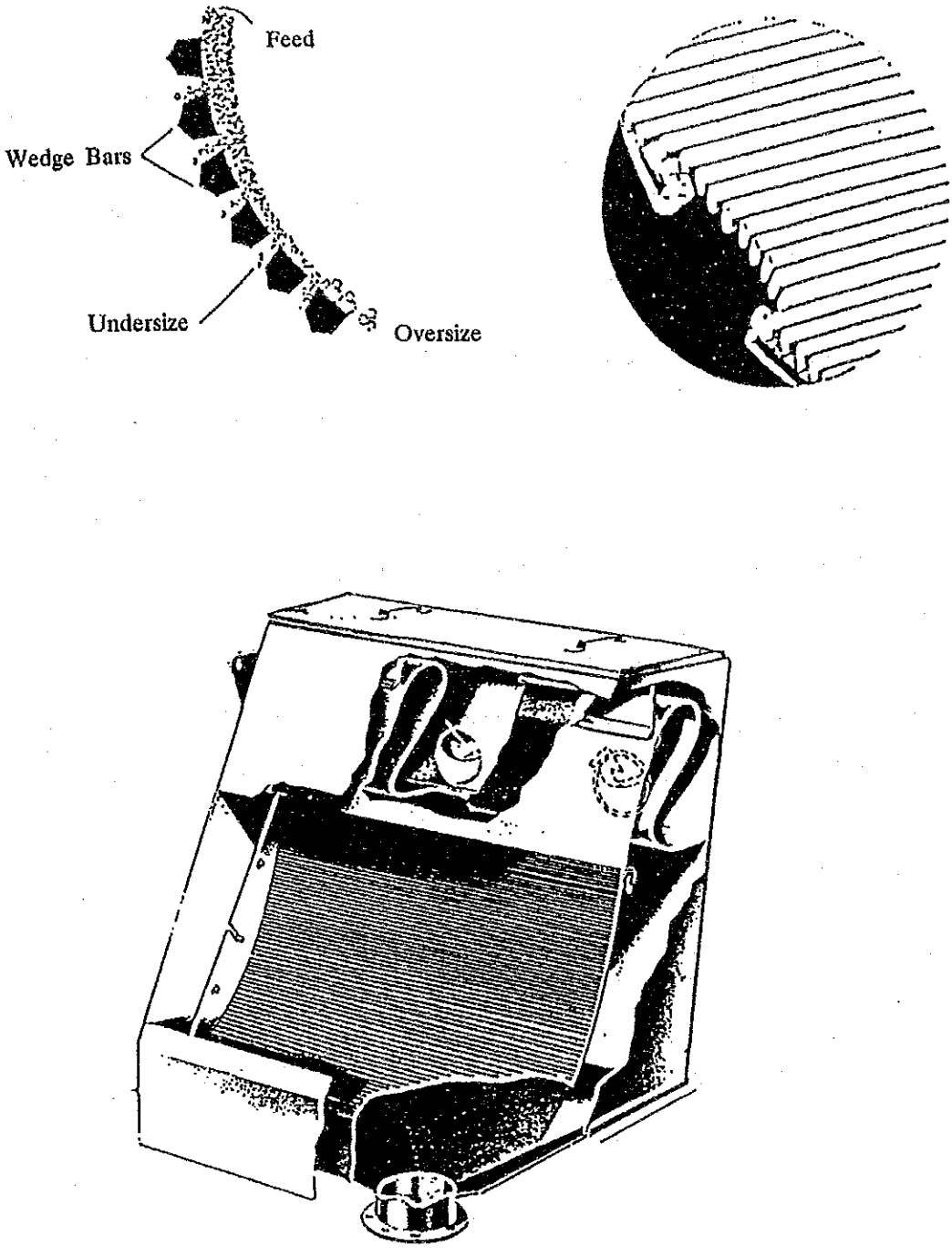

Figure II–4 Screen

(3) Recovery of by-products

(a) CSL (Corn steep liquor)

The dilute sulfurous acid contains various elements extracted from the maize during steeping. The solution is removed after repeated circulation through the steeping tanks. This solution contains microbes for lactic acid fermentation, which is then stored in a tank at a suitable temperature until the fermentation is completed. After fermentation, the liquid is sent to an evaporator and concentrated. The concentrate is called CSL (Corm Steep Liquor), which has a dark brown color and contains various useful nutrients. The liquid is used as a nutrient or a medium for various fermentation processes, particularly for the production of penicillin for which it is indispensable. The liquid has a high protein contents and can be mixed with fiber for producing cattle feed.

(b) Germ

Germ is carefully removed from the maize grain without being damaged as explained earlier. The germ is washed free of starch in multi-stage screens and is then dewatered by a screw press, and dried by hot air in a rotary dryer. The dried germ contains about 50% of lipid which is good as an edible oil. The oil may be squeezed out in a press after heating, but modern processes extract oil by a solvent such as hexane in a more efficient way. However, the amount of germ produced from a cornstarch factory may not be large enough to justify the equipment for this process, so the germ can be sent to an oil producing factory where many other sources of vegetable oil such as sunflower seeds and soy beans are processed together in most cases. The oil which is extracted from the germ is known as corn oil. Refined corn oil is used as salad oil, which is clear and has no unpleasant odor. The price of the oil is about 41 US¢/kg in the U.S.A. and about 2.0 Z$/kg in Zimbabwe when sold to retailers.

(c) Gluten feed

Fibers separated in the process producing cornstarch are used as a cattle feed by adding CSL, protein and other materials in order to improve its nutrition and taste. The fiber is dewatered by a screw press and mixed with the other nutrients, and then dried. The product is called gluten feed, which is sold at about 11 US¢/kg in U.S.A. and about 24 Z¢/kg in Zimbabwe.

(d) Gluten meal

Gluten separated by a centrifuge is thickened by another centrifuge and sent to a vacuum dryer. The dryer has a fine mesh screen on a drum, and water is removed by a vacuum on the inside of the drum. The gluten is scraped from the drum and collected. This gluten is then sent to a hot air drum dryer. Dried gluten is a brown colored powder, which is called gluten meal. The price of gluten meal is about 24 US¢/kg in the U.S.A.

It is not recovered from the existing process in Zimbabwe. Gluten meal can be added to cattle feed, but is more valuable for the production of amino-acid flavoring or as an adhesive.

(4) Water saving

Water is the medium of the cornstarch process. If water used for the process is dumped, it results not only in a loss of the resources contained in the process water such as cornstarch but also causes contamination of the environment due to its high BOD. Accordingly it is important to reduce the amount of effluent from the process. As shown in Figure II–2, fresh water is added to the process only at the last stage of the multi-cyclone used for final washing. The water from the multi-cyclones is collected at the centrifuges and re-used as the process water for washing germ and fiber. Water extracted from the dewatering press and starch thickeners is used for steeping. As mentioned before, steeping water is evaporated by a multi-stage evaporator and the water is collected as condensate. Other water is evaporated in the dryers or removed as part of the products.

It is said that the amount of fresh water being added to the process is $0.2m^3$ or less for the production of 100 kg of cornstarch is a modern process. As the water is used repeatedly for various processes, it must be pure enough to avoid contamination of the cornstarch. The water is purified by an ion-exchanger if necessary.

(5) Uses of cornstarch

It has already been explained that cornstarch is used as a raw material for the production of citric acid by means of fermentation. However, this is one very small use of cornstarch. The major uses of cornstarch will be explained briefly in the following section:

(a) Corn syrup

Starch consists of molecular chains called amylase and amylopectin, which can be changed to a mixture of glucose and maltose by adding an enzyme or acid and processing by hydrolysis. The hydrolyzed product is malt syrup which is used as a sweetener in candy, icecream, jam, etc.

Cornstarch can be hydrolyzed to glucose alone by a special enzyme, glucoamylase. Glucose is less sweet than sugar, but sweeter than maltose, and so glucose is a better sweetner than simple malt syrup and is used for bread, chewing gum, canned fruits and mixing in alcoholic drinks. Purified glucose is used for medical purposes such as intravenous feeding.

An enzyme, isomelase changes glucose to fructose, which is sweeter than sugar. Using isomelase, corn syrup can be modified to HFCS; high fructose corn syrup, which has an equivalent sweetness to sugar. HFCS is widely used for soft drinks, bread, icecream, confectionery and so on. In the U.S.A., the consumption of these corn syrups already accounts for more than 25% of all sweeteners. In Japan, it is assumed to have been about 20% in 1988. It is said that the price of HFCS is about 60–70% of sugar in Japan, which corresponds to about 70 US¢/kg*. In the U.S.A., it is said that the price of HFCS is about 40 US¢/kg*. However, in Zimbabwe, the price of refined sugar is 1,000 Z$/t (or 33 US¢/kg), so that competition with sugar is expected to be harder than in the U.S.A. or Japan.

A large percentage of cornstarch, may be 50% or more, is used for the production of corn syrups at present.

(Remark)

* HFCS is usually sold as a water solution, but the kg units used here indicate the equivalent weight of dry solid.

(b) Starches used for paper and corrugated cardboard

Paper industries and corrugated cardboard makers consume about 20% of the total production of cornstarch, which is the next largest use after corn syrup.

Cornstarch and chemically modified cornstarch are used for sizing and coating paper. Sizing means to spread starch on the surface of paper to prevent ink from running. Chemically modified, oxidized starch is used for this purpose, because it is easy to disperse in water, has a stable viscosity and is quick to dry. Coating means to coat kaoline or some sort of pigment on the surface of art paper. Chemically modified starch is also used for this purpose.

Corrugated cardboard is used for boxes for packaging a wide variety of products. Corrugated cardboard is manufactured using a special adhesive made by mixing high viscosity starch and suspended starch powder. The high viscosity starch is made from a chemically modified cornstarch.

The manufacturing processes for paper sizing, paper coating and corrugated cardboard are automated, so the starches used in these processes are required to be of a constant and stable quality. Also, in order to meet the requirements of the respective processes, they must be chemically modified.

The demand for corrugated cardboard, by thriving industries such as electric, electronics, precision machinery, household utensils, and apparel is expected to increase rapidly.

(c) Starch for food industries

In Japan, starch is also used for making fish cakes, but this usage is very unlikely in Zimbabwe. Starch is added to canned meat as well as being mixed with flour to make cakes in Zimbabwe. Starch is added to sauce and cream, and also is used as one of the raw materials for beer making.

(d) Other industrial uses

The textile industry also uses starch for sizing and finishing. Chemically modified starch is used for these purposes in most cases. As is well known, thin starch is used by laundries.

(e) Material for fermentation

As explained in this report, cornstarch is a good raw material for the production of citric acid by fermentation. Ethanol, butanol and so on can also be made from cornstarch by fermentation, however, most of these fermentation processes do not require any purification of the starch, and so maize grain can be used directly. An exception is beer making, where a certain amount of cornstarch is used.

(f) Summery

Figure II–5 summarizes this study and shows the sequence from maize to final uses including the products and by-products. Numerical data show assumed weights of maize and by-products if 100 t/day of Zimbabwean yellow maize with the characteristics shown in Table 7–2 are supplied to the factory.

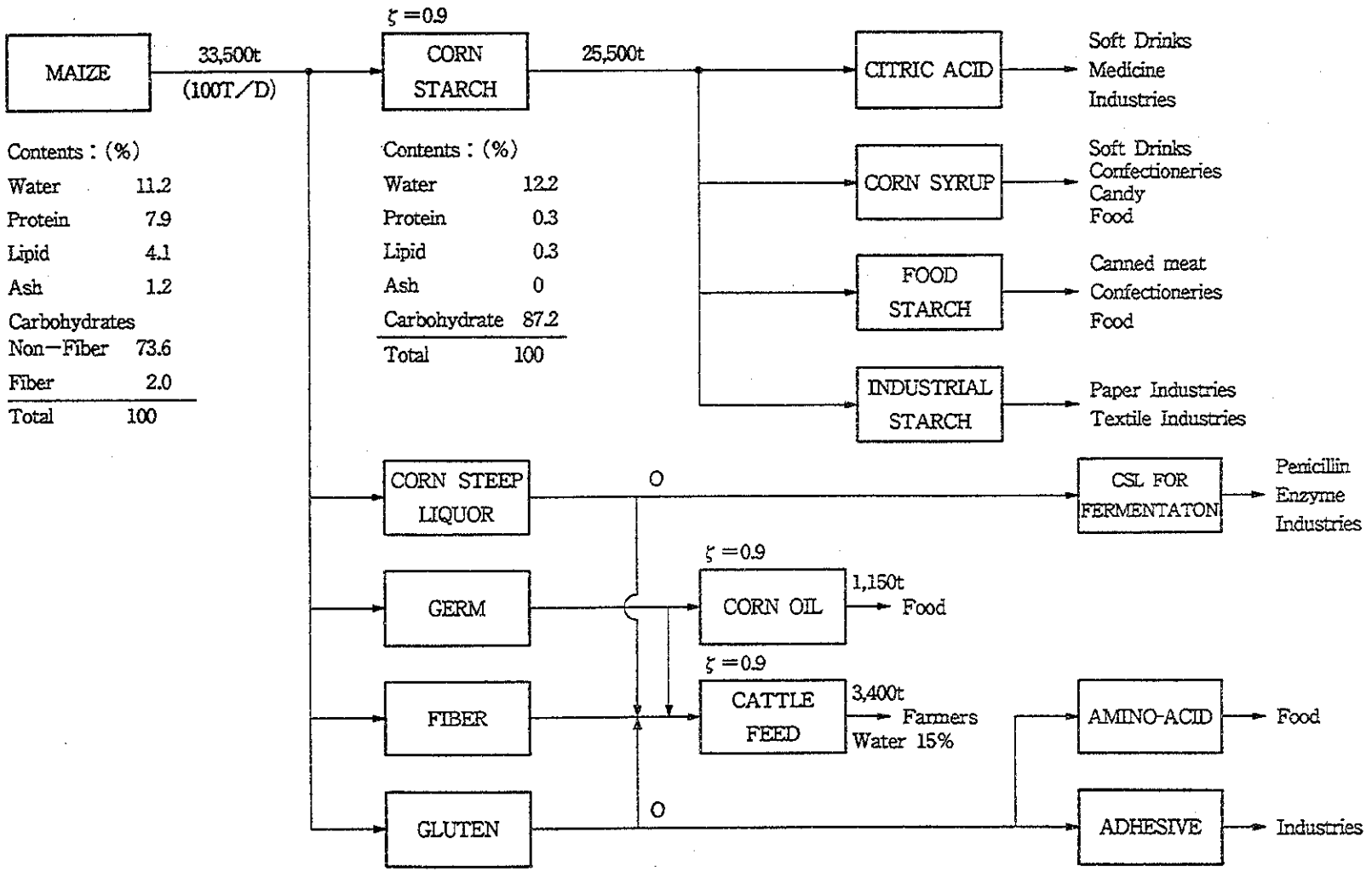

Figure II-5 Products of the Cornstarch Industry

(6) Recommendations

Cornstarch industries are important for Zimbabwe, in order to provide more added value to the maize. However, the production of cornstarch may not be so successful unless its uses are developed. It is recommended that the prospects and feasibility of a cornstarch industry should be studied from the overall viewpoint of the related industries mentioned in this appendix such as corn syrup, chemically modified starch, etc.

It is unnecessary to emphasize that maize is valuable and specialized resource for Zimbabwe and its effective and complete utilization might be an important theme for further study.