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INDUSTRIAL PROCESSING CONSIDERATIONS FOR THE CONVERSION OF GRAIN AND ROOT RAW MATERIALS INTO FOOD PRODUCTS IN DEMAND OF MARKETS*

by

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13

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INTRODUCTION

The world food problem is directly related to the degree of development of each country. Many developing states produce a variety of raw materials using agricultural practices that have not changed since hundreds of years, whereas developed countries have had a technological advance that allows them to harvest surplus of food. Not every state is able to adapt such large-scale technologies; besides the cost, it is rather difficult to change rural production habits, making this problem to continue. Developing countries have a structure of production different from that of the developed countries, and this has to be taken into account when selecting a technology.

Developing countries have high post-harvest losses, which are related as much to cultural-social phenomena as to physical, chemical and biological factors. The techniques of food conservation are frequently dictated more by traditional beliefs than by immediate utility. National efforts to reduce food losses cannot rely solely on technology or empirical data. Techniques and information must be culturally and socially acceptable if they are to be useful. Incentives are an important aspect of reducing food losses. Producers are unlikely to invest money or effort in loss reduction activities unless they foresee a good return, whether in income, security, or status.

In the same way, by-products utilization in developing countries has been poorly exploited; it is very important to take advantage of the large quantities of by-products generated in each agricultural practice.

There are appropiate or intermediate technologies that are more feasible for the developing countries, easier to be taught and implemented. Appropiate technology is a dynamic and flexible technology, designed specially for each specific situation, taking in consideration economic and social factors and considering the real possibility of application. Developing countries are different from each other, and therefore each one needs to study all available technologies to choose the most viable. A given appropiate technology may be the result of a combination between a highly specialized technology and a low-cost small-scale technology.

Each developing country has its own characteristics, problems, and idiosyncracy, so it is very complicated to generalize possible solutions as a whole. In order to propose solutions, each case needs special attention, and many factors, culture, socio-economic, political, religious, etc., have to bear in mind. The transformation in not easy, but it has to be done since the advent of modern technical opportunities can not be set aside.

Due to the magnitude of the raw materials and by-products processing, it is impossible to deeply treat every feasible alternative, and the following discussion is only related to some general ideas.

INDUSTRIAL PROCESSING CONSIDERATIONS FOR THE CONVERSION OF GRAIN AND ROOT RAW MATERIALS INTO FOOD PRODUCTS IN DEMAND OF MARKETS.

The most important cultivated grains in the developing countries are corn, rice, wheat, sorghum and barley, whereas among the roots, the main ones are cassava, yam and potatoes. A high proportion of the harvesting of these products are for the family's own maintenance, and are prepared according to traditional recipes; in many cases, such preparation is not, from a technological view point, adequate since produces either a poor nutritional food or a non-utilized wasteful material.

Another part of the grain and root production goes to industrialization to be transformed efficiently into other food products. Each grain and root has its own physical and chemical properties and therefore, it is rather complicated to homogenize the approach for its industrial conversion.

One of the main problems in the developing countries is a low harvesting productivity; such is the case of corn, which in Mexico and other countries is about 1.83 ton per hectare, whereas in the advanced countries is more than 3 ton/ha. It has been shown that if Central and South American states want to be self-sufficient by the year 2,000, then they should increase the productivity: corn from 1.83 to 2.84; wheat from 4.37 to 5.03; common beans from 0.55 to 0.99; rice from 3.57 to 4.61; sorghum from 3.08 to 5.89; and oleaginous seeds from 1.30 to 3.64. These increases are possible since they are normal values in developing countries, using better practices.

Mexico and other underdeveloped countries do not have an

adequate storage system and unfortunatelly post harvest losses reaches up to 40% in cereals and 50% in different fruits and vegetables. For this reason, it is very common to import grains and seeds, and in many occasions with different physical and chemical properties from the ones produced locally. The industry is usually located near the consuming centers and not by the producing areas; this situation increases the transporation cost as well as losses, which in turn increases the price of the final product.

The consumption habits have been changing and so the products in the markets; for instance, more flours and refined oils are consumed than before.

In order to convert grains and roots into food products, it must be necessary to condider the following:

a) Consumption habits. In many countries food preparation is very closed related to cultural, social and religious factors difficult to be changed. Many experiences have shown that when enriched and fortified products are introduced to rural areas, people do not accept them easily; in fact, most of them are completely rejected because they are different from what people are used to. Corn-soy flours with vitamins and minerals added, prepared by goverment agencies have been developed in Mexico and South American countries with very little success.

b) Nutritional effect in the population. If raw material is to be transformed and distributed, then it is a good opportunity to make a nutritional improvement with a better product; nutritional deficiencies common in Asia, Africa and America can be reduced if high quality foods are elaborated and sold in rural areas.

c) Characteristics of the raw material. Due to harvesting, storing, etc. conditions, the characteristics of raw materials may be different among rural areas. This can be a problem if highly mechanized techniques want to be introduced, which require homogeneity in the raw material; size, shape, solids content, microbiological load, etc. have to be considered in the design of the equipment needed to process such materials.

d) Technological requirements for the conversion. Developed countries sell "key in hand" plants, which are not necessarily adequate to underdeveloped countries. In this case, appropiate technologies are needed and therefore, national technological institutes play an important role in the selection, development, application and transfer of technology. It is necessary extension services, as well as professional engineers working on the design and manufacture of the equipment required for such industry.

e) Shelf life and easiness of use the converted product. Rural areas lack good storing facilities (e.g. refrigeration), and therefore products must be elaborated in such a way to mantain a reasonable shelf life under the prevailing climate conditions. In this sense, the so called intermediate moisture foods have many advantages and they may be a viable alternative; however, the longer lasting food products are dehydrated with a minimum water content. If water is needed to rehydrate, then the consumers must be informed on the quality of the required water, as well as the amount. To be consumed, the product should not require complicated procedures and should be prepared easily, according to the social and economical characteristics of the population. These considerations are even more important if such products are directed to children and elderly people.

f) Cost of production and selling price. There are many Government social-economic programs to produce different foods at a low price; in this case, the cost of production is not important. However, when private companies are involved, the price is usually higher. Each country has to decide in this sense, according to its needs and economical possibilities.

The following are some experiences in the raw material conversion that have been reported in different countries.

CORN

Traditionally, in Mexico and Central and South America, corn is consumed after a home lime-heat treatment (nixtamalizacion) which produces a dough used to prepare thin flat cakes called tortillas or arepas, as well as other basic foods. In Africa, corn is prepared boiled with no lime, and niacin deficiency illness (pellagra) is observed, which has been responsible for the death of many people. During corn preparation, some of the grain is lost and a lot of water is consumed and disposed, contaminating rivers and lakes; every day is more difficult to obtain enough water.

In some maiz-consuming countries, Government agencies and private investors have installed industries to convert corn into a ready to use flour. This is also a lime-heat treatment, but more efficient which reduces cost and wastes. Even though it has many advantages over the traditional transformation of corn, these industries have grown slowly since it is difficult to change consumption habits.

Since corn is deficient in several amino acids (e.g. lysine

and tryptophan) and vitamins, it is easier to add these nutrients to the flour; in this way, fortified high quality corn can reach needy people.

It is very important to consider that the industrial conversion of corn into a flour should be done following the same basic steps of the home lime-heat treatment. This is so since this procedure liberates the low niacin content and makes tryptophan more biologically available; both transformations avoid pellagra.

RICE

Traditional rice milling removes a high proportion of the bran and husk rich in oil and many of the vitamins B. Several Asian countries only fed on polished rice are susceptible to beri-beri disease caused by a thiamin deficiency. Vitamin B retention increases when rice is parboiled through the following steps:
a) cleaning and soaking the rough rice to 30% or more moisture; b) steaming the soaked rice; c) drying the steamed rice.

The main transformations are: a) starch is gelatinazed by heat in the presence of water; b) protein denaturation; c) enzyme inactivation; both bran and germ contain oil and enzymes, such as lipases and peroxidases, that cause the lipid fraction to spoil within a short time; d) soaking removes foreign material and microbial contaminations; e) increases resistance to insect attack; f) less bran is lost during milling; g) more oil, vitamins, minerals and proteins are retained.

Parboiling is practiced in India and Bangladesh and in some

African countries, but very little in Mexico and South America, except Colombia. People fed on parboiling rice show less beri-beri disease.

YAMS

Yams belong to the genus Dioscorea, such as D. rotundata, D. cayenensis, D. esculenta y D. alata, and are traditional tropical crops. Yams, as well as cassava, plantains, taro and sweet potatoes, are an excellent source of carbohydrates such as starch. Yam has a higher cost because it demands good soil, attention in all stages of growth, staking, and about 25% of the crop is utilized as a planting material. About 90% of the production in the world comes from West Africa.

Yams have been industrialized very little; however, many attempts have been carried out: fried products, chips and french fries, have been manufactured in Puerto Rico; Nigeria, Ghana and Jamaica have canned yams with little success, due to the breaking up into pieces and the liberation of gelatinazed starch into the brine during the heat treatment; in other countries has been used incorporated in bread and in some flours.

The main industrial yam transformation is the dehydration using drum-dryers to produce instant flakes capable to rehydration to yield the desired product without further preparation. Factories such as these are installed in Nigeria, Bardados and Puerto Rico.

The following are the main steps in the dehydration of yams: 1.- Sorting. 2.- Washing. 3.- Peeling; hand peeling is labor

intense and sometimes wasteful since it may involve up to 30% losses; mechanized peeling is difficult to apply because of the irregular shapes and sizes of the tubers; lye peeling, chemical and thermal action is a more effective option using 10% lye and 104 C. 4.- Cooking; it may be carried out at atmospheric pressure or under steam pressure of 5 to 10 psig. 5.- Mashing. It is done to produce a slurry of about 15% solids. 6.- Drying. Using a single or double-stage drier; not all varieties gives a fluffy product acceptable in some markets; a blue value index of about 100-140 and a moisture content between 2 and 4 are desired. 7.- Packing. In plastic bags or in carboard cartons.

In some cases, precooking (before cooking) is also done when a non-sticky product is desired; it lowers the amount of starch damaged in the final product; 71 C for up to 25 minutes cause partial starch gelatinization and so conferred resistance to further damage during processing.

CASSAVA

Most of the cassava varieties contain hydrocianic acid, and for this reason this crop has been diveded into two groups: bitter poisonous species (Manihot esculenta y Manihot utilissima) and sweet non-poisonous species (Manihot dulcis, Manihot palmatta y Manihot aipi).

This crop is a basic food in many tropical countries and contributes to fulfill the carbohydrate needs; South America (e.g. Brazil) and Africa are the main producers. In some countries it is used for the production of starch and ethanol through a fermentation.

Due to its hydrocianic content, cassava roots have to undergo

a detoxificacion through one of the known procedures; after this, cassava is converted into a flour using a similar process to that of the yam flour production. The flour is used in the preparation of different typical foods. It is also utilized as an important carbohydrate source in several animal feed preparations.

INDUSTRIAL PROCESSING CONSIDERATIONS FOR THE CONVERSION OF OIL-SEEDS AND OIL FRUITS INTO EDIBLE OIL AND PROTEIN ANIMAL FEED COMPONENTS

There are many seeds and fruits used in the developing countries for oil extraction; the following are the most important: olive, sesame, cottonseed, peanut, cocoa, safflower, coconut, colza, sunflower, palm and soybean. Their oil content varies with many factors, but in general goes from 18% up to 50%.

Oil production in underdeveloped countries is poorly mechanized, and the main product is crude oil; part of this is directly consumed and a low proportion goes to a secondary process, such refining. There are two main operations to obtain crude oil: the most sophisticated utilized in the developed countries through solvent extraction, and the one used in the developing countries consisting in a expression by screw-presses. In Asia, Africa and South America, the technologies employed are 8 to 10% on the village scale, 45 to 55% in small scale expellers, 25 to 30% in the medium to large-scale expellers, and 12 to 18% in solvent extraction.

Many countries depend heavily on the oil processing industry. The economy of the Ivory Coast and Malaysia is in part supported in the palm oil, and in the Philippines a large population works in the coconut industry. For this reason, it is very important to produce oil in the most adequate conditions; producers and consumers will be benefited if this industry, as a whole, improves through technological advances.

The industrial processing considerations that have to be

taken into account vary with many factors, but the important ones are as follows:

a) Organization of the small producers. In developing countries, most of the raw material comes from small-scale producers; collecting, transportation and distribution play an important role in assuring a continuos flow of raw material into the extracting industry. With such organization many socio-economical benefits are reached. The plant location is another factor to consider, but it depends on the location of the small-producers.

b) Efficient use of the native raw materials. Oil containing crops are very labile due to different oxidative chemical reactions; the producer has to know easy to apply procedures to keep the material in good conditions until it is collected. If not properly handled and stored, oil may go through lipolytic and oxidative transformations that reduce the commercial value of the raw material.

c) Use of the appropiate technology. The selected technology should fit with the characteristics of the raw material, the products to be fabricated, the available facilities, the estimated budget, etc. If exportation is the goal, then chemical and physical characteristics of the final product should be considered in selecting the technology. In general, solvent extraction is more efficient than screw-presses; there are different scales for both the batch and continuos solvent extraction procedures, ranging from 50 to 200 tons of crops per day. The type of solvent is very important since many of them are toxic and explosive if not handled carefully. This type of installation usually requires trained staff, as well as a good plant maintanance; if necessary, people should be properly prepared before operating the equipment.

d) Size of the industry. As in most of the industrial projects, the oil industry shows an economy of scale, and consequently many factors have to bear in mind to decide the optimum size. Large processing factories imply centralization of activities, more employees, etc.; on the other hand, many small-size industries are more difficult to be coordinated, and the production costs are usually higher than large companies. The bigger the plant, the more trained people are required.

e) Complete use of installed capacity. It has been observed that in many developing countries, there are oil-extracting industries working at a very low capacity. It seems that raw material is not available or the designed capacity was wrong; in some cases, the problem is an inefficient selling system that is unable to sell all production. Before building any industry of this type, it is important to verify the installed capacity and the level of use.

f) Adequate use of by-products. Many of the oil-containing crops are also rich in proteins; the oil-free cake or meal can be utilized to prepare and enrich typical human foods, or to elaborate animal feeds. If by-products want to be used, then more attention should be paid to each step of the process; for instance, the cake must be free from solvents and any foreign material.

The following are some considerations for few specific oil-bearing materials:

PALM

In terms of yield per acre, the oil palm is the most efficient of all edible oil-producing plants; adding the palm oil (3,300 lb/acre/year) and palm kernel oil (370 lb/acre/year), gives a figure of 3,670 lb/acre/year, which is larger than that of coconut (1120), groundnut (780) and soybean (340). The biggest palm plantations are located in West Africa but used for self-consumption; on the other hand, in Southwest Asia, mainly Ivory Coast and Malaysia, is produced most of the commercial palm oil consumed in the world.

Most industrial processing mills have a capacity between 20 and 30 tons/ hour of fresh fruit; the following steps are involved:

a) sterilization of bunches to destroy enzymes (lipases and peroxidases); it also softens the fruit and loosens it on the bunch. b) Separation of the fruit from the bunch using a horizontal rotating cylinder. c) Digestion and mashing of the fruit. d) Milling with screw-presses; the produced oil contains vegetable material and water which must be removed. e) Refining of the crude oil through the traditional steps: degumming, neutralization, bleaching and deodorization.

During this process a palm kernel cake rich in protein is also produced; mixed with some carbohydrate sources (e.g. yams), the cake is used in animal feeding.

Refined palm oil is every day more important in the world; many countries of the European Economic Community use this oil for margarine manufacture, as well as other lipid derivatives.

SOYBEAN

Even though the commercial value of soybean has been related to its oil content (18 to 21%), its deffated residue or cake is highly demanded due to its high quality protein. In some countries, this cake is used to prepare animal feeds; however, its use for human consumption is increasing. In Asia, soybean has been consumed for centuries in different forms, including the feremented one called tofu. In other parts of the world, soybean is rejected because its flatulence production and its antiphysiological factors; however, there are many available technologies to eliminate both inconvenients.

RICE-BRAN

Rice milling produces from 7 to 8% of bran with a 18 to 22% oil content. In the underdeveloped countries there are many small rice mills which produce bran that spoils rapidly because a lack of an adequate stabilization method. Once bran is oxidized its commercial values is very low. There are different appropiate technologies to mantain bran in good conditions until is recollected; unfortunately, such procedures have not been applied to rural areas, and bran keeps on spoiling.

COTTONSEED

Cottonseed oil is extracted with a low yield because the seeds are not properly treated. They need to be crushed, decorticated and the hulls separated. It is also recommended to cook the meats to increase the yield of oil, as well as the quality.

COCONUT

In some Asian countries, coconut oil is obtained from the fresh meat, whereas in South America and Europe, from the dried meat, called copra. Because of a lack of good processing conditions, copra is usually contaminated with fungus having a strong lipolytic activity; if this happens, the quality of oil and the cake is reduced. Sun-dried copra should be properly processed to reduce such contaminations. Extension services can be of a great help in teaching proper techniques to the producers.

AVOCADO

So far, avocado oil is only fabricated for the cosmetic industry; however, it may become an important source of edible oil. Mexico is one of the first avocado producers, but with post-harvest losses that goes up to 20% of the total national production. About 80% of the Mexican avocado is harvested in a small and well defined geographic area. Avocado losses represents about 40,000 tonnes per year, which in turn, would generate approximately 4,000 tonnes of oil; this amount is far beyond the cosmetic industry needs. Avocado oil could be an important product since its physical and chemical properties are very similar to those of olive oil.

INDUSTRIAL PROCESSING CONSIDERATIONS FOR THE OPTIMUM UTILIZATION OF RAW-MATERIALS, BY-PRODUCTS AND RESIDUES IN THE PRODUCTION OF ANIMAL FEED AND ITS PROPER UTILIZATION

Providing food for the world has become more vital than ever. There is an apparent struggle for nutrients between animals and men; nevertheless, with adequate planning a balance is established and a proper cycle land-animals-man would be sufficient to fulfill all needs, as shown in the attached figure. Animals are an excellent source of proteins, but unfortunately are scarcely consumed in the poor and developing countries of Africa, Asia and America.

On the other hand, agriculture practices produce by-products that are eaten either by man or animals; however, some of these materials are only utilized by animals. For instance, Mexico produces approximately 100 million tons of by-products and residues that can be used for animal feed (see attached table); this amount has an energetic potential for the ruminants equivalent to 35 to 40 million tons of grain sorghum; much of this material is burned, disposed in lakes and rivers, or incorporated to the land, without taking advantage of its nutritional value.

Many extensives studies of the nutritional requirements of animals have led to the development of nutritionally balanced feeds; not only protein, carbohydrates, lipids, minerals and vitamins are required, but also stimulators or accesory factors that improve the rate of growth and amount of growth per unit of food.

There are advanced technologies as well as intermediate or appropiate technologies to produce animals with a rapid rate

of growth; this allows the producer an early marketing and a rapid investment return.

Among the industrial processing considerations, the following are the most important:

a) Determination of the nutritional value. Every material has a different proportion of nutrients and this must be established through a proximate analysis (e.g. total protein fat, ashes, total carbohydrates and fiber). This information is not enough to know the nutritional value, and therefore tests as digestibility, protein efficiency ratio, total energy, metabolized energy, vitamins, and others must be done. Besides these analysis, some specific tests are also important in order to determine antiphysiological factors in certain by-products that may affect a kind of animals; for instance, tannins in grain scrghum, gossypol in cottonseed, trypsin inhibitory activity in soybean, etc.

b) Raw material quality and availability. Raw materials and by-products must be free from foreign material and dangerous compounds, such as solvents; they should be treated properly to reduce contaminations, as well as chemical reactions that can spoil them. In order to design an industry, it is very important to know the amount and characteristics of the raw-material. Some crop by-products are only produced once or twice a year, whereas others may be available all year long.

c) Nutritional requirements of the animal. Not all animals have the same nutritional needs; some may utilize a given by-product while others not. Ruminants (cattle, sheep, goats, deer, etc.) and non-ruminants (poultry, swine) require specific formulations for an optimum growth; even the members of each one of these groups present differences in their

necessities. Breed, sex and age are, among others, important factors to be considered in designing a correct diet.

d) Human food versus animal feed. Some by-products, such as those coming from legume processing (e.g. vines, stems, straw, leaves and pods) are edible for man, but also they can be given to animals. Other raw-materials traditionally utilized as animal feed can be used for human consumption, if properly processed. Soy-defatted cake is rich in proteins, and in many countries it is an important part of daily feeding; however, it is also an excellent product to elaborate different high quality human foods. For this reason, many countries are now producing soy-cake enriched foods. It is important to remenber that the rate of conversion of vegetable protein into animal protein is very low, whereas in man such rate of conversion is very high.

e) Location of the by-products. In order to reduce transportation costs, it is important to locate the feed industry near the place where the by-products are generated. Straw and many other residues are very bulky, and some are liquid; their transportation may implicate a high cost if the plant is located far away. Besides this, the industry should be prefentially closed to the consuming area.

f) Appropiate technology. Animal feed production may be carried out in small scale industries scattered all over the developing country. Large scale plants may also be an alternative if a cost-benefit study shows their viability. By-product production is not usually concentrated in a small region, but distributed in the whole country. Extension services should help small producers in using by-products to elaborate feed for the growing of their own animals.

There are many available techniques for small-scale producers; for instance, silage comprises essentially chopping and packing raw materials into a storage container, usually a pit in the ground, and allowing fermentation to take place with the production of lactic acid. The microorganisms present in the packed material, the supply of fermentable nutrients (e.g. carbohydrates such as starch or sucrose), the pH and the oxygen availability, determine the quality of the silage produced. Straw contains a high percentage of cellulose and lignin which are not easily utilized by the animals; a partial breakdown or hydrolysis of these compounds is necessary and for this reason ammonia or sodium hydroxide are used, preferentially at high temperature.

A proper combination of different raw-materials and by-products can make a good feed: 50% chopped corn straw, 25% molasses, 13% corn flour, 10% sorghum, 2% urea, phosphorous rock and sodium chloride.

The above feeds may reach a nutritional value of 80 to 90% of that of a commercial concentrated, but only a low cost of about 60%.

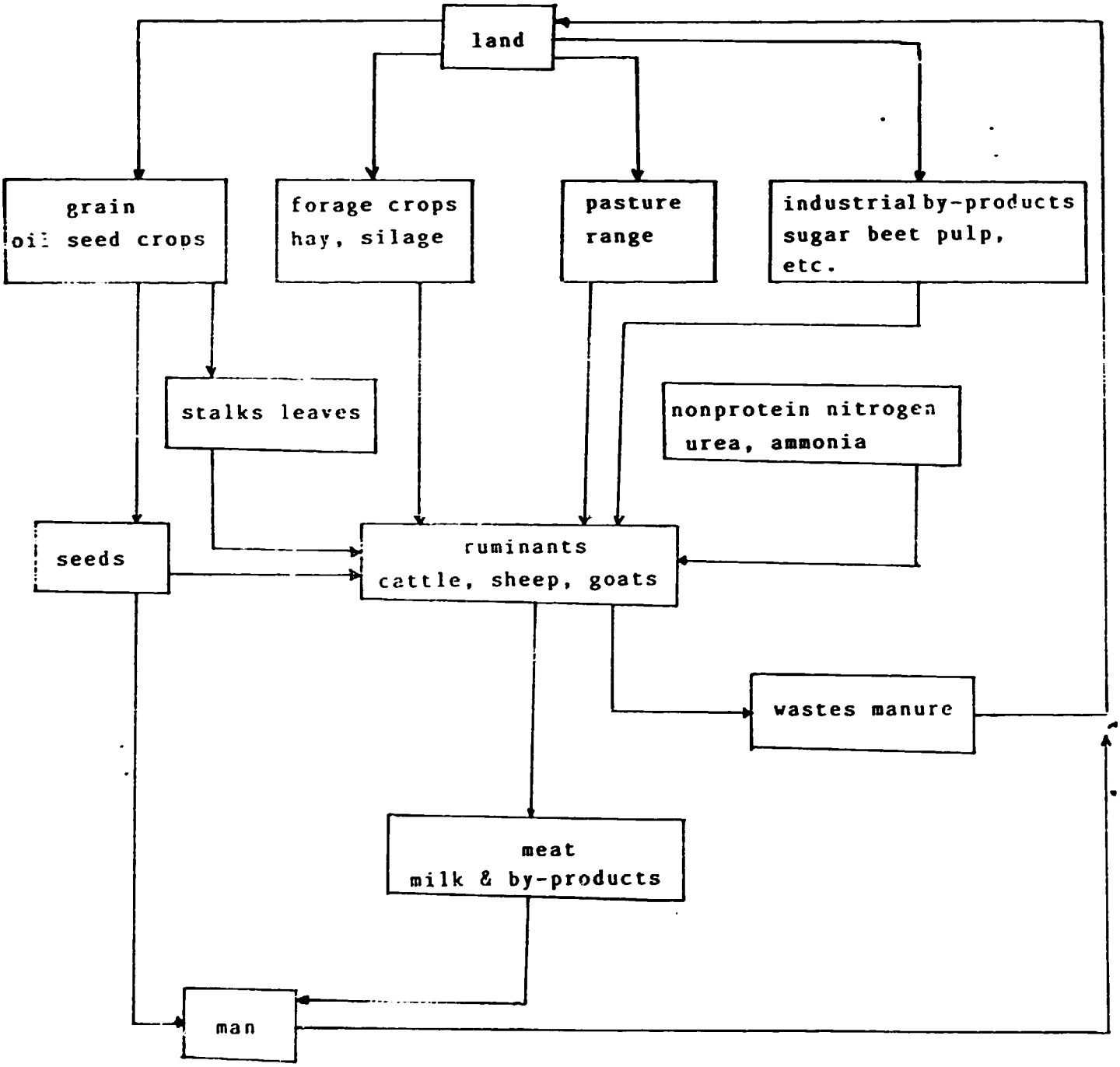
In recent years the sugar industry has declined due to the development of new sweeteners that offer, in many cases, more advantages than the traditional sucrose. It is very important to create new uses of sugar as well as the by-products generated. A sugar mill processing 1,500 to 2,000 tonnes of cane daily produces a bagasse surplus of 10 to 25% beyond its own fuel requirements. Chopped, bagasse can be used for animal feed; however, it is also utilized to fabricate paper, textile fibers, cellulosic derivatives, fiber boards, furfural and others.

The liquid residue from the process of sugar cristallization, called molasses, is very rich in fermentable carbohydrates and some countries use it with large-scale technologies to produce single-cell protein (for animal feed), ethyl alcohol and dextrans.

Soapstock is the residue obtained from the alkaline refining of vegetable oils, it contains a saponified fatty acid fraction, a phosphatide and sterol fraction together with some of the pigments of the oil; it is a high energy source for animal feeds.

Offal (heads, feet and viscera) from the poultry industry may be converted into a highly digestible feed product; it may be also combined with blood and feathers. There are large-scale and small-scale technologies to produce proper feeds according to the needs of each animal.

THE CENTRAL ROLE OF RUMINANTS IN HUMAN NUTRITION



PRODUCTION OF BY-PRODUCTS AND RESIDUES IN MEXICO

Material	Tons	Quality index
corn straw	48,000,000	3
sorghum straw	6,000,000	3
wheat straw	3,500,000	2
tops of leguminous plants	7,300,000	4
waste pulp of cane	11,000,000	2
cane low molasses	1,300,000	4
poor wine	220,000	3
citric pulp	35,000	4
hen droppings	4,500,000	4
henequen pulp	40,000	4
waste pulp from tequila	250,000	4
waste pulp from marigold	6,000	3
waste pulp from beer	40,000	4
rice wastes	103,000	2
soybean hull	80,000	2
millet	100,000	4

Quality index:

4 = Excellent
3 = Good
2 = Medium
1 = Low