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APPLICATION OF SCIENCE AND TECHNOLOGY IN AGRO-INDUSTRY

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Application of Science and Technology in Agro-Industry

I. Importance of food processing

The food-processing sector constitutes the main manufacturing sector in many developing countries. For example, according to a World Bank survey, manufacturing-added value in Africa is highest with food processing constituting over 40%, compared with 14% for textile, 6% for chemicals and 4% for machinery and transport equipment (World Bank, 1989). Agro-industries are usually the first to be established in modern manufacturing sector of a developing economy where agriculture has been the mainstay of the economy.

Moreover, food processing has a stimulating effect on agricultural production. The food-processing sector is a large employer of labour and it provides substantial revenues to farmers as suppliers of raw materials by keeping prices of these primary products upwards. The importance of food processing to food security is also very significant because it helps in reducing food wastage and in the utilisation of local raw materials (Odufa, 1996).

Agricultural products are processed in order to preserve them over substantial periods of time and make them more attractive and convenient in use and in transportation. The treatments applied range from simple processing which comprises such activities as drying, freezing, canning, husking, grinding to the more complex processing which include the processing of oilseeds into margarine, maize into sweeteners or oil or cane into sugar. This complex processing differs essentially from the simple processing because it requires a substantial change in the form of the product which is distinct from the cleaning, sorting and refrigeration of fresh produce of the simple processing method. Such processing can extend greatly the shelf life of products, present them in forms more attractive to consumers, facilitate their transport over long distances and overcome a wide range of marketing constraints.

Many of the processes involved are carried out most effectively with the aid of specialised equipment and scientific and technological know-how in plants assuring the necessary technical, sanitary and other conditions. They involve major fixed investments. To cover the capital and other overhead costs sound managerial techniques have to be applied. The operator needs a steady supply of suitable material for processing and a dependable marketing channel for the processed product.

If the processing operation is successful, it can offer a stable and profitable outlet for farmers who supply the raw product. It can add variety to local diets and make food available at times when otherwise it would be lacking.

Exports of processed products can be an important source of foreign exchange. Therefore, the processing enterprise is a powerful engine of development.

II. Overview of the processing of agricultural products

For some agricultural products, processing is essential if they are to reach consumers in an acceptable form. Many others are processed in order to extend the range and duration of the markets in which they can be sold and the duration of their shelf life. Below follows a general overview of the processing of a few agricultural commodities as reviewed by several authors (Abbott, 1988; FAO, 1988; Blanshard, 1996; Bokanga et al., 1996 and Donkor, 1996).

Rice is harvested as paddy with a protective husk and a second layer of bran. These two have to be removed before cooking since most consumers like white polished rice. The bran is then used as a livestock feed ingredient or is further processed to obtain bran oil while the husk is burned to provide power to the mill. Since most consumer prefer strongly whole grain, keeping the grain intact during milling operations is important. Thus, in order to increase the milling efficiency, in some region, the paddy is often soaked in water and steamed before milling. This process known as par-boiling gelatinises and thus hardens the grain leading to higher milling yields.

Maize is used as a human food or included in livestock and poultry feed. As such, it is ground into grits, coarse meal and flour. In many places, local mills have replaced hand pounding at the village level and large scale mills have been set up to serve the sprawling cities. A wet milling process has been developed to yield edible oil, sweeteners and starch.

Cassava has long been processed for direct food use in the countries where it is grown. It is peeled, grated, squeezed and fermented to remove the acid element, then roasted. For example, the gari processing in Africa includes a stage of fermentation. Cassava is also processed industrially for export as tapioca and flour for alcohol distillation, starch and glue preparation. In some areas, cassava is processed into pellets for export which will be used as an ingredient in livestock feed. The raw roots are chipped, air-dried, passed through a hammer mill, then pressed into cylindrical shaped pellets. These are convenient to handle and reduce greatly the shipping space required.

Processing is strategic in expanding the market for perishable fruits and vegetables which mature during a limited season. Drying, pickling with brine and vinegar, jam making, canning and preservation of juice under low temperatures enhance significantly the shelf-life of these products and thus can be brought to additional markets in time and space, and presented so as to suit the consumer preferences. Internationally, the demand for canned products has levelled off reflecting the expansion of frozen foods in home

consumption and of dried vegetables for industrial use. However, the demand for canned exotic fruit and juices such as papaya, mango and passion fruit is increasing.

Sugar cane is crushed to expel the juice which is then boiled to evaporate off the water. The end product is brown sugar. Quantities of up to 15 tons per day are commonly handled in this way. Centrifugal processing to produce a white sugar is generally based on a throughout of 1,000 tons per day. Refining to obtain white crystal sugar offers substantial economies of scale with 100,000 tons of product annually considered the minimum.

Tea is marketed after the leaves have been allowed to wilt and ferment, and have been chopped and dried. Usually, individual processing enterprises try to meet consumers' requirements by offering blends adapted to discriminating tastes. Thus, critical factors in the processing of good quality tea are that only the bud and the first two leaves are picked and that the leaves are brought to the factory for processing the same day. They can be transported easily, but the plant must still be relatively near to the production area. Picking and processing can be done throughout the year. One hundred kg of fresh green leaves produce 18 to 27 kg of tea. Economies of scale in processing call for a production base of 200 to 400 ha. Packing tea in consumer sized packages adds about 25 percent to its value, in tea bags 100 percent.

The processing of tobacco leaves start with the drying the leaves on racks, generally with the use of artificial heat. In some African countries such as Nigeria or Kenya, this is done by growers on a family basis, or in groups. They operate under contract to a tobacco company which provides seedlings and other inputs on credit and intensive technical assistance. In some other countries, tobacco is grown by small farmers under contract, but grading and curing is centralised.

Cotton fibre or lint is harvested together with the seed. Before they can be sold, they must be separated. This process, known as ginning, permits the fibre to be packed tight in bales for sale to buyers for spinning. The seeds are also sold to crushing plants for processing into oil and livestock feed. Because cotton as harvested is bulky, it is ginned near to the point of production. Where cotton is picked by hand, mature clean seed cotton can be collected separately from immature, damaged or stained growth and kept free of leaves and stalk. Cotton picked by machine is more variables in quality and requires extensive cleaning.

Edible oils for use in cooking are obtained from olives, cottonseed, groundnut, oil palm, sesame, soya, sunflower and other oil seeds. The oil is expelled by crushing and is then refined. The refined oil can then be sold directly or further processed into margarine and other solid fats. The residue is an animal feed with a high protein content. Traditionally, oil has been expelled by grinding and pressing on an artisanal scale. With such methods,

the residual cake still contains about 10 percent oil. Use of a mechanical press can reduce this to 5 percent. Solvent extraction can bring the oil level down to 1.5 percent but this is a more complex process involving higher capital investment. Mechanical presses are generally used for capacities of up to 200 tons of raw material per day and for seeds with high oil content. Vegetable oils are refined to achieve a product that is light in colour and bland in flavour. During processing, the proportion of free fatty acid must be kept below three percent.

Feed mixing is one of the fastest growing agricultural industries in the world. This is related to the increasing human demand for animal protein. Nutritionally, balanced feeds are particularly important for the most efficient grain to protein converters – poultry and pigs. They are also widely used for cattle and sheep to supplement natural grazing and in weaning young animals. A wide range of grain, oilseed and other product combinations and supplements can be drawn on to meet desired nutritional requirements at the lowest cost.

The slaughtering of livestock and preparation for consumption of the carcass and offal is a specialised operation in most societies. Chilling, freezing and canning facilitate marketing over long distances. Preparation and packing of special cuts add further value where adapted to market requirements.

In the past, poultry were killed, plucked and dressed for individual consumers on request. With access to refrigeration, the development of fast growing strains and integrated production and processing, the young chicken has shifted from a luxury eaten on special occasions to the cheapest source of meat. Average yields from live weight of product for retailing to consumers are beef 44, veal 50, lamb 45, pork 65, chicken 70, turkey 78 percent respectively.

Much milk is consumed near where it is produced without any processing. However, transporting milk to urban customers involves cooling and pasteurisation if its quality is to be assured. Conversion of milk into products such as butter, cheese and evaporated milk extends greatly the market. Drying into powder facilitates storage over time. The powder form is also convenient for manufacturing uses, for reconstitution into liquid milk and for blending with water and high fat content fresh milk. Processing into casein opens up another outlet for milk surplus to other uses.

Fish are highly perishable. Consumption in the developing countries has been limited to a few kilometres distance from where they are caught. Traditionally, they have been preserved by salting, drying and smoking. Canning or freezing brings them to the consumer with less change in form and opens the way to a much wider range of markets. Meal derived from drying and grinding fish that could not otherwise be sold, is a valuable high

protein ingredient for livestock and poultry feeds. In 1980-82, 27 percent of the world's fish catch was converted into meal.

III. Milk processing in Kenya

The Kenya Cooperative Creameries uses the Ultra-High-Temperature (UHT) technology (Tribe, 1990). This kind of technology requires sophisticated electronic control systems and regular inspection and maintenance because of the precision nature of the heating and cooling system of the milk, which uses the high temperature short time (HTST) system. The UHT treatment of milk is a process of high bactericidal effect. It is a continuous flow process in which the milk is heated to a temperature of 135-150 °C for about 2 seconds, destroying even heat-resistant spores to such an extent that for practicable purposes the milk is sterile. There are two basic methods for UHT treatment. The *direct* method involves heating the milk by steam injection or infusion, which results in dilution of the milk, followed by evaporative cooling under vacuum which removes the added water, restoring the milk to its original composition. In the *indirect* method, the final heating of the milk is done by heat exchange without involving steam injection (Hall, 1976).

This technology is usually used in conjunction with aseptic packaging in sterile containers giving an overall result whereby there will be not more than one viable microorganism in 1000 packages. The Kenya Cooperative Creameries uses the Tetrapack containers. This system gives the milk thus produced a three to four-month shelf life without refrigeration. After this time spoilage will almost certainly be caused by physico-chemical, rather than bacteriological, factors (Tribe, 1990).

However, the use of this advanced technology requires highly skilled personnel. The wider diffusion of the technology depends on the acquisition of a large number of technical operators with the necessary engineering knowledge and experience.

Kenya Cooperative Creameries uses also an alternative technology for raw and pasteurized milk production cooling and packing which does not require the use of the sophisticated technology of the UHT. Pasteurization is a key process in dairy plant operations. Although many combinations of temperature and time can be used to achieve pasteurization, the process most commonly used consists of heating the milk in continuous flow to a minimum temperature of 72 °C and maintaining it at this temperature for at least 15 seconds after which the milk is rapidly cooled. In practice, it is common to operate at slightly higher temperatures for slightly longer times to provide an additional safety margin (Hall, 1976).

To pack the milk, the technology that has been adopted by KCC consists in packing machinery designed to put milk into dated plastic bags

(polyethylene) of a capacity of 500cl or alternatively 200cl by adjusting the equipment. The throughput of a single head is usually about 1800 packages per hour. This type of machine is suitable for handling up to about 15,000 litres/day in 500cl packages. With this kind of sterile packing system, the milk produced has a two-week shelf life without refrigeration.

IV. Maize Processing

As Salunkhe and Deshpande (1991) note the manufacture of maize is one of the largest food-processing industries in the world. The milling of maize is centered on the transformation of a basic agricultural product into even more basic fractions for consumption by people and animals. There are two main types of process: dry milling and wet milling.

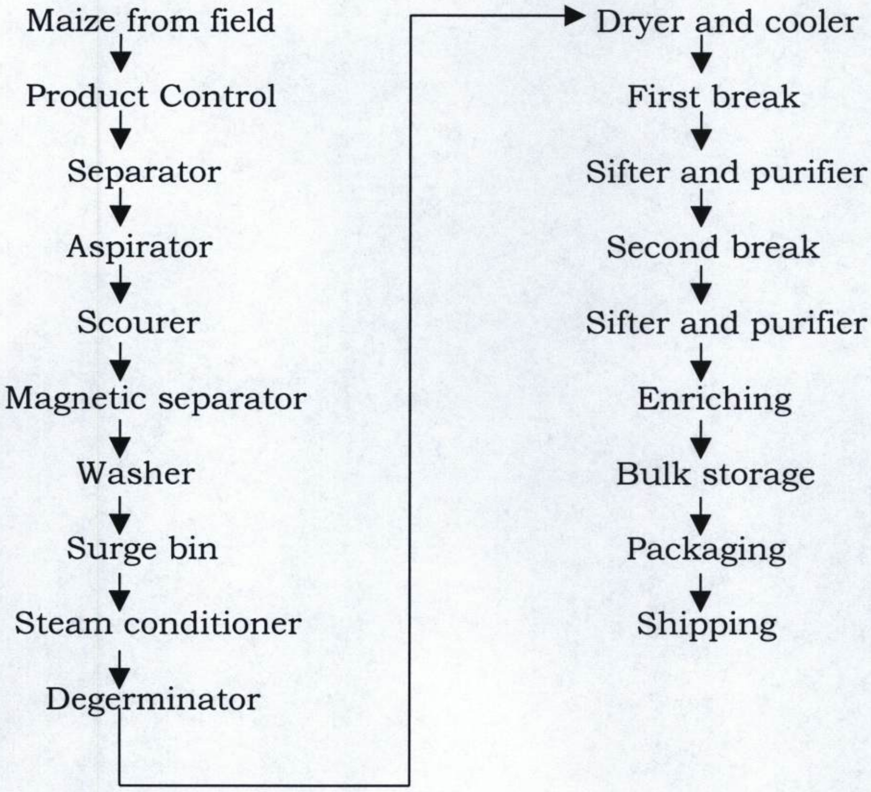
Dry Milling

Dry milling of maize is carried out both by old-process milling from non-degermed and by new process milling from degermed grain. In old-process milling, the grains of maize are ground to a coarse meal between millstones run slowly at a low temperature, with the meal not being sifted frequently. In the larger mills, about 5% of the coarse particles of the hulls are sifted out. In some large mills, the maize is dried to 10-12% moisture before grinding.

In new-process milling, steel rolls are used to remove the bran and germ and to recover the endosperm in the form of hominy or maize grits, coarse meal, fine meal, and maize flour. The grain is cleaned and passed through a scourer to remove the tip cap from the germ end of the kernel. Depending on the variations of the processes, the grain is either untempered or tempered by the addition of water to a moisture content of 21-24%. Then, it is passed through a degerminator, which frees the bran and germ and breaks the endosperm into two or more pieces. The stock from the degerminator is dried to 14-16% moisture and cooled in revolving or gravity type coolers (figure 1 below).

The large endosperm pieces obtained from the first break are used for making corn flakes. The stocks are passed through a hominy separator first to separate the fine particles, and then to grade the larger fragments to various sizes and polish them. The various grades of broken grain are passed through aspirators to remove the loose bran from the endosperm fragments. These are reduced to coarse, medium and fine grits by gradual reduction between corrugated rolls and subsequent sifting of the stock. The coarsest stock from the aspirator, which is highly contaminated with germ, goes to the first break rolls. The germ is flattened between the break rolls with minimum endosperm grinding and separated by sieving.

Figure 1 : Flowchart for maize milling by the new process



Wet Milling

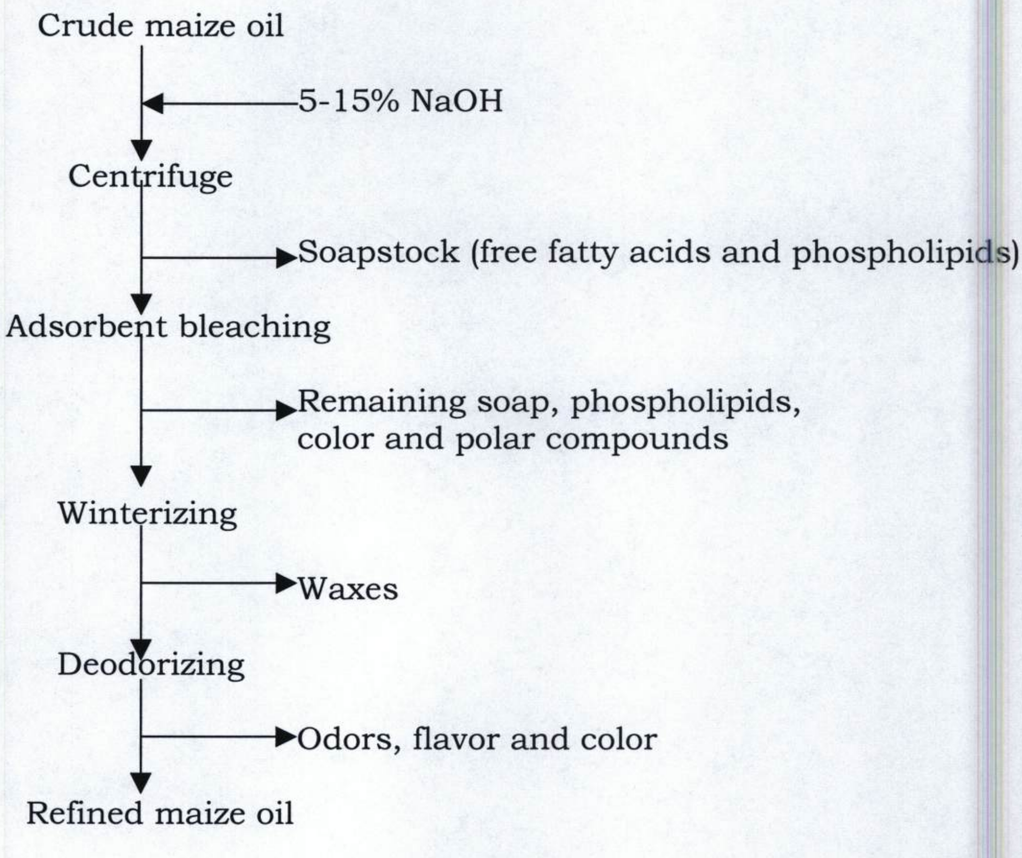
In the wet-milling process, the clean maize is first softened by steeping in a very dilute solution of SO_2 at 48-52 °C for 30-50hr. For optimum milling and separation of maize components, the maize should have absorbed about 45% water at the end of the steeping period, released about 6.0-6.5% of its dry solids as solubles into steepwater, absorbed about 0.2-0.4 SO_2/kg, and become quite soft. When the maize has been optimally steeped, the germ can be removed easily and intact in the degerminating mills. After the removal of germ, the kernels are transported to the grinding mills, where they are broken down in a slurry mixture of starch, gluten protein, and hull. The hulls are removed by specially designed screens to produce a slurry of gluten and starch. This slurry is then sent through a hydrocyclone that separates out a purified cornstarch stream and a gluten feed stream.

Maize Oil

In the manufacture of maize oil, the germ – the first major fraction isolated in the maize processing – is removed by centrifugation. It is sent to a continuous screw press where its oil content is reduced from roughly 50% to 20%. In larger commercial processing plants, the remaining 20% residual oil is reduced further by solvent extraction, after which the germ meal contains 1-3% oil. The germ meal is used as an animal feed.

The crude oil from the extraction process must be refined further before it is acceptable for use in food products. The undesirable components of the maize oil (free fatty acids, phospholipids, waxes, carotenoids, odors and flavors) lower the quality of the oil. They are removed during the oil refining process (figure 2).

Figure 2 : Maize oil refining process



Maize sweeteners

The sweeteners derived from maize are produced by the hydrolysis of the starch that has been refined during wet-milling operations. The manufacture of corn sweeteners is a multi-step process. There are three commonly used methods for syrup production: acid catalyzed hydrolysis, acid-enzyme conversion and enzyme conversion. Each of the three methods produces a certain type of syrup with different saccharide distributions that give them their specific qualities.

1. Acid conversion or acid catalyzed hydrolysis process

In this process, a starch slurry of about 35-40% dry matter is acidified with hydrochloric acid to pH of about 2 and pumped to a converter. In the

converter, the steam pressure is adjusted to 30 psi, and the starch is gelatinized and depolymerized to a predetermined level. The process is ended by adjusting the pH to 4-5 with an alkali. The liquor is clarified by filtration and/or centrifugation, and concentrated by evaporation to around 60% dry matter. The syrup is further clarified and decolorized by activated carbon treatment, and refined by ion exchange to remove soluble minerals and proteins and to deodorize and decolorize. It is further concentrated in large vacuum pans or continuous evaporators.

2. Acid-enzyme process

In this case, the liquor, containing a partially converted product, is treated with an appropriate enzyme or combination of enzymes to complete the conversion. Thus, in the production of 42-DE high-maltose syrup, acid conversion is carried out until dextrose production is negligible; at this point, β-amylase (a maltose-producing enzyme) is added to complete the conversion. The enzyme is deactivated, and purification and concentration are continued as in the acid process.

3. Enzyme conversion process

The starch granules are cooked, preliminary starch depolymerization is done by starch-liquefying α-amylase, and the final depolymerization is effected by either a single enzyme or a combination of enzymes. Different enzyme combinations make possible the production of syrups with specific composition and/or properties (e.g., high maltose or high fermentable syrup).

V. Sorghum Processing

Sorghum processing is not fully developed on a commercial scale (Salunkhe et al., 1991). However, modern concepts in cereal grain processing can also be sued for sorghum. For example, the conventional dry, roller-milling process can be employed for the preparation of whole and refined sorghum products. The preliminary operations in dry milling of sorghum involve the removal of impurities such as adhering glumes, broken kernels, chaff, foreign seeds, stones, etc. The addition of moisture to the grain (i.e., conditioning or tempering) prior to milling is a common practice. Preconditioning of the grains offers such advantages as swelling and separation of the germ from the cementing layer of endosperm, toughening of the bran, and mellowing of the endosperm.

The grooved or corrugated rollers in the conventional roller milling break open the grains. The exposed endosperm is then crushed between a series of smooth reduction rollers and freed from the toughened bran. The fine grains are separated by screening, and the coarse fraction is further fed to the next set of rollers after every pass. The bran is generally removed by screening

and aspiration. The roller-milled flours are sieved to yield products varying in extraction and composition. For the production of high-extraction flours, impact is preferred as t requires less space and equipment than the roller-mill system.

Attrition milling is also used for the dehusking of sorghum grains. Most attrition-type dehullers are comprised of two stone or metal disks, either or both of which rotate around a vertical or horizontal axis. The attrition is provided by introducing metal pins or blades into the surface of either or both rotors, or of the rotor and stator.

The bran of the sorghum kernel can also be removed mechanically by abrasion. The abrasive mill consists of thirteen carborundum stones (12-inch diameter) driven at a speed of up to 200 rpm. The grain is fed through a hopper at one end and released after stone action through an overflow outlet at the other end. The amount of kernels removed as fine is determined by the retention time in the mill, which in turn depends upon the grain-feeding rate. The grains are then passed through an air separator on the attrition mill to remove the fines.

Peeling of bran layers from sorghum kernels can also be achieved chemically. A caustic dip (0.25%) of sorghum grain after solvent extraction loosens the seed coat, which is then removed by rinsing and brushing.

Wet-milling processes similar to that of corn have also been used for sorghum processing. However, finer-mesh screens are necessary for efficient operation.

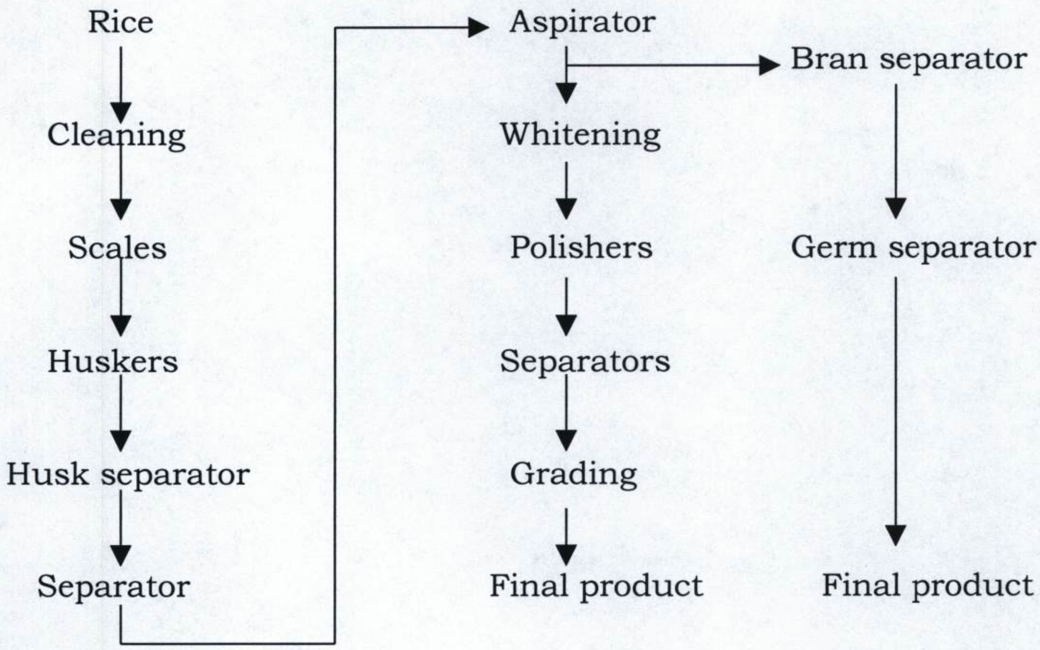
VI. Rice Processing

The basic stages in the processing of rice are (a) cleaning, (b) husk removal, (c) whitening, and (d) grading. Figure 3 below shows the whole process (UNIDO, 1985).

The primary objective of rice milling is to remove the hull, bran and germ with a minimum breakage of the endosperm (Salunkhe and Deshpande, 1991). In the threshed grain (rough rice or "paddy"), the kernel is enclosed in a tough, siliceous hull, rendering it unsuitable for human consumption.

Cleaning is based on differences in the size, weight or form of the foreign matter in relation to the grain. Depending on their characteristics (weight, size and density), impurities are removed by aspiration, sieving and gravity. The machines used in this operation, namely, the scalping machine, the separator sieve, the vibratory grading sieve, the gravity separator or densimetric table and the disc separator, may or may not combine suction, sieving and gravity separation. At a later stage, the impurities are also separated by means of a magnetic separator.

Figure 3 : Processing in a rice mill



The paddy is then conveyed to shelling machines that loosen the hulls. Conventional shellers consist of two steel plates, mounted horizontally, whose inner surfaces are coated with a mixture of cement and carborundum. As the moving plate revolves around the stationary plate, the pressure on the ends of the upturned grains disengages the hulls, which are removed by aspiration. The mixture of (de)hulled and unhulled grains is separated on a large box shaker fitted with vertical, smooth steel plates set on a slight incline to form zigzag ducts. The plates and the shaking action cause the less dense paddy grains to move upward and the heavier hulled grains to move downward. Paddy may also be shelled with rubber rollers or with a rubber belt operating against a ribbed steel roll. The rubber shellers cause less mechanical damage and improve the stability against rancidity.

The hulled rice is then milled to remove the outer and inner bran layers, the aleurone layers and the germ. The milling and polishing machines consist of grooved, tapering cylinders that revolve rapidly in stationary, uniformly perforated cylinders. The entire machine is filled with grain and the packing force is regulated by a blade that protrudes between the upper and lower halves of the perforated cylinders. The bran, aleurone and germ are removed by scouring action of the rice grains against each other near the surface of the perforated cylinders. After passing through a succession of hullers, the rice is practically free from germ and outer bran. Scouring is usually completed by polishing in a brush machine. The polished (white) rice is then sorted according to size class.

A solvent extraction process has also been developed to increase the yield of whole-grain rice. Hulled brown rice is softened with rice oil to improve bran removal. Fully milled rice is sometimes treated with a talc and glucose solution to improve its appearance. After the coating is evenly distributed on the kernels and dried with warm air, the rice emerges from the equipment with a smooth, glistering luster and is known as "coated rice."

The conversion of brown rice to white or polished rice removes a substantial amount of proteins, minerals and fat and fibres. To limit these losses several practical methods have been developed to retain some of the nutrients in the milled rice kernel. One of these methods is par-boiling which increases the retention of some of the nutrients by diffusing them (vitamins and other water-soluble nutrients) from the outer portion of the grain into the endosperm. The paddy is soaked in water either at room or at elevated temperatures, then drained, steamed and dried (Salunkhe and Deshpande, 1991).

VII. Sugar Cane Processing

Avestruz (1985) describes the processing of sugar cane. This processing begins with the extraction stage. In the mill-tandem method of milling, the extraction of the juice is carried out by means of pressure. A hydraulic pressure is applied to the cane when it passes through the first one or two milling units known as crushers. This stage of the process releases the greater part of the juice and sugar. To remove the remaining extractable sugar, the cane is shredded. A process called imbibition is then applied on the shredded cane. This consists of spraying the cane first with more dilute mill juice and later with water, to enable the mills to extract the sugar more completely from the fibers. The cane is then sent to rollers where a 400-ton pressure is applied to complete the extraction process. An extraction rate of 94 percent of the sucrose in cane leaving 6 percent as losses is considered optimal.

In an effort to improve the extraction rate, a new method known as continuous cane diffusers has been developed. The diffusion process consists of a series of simple continuous washing machines or percolators designed to extract sugar and other soluble solids from finely prepared sugarcane, mainly by the process of lixiviation or washing, in the case of ruptured cells, and partly by osmosis on undamaged cells. The efficiency of a diffuser as a sugar extractor is largely dependent upon the proper preparation of the cane before it is fed into the diffuser, the quantity of fresh water used, the number of percolations or washings to which the bagasse is subject to per unit of time, and the operating temperatures of maceration water and recirculated juice.

The raw juice obtained from either method goes through a cold liming process where a pH level of 7.5 to 7.6 is maintained and then heated to a

temperature of 215 °F to 218 °F and allowed to settle. The impurities and suspended solids are removed through the combined effect of the heat and the precipitation of calcium triphosphate. The juice passes through continuous clarifiers and is decanted off. The settlings are filtered through continuous vacuum rotary type of filter. The decanted and filtered juices go through the evaporation process. The evaporators are vessels where pressure is so reduced and regulated that the steam evaporated from one vessel will boil the liquid in the next because of its lower boiling point due to a higher vacuum. These are known as triple or quadruple effect evaporators.

The evaporation process results in the formation of a syrup containing about 50 percent of sugar which will have to be boiled to grain. The boiling process is carried out in a closed pan, also maintained at high vacuum. When super saturation has been attained, a fine powder of sugar in isopropyl alcohol is admitted into the pan to induce crystallisation. Crystallisation is completed in large tanks called crystallisers, where the mother liquid and crystals, known as massecuite, are poured from the boiling pans. The process is hastened by keeping the semi-solid mass in continuous motion by some mechanical device and by cooling the tanks.

Sugar crystals are separated from the liquid phase of the massecuite, known as molasses, through centrifugal force. The centrifuges are shallow cylindrical vessels about 36 to 48 inches in diameter containing an inner concentric framework of fine copper gauze. The vessel, with the aid of an electric motor, is rotated at 1,200 or more revolutions per minute at which the molasses spins out through the interstices of the gauze, leaving the sugar in the inner compartment. The molasses is returned to the boiling process two or three times, until no more sugar can profitably be crystallised from it.

VIII. Transmission of technology and managerial capacity

The most direct vehicle for the transmission of technology by processors has been the production/marketing contract. Experience shows that farmers with no prior experience of a crop have been supplied with a proven package of input and husbandry procedures backed up by credit and a guaranteed market outlet or protection against risk. They have adopted successfully the new technology (Abbott, 1988). Standard technology can also be acquired quickly enough without such contracts if the price incentive is sufficiently attractive.

A producer cooperative processing enterprise can be an effective frame for the transmission of technology to members and staff through group pressures and individual participation in policy and decision-making. It has also been shown that a family enterprise can also be an effective vehicle for technology transmission to large numbers of suppliers, at less economic

cost than the cooperatives taking into account their tax exemptions ad subsidies.

Government support seems to be especially important when:

a) the investment in the productive resource for processing is very long term;

b) the support services needed call for authoritative backing and maintenance on a country-wide basis over long periods.

The support of government advisory and extension service can also contribute greatly to a wider diffusion of technology. Often, however, a specific additional input by a processor may be required if full advantage is to be taken of existing institutional services. The research and development undertaken by governments and their extension service messages tend to be too general. They are insufficiently adapted to the needs of particular sets of producers and to the conditions under which they operate. Offering a financial incentive to farming and fishing enterprises to adopt a new technology through a contract can be decisive in their breaking out of a static situation.

In general, recognition of a market opportunity and application of the appropriate technology to meet market demands especially export market standards are important factors for development of the processing sector. Moreover, processors have found it much easier to introduce new technologies as a complete package associated with a new product than to improve the handling and management of traditional agricultural products. In this area, government intervention may be needed to promote new processing technology. Frozen chickens are the classic example of the new production/processing/marketing system introduced as a whole. In contrast, in Botswana, Chad and Swaziland, entrepreneurs exploited the marketing potential of traditional livestock when government secured financing for new abattoirs required and backed it up with disease control and other support measures.

Physical inputs such as facilities, basic stock, boats, nets and fuel, refrigeration for production/processing of fish are rather costly and capital intensive in most developing countries. Many of these inputs have been provided directly or financed by processors. The joint venture between local and foreign interests has been an efficient way of acquiring physical technology and of inducing technological advances. Striking examples include the provision of new facilities for ice making, processing and freezing, increasing offshore catches at Nouadhibou in Mauritania. In contrast are the problems encountered for lack of foreign exchange and access to market technology in Senegal (UNCTAD, 1984).

Many different mechanisms can be used for the diffusion of technology. Irrespective of the mechanism, the technology package has to be adapted to the socio-economic environment in which it is to operate. Its diffusion evolves best through interactions and reaction with progressive minded individuals and leaders among farmers. Emulation will spread following demonstrated success. For this reason, one of the surest methods of transmitting knowledge and experience is through close working contacts with enterprises or technicians possessing suitable advanced technology. The process is hastened and consolidated where there is a direct shared financial incentive.

Employment for a time of qualified managers and technicians including expatriates is also an effective way for transferring the requisite technology and marketing techniques. When local technological capability is fairly high, incorporating accumulated technology can be acquired from an external source and multiplied locally. Many technologies are transferred to developing countries under licensing and purchase arrangements.

XI. Prospects for the application of Science and Technology in food processing

The following constraints have been identified as major impediments to the application of science and technology to the food industry in Africa (Abbott, 1988; FAO, 1988; Blanshard, 1996; Bokanga et al., 1996; and Donkor, 1996):

- Limited ability to purchase inputs, land tenure problems, lack of credit for seeds, fertilisers, implements and other inputs, and poor agricultural extension delivery.

- Lack of road infrastructure and transport, inappropriate handling containers and a neglect of food handling and packing in technical training; poor facilities, lack of utilities and deficient quality control.

- Problems of raw material supply, including over estimation of potential supply, lack of suitable varieties for processing, insufficient incentives to farmer suppliers and lack of production support services such as extension and credit.

- Problems of market demand, including overestimation of prospective demand; misjudgement of tastes, preferences and habits of consumers; under estimation of competition from other sources and substitutes, and of obstacles to entering foreign markets.

- Problems of management, in particular irregular supply and poor handling of raw materials, product storage and distribution; irregular

supply of products, short shelf-life, price fluctuations and lack of product quality assurance.

- Inefficient internal management including mobilisation of working capital, collection of payments due, and overstaffing; inappropriate government interference.

- Lack of marketing management and sales promotion; insufficient product publicity, lack of market information and lack of retail opportunities and outlets. Packaging materials used usually suffer from lack of attractiveness and unsuitability to a good preservation of the products.

- Limited technical knowledge, skilled labour availability and adequate managerial skills. Lack of trained personnel, especially at the managerial level; lack of training facilities for middle-level manpower required for technological activities, industrial extension services and maintenance and operation of machinery and for graduates in food technology on practical experience.

- Inefficient links between industry, government and research.

XII. Conclusion

An important expansion of agricultural and fish processing in the developing world in general and in Africa in particular is foreseen in official projections such as those made by FAO and other institutions. Export of processed products from developing countries to the more developed is also forecasted to increase considerably. But more dramatic, will be the expansion needed to serve exploding city populations in the developing countries themselves. All these forecasts are the conclusions of several projections of population growth, food consumption and national development requirements. It is thus primordial to introduce new technologies and scientific methods of doing business in the processing of agricultural products so that the sector can become a powerful engine of development.

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