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THE ANIMAL FEED INDUSTRY FOR DEVELOPING COUNTRIES

Background paper*

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1. The animal feed industry as an important factor in development

The animal feed industry is an important market for agricultural and agro-industrial by-products and residues which it uses as raw materials for the production of a great variety of animal feedstuffs. Animal feed, in turn, is the basis for the organization of efficient animal husbandry in developing countries. The animal feed industry, therefore, has a considerable role to play in agro-industrial development.

1.1 An instrument for agro/food industrial integration

Animals have always played an important role in human life. In many communities, animals are the background for their existence. They supply food and clothing and the basis for human well-being and even wealth.

Over centuries, goats, cattle, sheep, etc. were led to the open country to feed on grass, plants and fruits. Also considerable farm land was used for growing feed plants and feed grains. In some areas such practices are still common but for many reasons pasture land has become rare and the available farm land is not even sufficient for the production of grains and fruits for human consumption. The importance of farm animals for human life, however, remains unchanged in most developing countries.

In light of this situation, many by-products of the agro-based industry have been found suitable as animal feed. Each by-product, in itself, may not have a very high feed value but appropriately composed and mixed they give an excellent feed product. For appropriate formulation, blending and mixing an animal feed industry is required. The animal feed production sector, therefore, is the link to other agro-based industries, the productivity of which may be increased because their by-products receive an added-value and raw materials will be utilized to a greater extent.

The human population is increasing and more and more food is required. Human food is not only based on agricultural products but also to a large extent on meat, milk and eggs which are animal products. A decrease in farm animals due to lack of feedstuff also means a decrease of human food supplies. The only solution to these problems appears to be changes in the animal husbandry situation by setting-up "industrial" animal ranching systems in developing countries. A pre-condition for such changes is certainly the industrial production of animal feed.

As the relationship becomes visible between the animal feed industry and other agro-based industries with regard to raw material (by-product) supplies, it becomes evident that an animal feed industry has an important role to play in future food production and supply programmes of developing countries.

The animal feed industry, therefore, greatly stimulates agro-industrial development and holds a key position to the future animal-based food production and supply sector of developing countries. It should, therefore, receive special attention.

1.2 The relationship between the animal feed industry and other agro-based industries

The animal feed production sector provides the market for a number of agro-based industries.

The vegetable oil industry (oilseed processing industry) produces vegetable oil and oilcakes by mechanical pressing and extracted meal by solvent extraction. In order to make a vegetable oil factory economically feasible, both products, namely oilcakes/extracted meal and the vegetable edible oil, have to be sold. Normally in developing countries a considerable market demand exists for edible oil. However, in the absence of a local animal feed industry no market exists for oilcakes/extracted meal despite the fact that these are valuable protein animal feed components. To enter the international export market means competing with soya meal which is most difficult if not impossible to be met by vegetable oil factories in developing countries. On many occasions, despite high local market demand for vegetable oil and available oilseed raw materials, the establishment of a vegetable oil factory was not feasible because there was no local market for the oilcakes. No animal feed industry existed to buy and utilize the valuable oilcakes as a protein animal feed ingredient.

A further very important supplier of animal feed raw material is the grain milling industry producing flour and bran. In many developing countries the bran is directly fed to animals; it would, however, be better utilized as a carbohydrate component in mixed feed. An existing animal feed industry would provide a secure bran market for the flour milling sector and both the animal feed producer and the grain miller would profit from regular supplies and less fluctuating prices.

Considerable quantities of spent grains become available from the beer brewing industry. These spent grains are a valuable animal feed ingredient but remain largely unutilized. They have to be dried which is an expensive process. Spent grain-drying may, however, become economically feasible, together with a secure local market for dried brewers' grain as an animal feed ingredient. Again the animal feed industry may prove to be an important local market for an agro-industrial by-product with a strong development (dehydration technology and economy) aspect.

Another important sector of the agro-based industries with considerable dependence on the animal feed industry is cassava processing. Cassava is abundantly available in most developing countries but remains largely unutilized in industry. For many reasons, the utilization of cassava for the production of human food is limited although it offers a potential as a carbohydrate raw material for the animal feed industry. Let us recall in this context the very large quantities of cassava chips or pellets produced in Thailand solely for exports to European Community (EC) countries for use in their animal feed production sector. At the request of the EC, the exports had to be reduced and eventually ceased because of an excess of feed grains produced by the EC itself. This example shows that the animal feed production sector is in a position to stimulate agro-industrial (cassava) processing operations to a very large extent and is also able to abandon them with all the economic and social consequences involved.

Let us look at the fish processing industry. A high percentage of the catch is frequently wasted (heads, tails, bones, small fish, etc.). These waste materials are high value protein components in mixed animal feed if appropriately processed to fish meal and dried. But who would set up the necessary milling, pressing and drying equipment for the production of quality fish meal if there is no market for the final product? The market would be the animal feed industry and in its absence and lacking export opportunities, large quantities of fish residues would remain unused causing environmental and other problems.

The same applies to organic factory wastes from the fruit and vegetable processing industry. Masses of peel accumulates from citrus juice production. The disposal costs are considerable and the rotting peels cause ecological and pollution problems. Suitable technical and economic drying methods and the addition of small amounts of lime would turn the peels into feed for cattle of high nutritional value. This example again shows the importance of the animal feed industry as an instrument for the improvement of the production economy of other agro-based industries and their interdependence becomes visible.

The above illustrations show the important relationship between the animal feed industry and other agro-based industries which should find due consideration when planning the establishment of animal feed production plants.

1.3 Processing of by-products and residues

Most of the agro-industrial by-products and residues - although valuable for the production of animal feed - cannot be used directly as feed raw material as they require intermediate processing, the most important of which is dehydration.

The producer of the by-products and waste materials will only process it if it is profitable and/or does not negatively affect his overall cost/price calculations. And here is a serious problem. Unfavourable financial calculations have often prevented producers and users from preparing valuable agro-industrial by-products and residues for the production of animal feed with the result that no animal feed production plant was established despite the urgent need for the country and its population.

Let us look at this problem from the technical and economical viewpoint. The most important technology for the preparation of feed raw materials is dehydration and there also appears to lie the problem. Drying requires energy and energy is costly if it cannot be drawn or recovered from the main production process. Technological development work is, therefore, urgently called for especially with regard to the production and use of cheap energy. Direct sun-drying methods may have to be more effective and the use of solar energy may soon lead to solutions. Solar energy generation systems are indeed on their way and one may expect important developments in the near future. On a case-by-case basis technological development work needs to be carried out, sponsored and promoted in view of the definition of technically and economically efficient dehydration methods, the industrial utilization of which will greatly favour the production of animal feed from local raw materials in developing countries.

When looking at the problem from the financial viewpoint, it appears that in many cases public support is needed with regard to taxation, loans and interests in the animal feed development sector. Public support in this context may also be seen politically. It would facilitate the establishment and operation of animal feed production and utilization systems in the interest of a country's national economy.

1.4 The feed value of agro-industrial by-products and their utilization for the production of animal feed

Animals fed "naturally" on grass normally have a balanced diet because of the variety of plants they eat. The "artificial" feeding of animals with industrially produced feedstuff has to accept this fact by tailoring the feed products to the nutritional requirements of the animals to be fed. This is the basic philosophy of industrial animal feeding.

Agro-industrial by-products and agricultural residues have distinct feed value criteria. They are either rich in protein or in carbohydrates and in many cases, are a mixture of both. There is roughage material which is a' o a very important animal feed component especially for ruminants. All these different raw materials have to be appropriately composed to result in an animal feed product which is different for pigs, poultry, beef cattle, milk cattle, etc. An attempt has to be made - and this is not really scientific feeding - to give the different animals the feedstuff they need for a healthy life useful to the holders.

The production of compound animal feed, therefore, requires a good knowledge of the feed value of the raw materials. The feed producer has to know the exact composition (protein, energy vitamins, etc.) of the raw materials to be processed in order to produce a defined feed product of value and constant quality. The most appropriate feed formulation if of great importance and it is strongly recommended that expert advice be sought at the planning stage of an animal feed factory.

The raw materials used for animal feed production purposes may generally be divided into three groups, namely, roughage, concentrates and supplements.

Roughage, in principle, is fibrous material and can be drawn from agricultural residues predominantly dried. It is essential for feeding mature ruminants.

Concentrates are the actual suppliers of protein and energy. They can be a complete feed for monogastric animals or immature ruminants. Raw materials for the production of concentrates may be cereals and their by-products (brans) such as wheat, oats, barley, maize, sorghum, millet, rice, etc. Further, oilcakes and/or extracted meal from various oil seeds, starchy roots and tubers (cassava) and by-products of the animal-based and agro-based industry such as fish-, meat-, bone-, and blood meal as well as molasses, whey and brewers' spent grains, dehydrated grass, lucerne meal, etc.

Supplements are essential minerals as for example sodium chloride, calcium carbonate and trace elements such as metal salts, vitamins A, B, D and E, antibiotics and sometimes essential amino acids such as lysine

and methionine to correct possible protein deficiencies. Supplements are very often used in the form of ready-made pre-mixes.

1.5 The utilization of compound animal feed

Let us face the fact that compound animal feed is expensive and the more varieties produced (scientific feeding) the more expensive it becomes. Utilization of compound animal feed, therefore, requires special feeding techniques in order to meet economic requirements. Very careful rationing is necessary and correct and timely feeding plays a role as well as the number of meals given to the animals per day.

One should remember that the production of compound animal feed was introduced and established primarily in industrialized countries in order to meet the requirements of industrial animal raising systems. The animals (poultry, pigs, etc.) are held in specially-designed stables which they never leave during their life and in this context feeding means to facilitate the quickest possible growth or the largest possible number of eggs or quantity of milk. Without any doubt, the system has succeeded so far in the industrialized world. It may be questioned for many reasons but it works technically and economically well.

The question now arises "Is the production of compound animal feed and its appropriate utilization also suitable and profitable in developing countries? Yes, it may well be suitable and also profitable but only in connection with adequate animal raising and holding systems which doubtlessly also exist in developing countries but are still the exception rather than the rule. In many developing countries, well-organized poultry farms exist and for the efficient functioning of such farms compound feed is necessary. Also some well established sheep and pig raising systems are operational. For such systems, compound feed may not be absolutely necessary if other feedstuff are available in sufficient quantity and quality. The use of compound feed would, however, give food security and increase production efficiency.

In some developing countries cattle, traditionally fed on grass, wander long distances in search of new forage and by so doing get further and further away from existing slaughtering facilities. Eventually - normally at the end of summer or the rainy season - they have to be brought back to their base at which time the natural green forage has become rare. On their way home, the animals lose their accumulated weight with the result that their meat is of low quality and marketing becomes difficult. It goes without saying that at least periodical feeding with compound feed would be very advantageous.

However, the use of compound animal feed in the traditional way of feeding animals on a small- or large-scale is not feasible. The feeding of poultry or other animals on open land is certainly not useful and would be highly inefficient and uneconomical. The efficient use of compound animal feed is based on certain conditions which have to be created in the animal raising sector. Industrial ranching systems have to be established, well organized and controlled in all aspects which include animal housing, animal hygiene and health, manure disposal, milking, slaughtering, etc. and, last but not least, appropriate feeding. In such systems, the use of compound animal feed is not only useful but essential.

The production and use of industrially-produced animal feed in developing countries is very important. Modern animal holding systems will increasingly be found in developing countries and time is working in favour of production and use of animal feed compounds. Animal feed, however, is needed now for immediate production and use. Immediate solutions to the animal feeding problem in developing countries will have to be found without losing sight of the smaller or larger scale industrial production of animal feed concentrates, the future broad utilization of which remains the aim.

1.6 The revalidation and utilization of agricultural residues for animal feeding purposes

Domestic ruminants need not compete with man or monogastric animals for nutrients. Their unique digestive and metabolic apparatus enables them to utilize roughage and similar "low value" feed which others cannot. This ability is an important factor for their survival and their value to man as a food source for the years to come.

Considerable quantities of roughage (straw, etc.) are available from agriculture which may often cause a disposal problem. This poor quality forage is a remarkable feed for ruminants if appropriately prepared. Straw should be chopped or milled which increases the voluntary intake of the animal. The utilization of poor quality forage may further be improved by chemical treatment. Sodium hydroxide treatments will considerably increase the digestibility. Chopped straw should be soaked in a sodium hydroxide/water solution (up to 6% NaOH) and then pelleted. No washing should take place and the pellets should retain all components.

The same method may be applied, for example, to whole cottonseed from small gins where no commercial disposal is possible. Also groundnut post-harvest residues or the pods and browse from leguminous trees such as locust beans are useful feeds.

Another underestimated feed is corn cobs for ruminants. Corn cobs are treated with calcium hydroxide by soaking them in a 3% Ca(OH)2/water solution for 24 hours. The treated corn cobs may be mixed with rice bran or oilcake (cottonseed)/meal, and is reportedly even suitable for dairy cows.

A number of other agricultural or post-harvest residues may be available for use as ruminant feed with or without alkaline treatment, and efforts should be made to study existing situations on a case-by-case basis.

1.7 The animal feed industry and the environment

The animal feed industry does not cause pollution if appropriately managed. There may be some dust problems during the milling process but this can easily be brought under control. On the contrary, the animal feed industry may considerably contribute to a clean environment by using agro-industrial wastes for the production of quality feed which may otherwise cause environment problems. Let us look at the large quantities of rice bran from small-scale rice milling operations which often remain unused and are piling up on river banks or are thrown into

rivers. Rancid rice bran may easily become a threat to the environment and a breeding place for insects. By-products from the sugar industry (diluted molasses) and fruit processing residues (peels) may also cause an environment problem in seasonal peak operations. The animal feed industry can use such products as raw materials and could even become a party to environment protection exercises.

2. Large-scale production of compound animal feed

When discussing the animal feed industry in connection with development, one cannot ignore the large-scale animal feed industry which has become a very important branch of the agro-based industry in the industrialized world. Some of its principles shall, therefore, be considered in comparison with the developing animal feed production sector in developing countries.

2.1 The market-oriented approach

Like any other industry, the animal feed industry in developed countries is guided by its market, the animal production sector. The market-oriented approach is clearly visible. The market calls for products and the industry tries to satisfy demands. So a great variety of feed products have been developed and are being produced. Based on scientific feed formulations, feed products have been designed especially for both young and mature animals, for ruminants and monogastric animals, for milk cattle and beef cattle, for laying hens and meat poultry, etc. Each feed product has the optimum feed value and the growth and productivity of the animals highly depend on it. A market-oriented production once in progress, however, cannot easily be slowed down or stopped and overproduction may occur with all its consequences. It is certainly beyond the scope of this paper to discuss this in further detail.

2.2 Feed raw materials

All feed raw materials are commodities and may be ordered to world market prices which more or less fluctuate. One should recall, in this context, that large agricultural and agro-industrial programmes have been developed and also implemented solely for the production of the animal feed raw materials in demand. A very good example is soya beans which are not being grown for the production of vegetable oil but primarily for the production of soya meal which is an excellent plant protein product most suitable for animal feeding because of its well-balanced essential amino acid composition.

As was mentioned earlier in this paper, the animal feed industry is in a position to greatly stimulate agro-industrial development. The best proof is the existing animal feed industry in developed countries.

2.3 Feed formulation (scientific animal feeding)

It is not within the scope of this paper to enter into detail of scientific animal feeding but it is an unquestionable basis for the most effective production and utilization of animal feed and some remarks are, therefore, necessary.

Animal food consists of three groups of substances, namely, **carbohydrates** and **proteins** plus **vitamins** and **minerals**.

Carbohydrates are generally divided into sugars (glucose and sucrose) and starches. In addition, fibrous material is important as are oils and fats, which are an important source of energy in animal feed. The energy value is about twice as high as that of starch. Fats are fatty acid glyceride and a supplier of fatty acids which are essential for the metabolic process of animals.

Proteins are essential for growth and replenishment of animal tissue and, therefore, particularly important for young growing animals. The quality of protein is determined by the proportion of the essential amino acids contained therein.

Vitamins are substances which facilitate the function of certain enzyme systems. The intake of vitamins by the animal in sufficient quantity is essential for the body metabolic process and the nervous system. Vitamins are divided in fat soluble (A, D, E, and K) and water soluble (B and C).

Minerals form about 3 to 5 per cent of the body weight of animals. They are available in the skeletal tissue and also in the body fluids. The most important minerals are the salts of calcium, phosphorus, magnesium, potassium, sulphur, sodium, iodine and fluorine.

Scientific feeding of farm animals should aim at obtaining optimum yields of milk, eggs or meat by feeding appropriate quantities (rations) of feedstuff which is formulated to provide the correct quantity and proportions of the above-mentioned feed components to the animal.

Feed formulation, therefore, requires in-depth knowledge of animal digestion and the digestibility of feedstuff, and the knowledge of the nutritional requirements of different animals. This sounds more complicated than it actually is because the composition of the various feed products has been determined and is available to all interested. Publications exist on most issues of scientific feeding.

The animal feed producer only has to know what types of animal and what age have to be fed with his feed product and - this is important - he has to use the appropriate feed raw materials in order to produce a final product with the required protein, energy, vitamin and mineral content so that optimum yields may be obtained on milk, eggs, meat, etc.

2.4 Storage, production, automation and computerization

Storage of raw materials plays an important role in large-scale plants and is an important cost factor. The production process is fully automatic and the various production stages are interlocked so that a breakdown in the continuous production process automatically stops the relevant sections of the production plant. Computerization has become an important factor in the production process. Computers constantly control the composition of the end product by re-adjusting and regulating the quantity of the raw material input especially if changes in the various raw material components become necessary. The production technology is otherwise no different from non-automatic, medium- or

small-scale animal feed production plants and in principle consists of grinding, blending, mixing, pelleting, cooling and bagging.

3. Small-scale manufacture of compound animal feed

In developing countries the establishment and operation of medium- and small-scale compound animal feed production plants should receive special attention. Smaller scale operations will better meet with a raw material supply situation and with existing market requirements and will still favourably influence the animal holding and production sector.

3.1 Market-oriented or raw material-oriented approach

Would the market-oriented approach be appropriate in the small-scale animal feed production sector of developing countries? The market (users of animal feed) is still quite different from the market in industrialized countries. With few exceptions, no animal feed market exists which would be in a position to demand from the industry the production of specific feed products. Without any doubt there is a tremendous need for animal feed but functioning local animal feed markets still have to be developed.

Considering this situation one comes to the conclusion that - at present - the raw material approach will generally be valid. The first question to be asked would be "What raw materials can be made available and what types of animal feed can best be produced therefrom? Surely there must be buyers/users, and in light of the present situation it will not be very difficult to find them if the feed price structure is adequate.

This approach will also be a first step towards market development. Once accustomed to the use of industrially produced animal feed compounds, feeders will continue using them and a market will start growing.

Small-scale animal feed production plants can only supply a limited selected market area and would, therefore, best be set-up and operated as close as possible to the animals to be fed. The risk is relatively small and can be calculated.

3.2 Raw materials and feed formulation

Small capacity animal feed production plants in developing countries are not necessary to produce compound animal feed based on scientific feed formulations but if they are able to do so the better. Raw materials may in the first instance be oilcakes and cassava. The availability of agro-industrial by-products will depend on the location of the animal feed factory. The utilization of agricultural residues and/or fruit and vegetable processing residues will in many cases be useful. As was said earlier, the production of feed for ruminants may be easier because considerable quantities of roughage raw material can be used. In developing countries ruminants play a more important role than non-ruminant animals - perhaps with the exception of chicken.

The production of chicken is a different story altogether. Industrial chicken raising activities, whether aimed at the production

of eggs or meat, are growing rapidly in developing countries. Chicken grow quickly and give a high turn-over which can be increased by feeding them with feed concentrates. Any chicken farm, therefore, will require industrially-produced feedstuffs and would give a small capacity animal feed factory the necessary market and economic background.

Another very useful production opportunity would be feed supplements for dairy cattle. The following examples illustrate possible simple feed formulations which may have to be verified or altered as required.

a.	26% rice bran	b.	27% citrus pulp
	64% copra cake		63% copra cake
	8% molasses		8% molasses
	2% minerals		2% minerals
c.	64% maize or wheat	d.	55% rice bran
	26% groundnut cake		35% soya cake
	8% molasses		8% molasses
	2% minerals		2% minerals
e.	27% cassava chips	f.	50% sorghum/millet
	63% palm kernel cake		40% palm kernel cake
	8% molasses		8% molasses
	2% minerals		2% minerals

Source: Tropical Products Institute, London, U.K.

No rules can, however, be given for the feed raw materials to be used and the feed products best to be produced therefrom by small-scale feed production plants, but it goes without saying that background conditions are often favourable and little effort needs to be made to recognize a chance and create the conditions required for successful production.

3.3 Scale of production

The scale of production largely depends on the availability of the relevant equipment. The equipment has to be suitable for this purpose and should permit the design of small-capacity factories with all the transport elements as well as technical links and connections permitting uninterrupted production.

From this viewpoint, "small scale" may start with a capacity of 1 (one) ton per hour or 2400 tons per annum (one 8 hour shift for 300 days per year) and increase to 10 (ten) tons of feed concentrate per hour or 24,000 tons per annum (one 8 hour shift for 300 days). The operation of three 8 hour shifts per day (round the clock operation) would triple the capacity to 7,200,- per annum or 72,000 tons respectively.

The production capacity of 1 ton per hour (2,400 tons per annum) may be sufficient for one medium commercial pig or chicken farm while the capacity of 10 tons per hour would already mean commercial marketing and a large-scale operation would be on its way.

3.4 The factory

As mentioned earlier in this paper, the technological production process is relatively simple. The flow chart and flow diagram of the technological production principle is shown in figure 1 of the Annex to this report.

The raw materials usually arrive in sacks and are transported by hand or mechanically into the warehouse (reception) from where they enter the storage bins (silos). Normally, in small-scale operations, no provisions are made for cleaning and drying of the raw materials.

Storage must be in containers which keep the raw materials dry and free from insect pests. Continuous controls are required. From storage the material goes to the grinding section which mostly consists of impact grinders (hammer mills) with perforated screens. The ground products are then blended using mechanical bin dischargers. Blending means the measuring and assembling of the required quantities of raw materials. In small-scale operations blending is normally made in batches. The blended materials are then mixed intensively in horizontal or vertical mixers. Mixing is also a batch operation in small-scale factories. The ground, blended and mixed feed may have to be pelleted which reduces the volume of the feed product and is necessary for poultry feed. The pelleting process consists of conditioning (heating), pelleting (the pressing of the feed meal through a die) and cooling. Molasses is normally added to the conditioner prior to entering the pelleter. The cooled pellets are then bagged, weighed, and transported to the final storage or distribution section.

Small-scale animal feed factories require a steam boiler for the pelleting process. The building should be suitable for prevailing climatic conditions. Water is required for steam generation and power (electricity) supply is essential. Last but not least raw material and product quality control activities cannot be avoided.

From this brief description it is clear that a small-scale animal feed factory with "simple" technical and technological arrangements is a considerable investment and economic feasibility calculations are certainly required prior to investment decisions.

4. Village-scale animal feed manufacture

Village-scale animal feed manufacture is quite a different issue. It has nothing to do with compounding of scientific feeding but it might be useful if not important for communities living in remote areas with no access to animal feed markets which depend on animals and their products. An attempt should, therefore, be made to discuss the application of non-traditional feed manufacturing and feed utilization opportunities.

4.1 The usefulness of village-scale animal feed manufacture

Village people will surely not normally require mixed "ready-made" animal feed. Their animals graze on grass and plants but there will be times when this is not possible especially in dry seasons or under extreme climatic conditions which unfortunately have often occurred

in recent years. One single very dry season may cause starvation or even death to the animals on which human life depends. It may, therefore, be very important to find a way out of such dilemmas and this could be by manufacture of mixed feed from available raw materials such as oilcakes, dried cassava or dried grass, fruit residues and others.

People in the Northern hemisphere are used to making preparations for long winters with snow and ice and alot of work is carried out for the production of sun-dried grass, straw and roots, etc. For those in the Southern hemisphere, there was no need for such preparations until food and feed became rare. But the time has now also come for these people to prepare for "difficult" periods by manufacture of mixed, well-composed animal feed at times when raw materials are available for times when animal feed becomes scarce.

Very simple locally-produced equipment will be required for the production of cassava chips or pellets. Drying methods for grass and fruit residues may have to be introduced. The oilcakes produced in oil expeller units - which are common in villages - should not be fed to animals just to get rid of them but should be used more effectively in mixed feed. This would mean drying, shredding, blending and mixing of oilcakes, cassava chips, dried grass and plants, etc. to produce a mixture with the best possible nutritive value. In principle, it is nothing else than the "industrial" production of animal feed only not aimed at obtaining optimum benefit but based on the need for survival when times are difficult.

Nomads may have better survived the extremely difficult dry periods in the Sahel Zone with their animals if it had been possible to set up animal feed stations based on the above-mentioned principles.

4.2 Viability and the market for village-scale animal feed

The village-scale production of animal feed may not be economically feasible but it will certainly be viable under the above-mentioned conditions. There will also be a "market" which may even attract special Government support. Village-scale manufacture of animal feed is certainly not an industrial development activity but primarily a social activity which would fully fall in line with rural development to which priority has been attached by the authorities of many developing countries.

5. Some special remarks on feedstuff and feed ingredients

For information purposes and as encouragement for some detailed studies some feed and feed ingredients shall be discussed as follows.

5.1 Oilcakes and extracted meal

As protein carriers oilcakes and extracted meals are highly important raw materials for the production of animal feed compounds. Oilcakes have a protein content of between 20% and 50% depending on the type of oil seed processed and whether or not decortication of the oil seed has taken place in the oil mill. Decortication also reduces the fibre content of the oilcakes/meals.

Some of the oil seeds contain toxic substances which may pass unaffected by the oil extraction process into the cakes and some caution is required. Cottonseed, for example, contains gossypol which may cause the decolourization of the egg yolk if fed to laying hens in high quantities and may cause other health problems to monogastric animals. Cottonseed should, therefore, be used primarily in ruminant feed and only small quantities should be added to non-ruminant feed rations.

There is the ricin and a powerful allergen contained in castor seed which pass into the oilcakes during the oil extraction process. Undertoxified castor seed cakes/meal should, therefore, not be used at all in animal feed formulations. UNIDO has, however, developed a detoxification technology for application in the castor oil extraction process which makes castor bean meal safe and suitable for animal feeding. Attention is drawn, in this context, to the UNIDO publication IO.7(SPEC.) entitled "The Production of Non-Toxic Castor Bean Meal Free of Allergen."

There are also certain anti-nutritional substances contained in oil extraction residues which are measured by determining the "Anti-Trypsin Factor". Such substances are, for example, available in soya bean meal but are normally dealt with in the toasting process forming part of each soya bean solvent extraction plant.

5.2 Fats and oils

Fats serve a three-fold purpose in mixed feed. They provide the essential fatty acids, a rich source of energy and improve the physical characteristics and palatability of feedstuff. The use of oils and fats as an energy component in feed may lead to the same nutrient and energy density in a smaller feed quantity without having to make up the difference with a filler (fibrous materials). This is of special interest in poultry (broiler) feeding. The following comparative figures illustrate this effect.

	Feed No. 1 (kg)	Feed No. 2 (kg)
Maize	600	490
Soya bean meal	340	360
Minerals and vitamins	50	50
Fats (animal based)	10	10
TOTAL WEIGHT	**1000**	**950**
Megacalories	**3000**	**3000**
Protein (kg)	**230**	**230**
Minerals and vitamins	**50**	**50**

Source: Department of Poultry Science, University of Georgia.

5.3 Lalobe (Balanites aegyptiaca) kernels

Attention is drawn, in this context, to a considerable number and variety of oil seeds/fruits which have not yet been utilized for the production of vegetable oil and oilcakes. Such seeds/fruits grow in limited local areas and are still waiting exploitation.

For example, the Lalobe (arabic name) kernels (Balanites aegyptiaca) the fruits of the Heglic tree which is widely spread throughout the Sahel Zone from East to West. Lalobe kernels have proved themselves an excellent but largely unexploited raw material for the production of vegetable oil and animal feed. This is of special interest to African countries.

Extensive research and development work has been carried out by UNIDO in the Balanites aegyptiaca utilization sector including animal feeding tests. The following UNIDO publications refer:

1. UNIDO/IO.494 entitled "The Balanites Aegyptiaca - An Unutilized Raw Material Potential Ready for Agro-Industrial Exploitation" and

2. IO.42(SPEC.) entitled "A Model Concept for the Utilization of Balanites Aegyptiaca Fruits for the Production of Vegetable Oil and Animal Feed."

5.4 Rubber seed press cakes

Another raw material so far not utilized for the production of vegetable oil and animal feed is rubber seed. UNIDO studies, laboratory research work and pilot plant operations as well as animal feeding tests show that rubber seed press cakes are a useful protein feed ingredient. Details may be obtained from the following UNIDO publications:

1. IO.8(SPEC.) entitled "The Development of a Rubber seed Processing Technology or the Production of Vegetable Oil and Animal Feed" and

2. IO.41(SPEC.) entitled "Rubber seed Processing for the Production of Vegetable Oil and Animal Feed."

5.5 Cassava

Cassava is a well-known root grown world-wide in tropical areas and widely used for human consumption. The existing cassava potential has, however, by no means been exploited and leaves room for rewarding processing activities.

Cassava is a valuable energy component in mixed animal feed but it has to be dried to a moisture content of 15% or less in order to permit appropriate storage and transport operations. Drying may be done in the sun in the form of chips but also in the form of pellets made from ground cassava roots by using other sources of energy in mechanical drying systems.

Drying (heating) is further required for the removal of cyanide which are present in most cassava varieties and which are harmful to humans and animals if insufficiently cooked or otherwise heat treated and eaten over long periods. The production of cassava chips or pellets as

an animal feed ingredient should become a widely spread activity in Africa especially in rural areas and should find the support of authorities and all concerned. UNIDO has extensively studied cassava processing operations in developing countries. The following UNIDO publications refer:

1. UNIDO/IO.534 entitled "A Factory Concept for Integrated Cassava Processing Operations".

2. UNIDO/IO.582 entitled "The Raw Material Cassava Chips, Production Systems, Quality Criteria and Techno-Economic Factors" and

3. IO.R.123 entitled "Supporting and Background Information on the Production of Cassava Chips".

5.6 Molasses cattle feed lick blocks

The value of molasses as feed for livestock has been known since sugar was first manufactured. As early as 1935 500,000 tons of molasses were used annually in the USA for cattle feed. This has now reached 2 million tons.

Molasses is rich in carbohydrates (sugar); it also provides a small amount of protein and other important nutrients especially valuable for ruminants. It contains vitamin B and essential trace elements such as cobalt, iodine, copper, manganese and zinc.

A very useful molasses-based feed product are lick blocks which are easy to produce and which are liberally taken by cattle. A suggested formulation is the following:

Cereals	46.8%
Urea	4.0%
Salt	4.0%
Di-calcium phosphate	4.0%
Magnesium oxide	2.0%
Minerals	0.2%
Fillers (roughage)	10.0%
Binders	4.0%
Molasses	25.0%
	100.0%

5.7 Sugar cane

Sugar cane has a large potential for capturing solar energy as it possesses an additional enzyme system not found in temperate grasses. This particularly efficient transfer of solar energy into carbohydrates makes sugar cane an especially important "tropical grass". Experts (T.R. Preston), therefore, believe that in tropical countries sugar cane

should be grown for animal feed purposes and would very favourably influence the animal feed production sector in tropical developing countries. Although sugar cane will certainly remain the raw material for the production of sugar in tropical developing countries, it is also doubtlessly an excellent raw material for the production of animal feed.

In addition to sugar cane leaves and tops, the cane itself may also be used for animal (cattle) feeding purposes after removal of the indigestible rind. The sugar cane stalks are split in two halves and the pith containing the sugar is ground out and the two strips of rind are discarded. The coarsely ground pith is a creamy white palatable feed with the consistency of wet sawdust which is readily eaten by cattle and considered an excellent energy source for intensive beef production. It has been reported that a machine was developed for this purpose by Miller and Tilby in Canada (Canadian International Development Agency Seminar on Sugar Cane as Livestock Feed, Barbados, 1973).

5.8 Other feed raw materials to be prepared and developed

Many agricultural residues, post-harvest residues and agro-industrial by-products exist of which the feed value has not yet sufficiently been studied. But studies alone may not lead to their industrial utilization. Feeding experiments need to be carried out with different feed compositions and different animals. In this context organization schemes of collection, processing, storage and transport also have to be studied and economic evaluations are of particular importance. This would be the task of research institutes and universities, under central control and guidance to avoid duplication of work and to proceed to practical results.

Important materials and processes to be studied and evaluated would be the dehydration technology in general and the dehydration of grass, brewers' spent grains and fruit processing residues (peels, etc.). Other materials for further study for use as animal feed ingredients may be whey, coffee pulp and hulls, cashew scraps, kernel meal and last, but not least, the economically feasible production and use of single cell protein.

6. Aspects to be considered

When discussing the industrial production and use of animal feed, three aspects need to be highlighted: the need for economic feasibility calculations, the problem of aflatoxin and pest control, and analytical quality control activities.

6.1 The economic feasibility

It is relatively easy to recommend a product for industrial production or a technology for implementation in industrial operations based solely on the result of well-founded laboratory research work.

Research work has to pass through three stages, namely the laboratory research phase, the pilot plant testing phase and economic evaluation. If the economic evaluation shows negative results, the project is usually dropped and the animal feed industry has numerous examples of such cases because they were not economically feasible. It

should be repeated, in this context, that the animal feed industry is a very important element in agro-industrial development of developing countries. Should the production of a product of value prove to be economically unfeasible, ways and means have to be sought to make it feasible. This may be with financial support from, inter alia, the Government or simplification of the technical aspects involved in order to reduce production costs or to reduce investment costs by local manufacturing or otherwise.

It should be stated that the favourable results of economic feasibility calculations are the key to investments. Economic feasibility studies are essential but they have to be carried out very carefully and critically. Similar to a court of justice: "Any doubt should be in favour of the defendant", which would be the animal feed industry in developing countries at this stage.

6.2 Storage, pest control and aflatoxin

Storage is not just a cost factor but is very important generally in animal feed production and utilization schemes because appropriate storage prevents pests and mould. Storage facilities exist which are well designed and proven over long periods. Whether bag storage or silo storage the stored product has to be kept dry without permitting access to insects and pests.

The problem may already start with the raw materials. Sun-dried cassava chips, for example, may introduce insect eggs or pathogenic bacteria which may not have been noticed early enough and which, after a short time, will infect tons of raw material. It is for this reason that sun drying methods of cassava or similar feed raw materials are increasingly being replaced by mechanical drying methods (solar energy!)

In this context, aflatoxin plays a role. Particularly unsuitably stored oilcakes may introduce aflatoxin into the feed product. Aflatoxin effects on life stock were studied by the Western Regional Laboratory in California, USA, with the result that pigs and meat cattle showed no adverse effect when fed with aflatoxin intoxicated feed whereas particularly young animals and poultry appeared to be less resistant. Under extreme conditions, aflatoxin may even reappear in the milk of dairy cattle. In any case, aflatoxin intoxicated feedstuff has to be avoided and relevant precautions have to be taken.

6.3 Quality control activities

The quality and composition of the raw materials need to be determined and the product composition and quality should be constantly controlled in the production process of compound animal feed. This also applies to small-scale operations. Without chemical analytical tests, appropriate feed formulations would not be possible. This must be recognized although quality control activities often cause a serious problem especially to small-scale animal feed producers in developing countries. The necessary laboratory equipment has to be obtained and maintained, the relevant chemicals have to be procured and skilled manpower is required.

Small-scale animal feed producers may, therefore, find it more economic to obtain the required quality control services from outside institutions, or chemical or agricultural analysts from relevant firms or public institutes which exist in most developing countries. Minerals, vitamins and other feed supplements may best be ordered in the form of "pre-mixes" from relevant commercial companies which are also usually willing to calculate least-cost feed formulations based on available raw materials which they also analyze on request.

Product quality routine tests are very important especially if a brand image is to be built up or has to be maintained. It may be necessary to comply with legal requirements, if any, and it may be vital to check that a raw material or product is free from dangerous levels of contaminants.

In addition to laboratory testing, the conduct of animal feeding trials is of great important because the feed value of a newly-formulated feed product can best be determined by practical feeding tests.

7. The need for co-operation

The industrial production of compound animal feed in developing countries should find the sympathetic co-operation of the authorities because Government support may be called for at least in the early production stages.

Co-operation is further required between the feed producer and the raw material supply organizations as well as with the users of the feedstuff produced. Co-operation may be needed with regard to quality control operations, with regard to intermediate processing of agro-industrial by-products and with regard to the economic aspects involved, which are certainly of concern to all three partners.

Should special outside assistance be made available with regard to all aspects of the establishment and operation of animal feed factories, the assistance of international organizations as well as United Nations agencies may be requested and will certainly be made available subject to relevant financial resources.

8. Final remarks

The animal feed industry in developing countries, at present, is in the early stage of its development. It is a very important branch of the agro-based industries on which food supplies and the overall living standard of people may depend in the foreseeable future. The importance of the industrial production of animal feed and the corresponding changes in farm animal holding systems may not yet have been fully recognized, but the time has come to do so and action is needed as soon as possible.

Appendix 1

Table 1: Composition of cereals and their by-products

Material		Dry matter per cent	Crude protein (N x 6.25) per cent	Oil (ether extract) per cent	Crude fibre per cent	Nitrogen free extract per cent	Mineral matter (ash) per cent
Common name	Latin name						
Barley	*Hordeum spp*	86.0	9.0	1.5	4.5	67.4	2.6
Barley feed	"	88.0	13.0	3.4	8.5	59.9	4.2
Barley, Brewers' grains, dried	"	88.7	18.3	6.4	16.2	45.9	3.9
Wheat	*Triticum vulgare*	87.0	12.2	1.9	1.8	68.3	1.7
Wheat feeds from flour milling	"	86.7–87.0	14.7–17.0	3.8–4.5	2.3–10.3	52.1–60.8	2.4–5.8
Maize	*Zea mays*	87.0	9.8	4.4	2.2	69.2	1.3
Maize germ meal	"	88.0	13.0	12.5	4.1	55.8	3.6
Flaked maize	"	88.0	9.8	4.3	1.5	72.5	0.9
Maize gluten feed	"	90.3	24.8	2.5	7.2	48.1	7.7
Oats	*Avena sativa*	87.0	10.4	4.8	10.3	58.4	3.1
Brown rice	*Oryza sativa*	86.6	8.3	1.8	8.8	64.7	5.0
Polished rice	"	87.0	6.7	0.4	1.6	77.6	0.8
Rice bran	"	90.8	12.4	13.6	11.6	38.9	13.3
Rice meal	"	91.1	12.9	13.7	6.4	48.5	8.6
Sorghum (American)	*Sorghum spp*	88.6	10.8	2.8	2.3	71.7	2.0
Sorghum (gumaseorm)	"	88.0	10.4	3.4	2.0	71.0	–
Millet American foxtail varieties	*Setaria italica*	88.1	12.1	4.1	8.6	60.7	3.6
Millet, bulrush type	*Pennisetum americanum*	88.0	11.0	5.0	2.0	69.0	–
Millet, finger	*Eleusine coracana*	88.0	6.0	1.5	3.0	75.0	–
Teff	*Eragrostis tef*	88.0	8.5	2.2	2.2	73.0	–
Buckwheat	*Fagopyrum esculentum*	88.0	10.3	2.3	10.7	62.8	1.9
Fonio	*Digitaria exilis*	90.0	7.7	1.8	6.8	71.0	–
Job's tears	*Coix lachryma-jobi*	88.0	14.0	4.0	0.7	68.0	–
Rye	*Secale cereal*	87.0	11.6	1.7	1.8	69.8	2.0

Source: Tropical Products Institute, London, U.K.

Table 2: Composition of dried starchy roots and tubers

Material		Dry matter per cent	Crude protein (N x 6.25) per cent	Oil (fat) per cent	Crude fibre per cent	Nitrogen free extract per cent	Mineral matter (ash) per cent
Common name	Latin name						
Cassava roots, dried	*Manihot esculenta*	84.4	2.8	0.5	5.0	84.0	2.0
Cassava flour	"	88.1	1.6	0.6	2.4	82.2	1.3
Potato meal or dried potatoes	*Solanum tuberosum*	81.4	8.7	0.3	2.1	75.0	4.3
Sweet potato meal or dried sweet potatoes	*Ipomoea batatas*	90.2	4.8	0.8	3.3	77.0	4.1
Yam peeled and dried	*Dioscorea spp*	90.0	7.1	0.7	2.1	76.7	3.4

Source: Tropical Products Institute, London, U.K.

Table 3: Composition of animal products used as feed ingredient

Material	Dry matter per cent	Crude protein (N x 6.25) per cent	Oil (ether extract) per cent	Crude fibre per cent	Nitrogen free extract per cent	Mineral matter (ash) per cent
Blood meal	86.0	81.0	0.8	–	1.5	2.7
Pure meat meal	89.2	72.2	13.2	–	–	3.8
Meat and bone meal	90.3	50.3	15.0	–	1.0	24.0
Meat and bone meal (solvent extracted)	93.7	49.9	3.7	2.4	3.3	34.4
Bone meal (cooked)	93.6	26.0	5.0	1.0	2.5	59.1
Bone meal (steamed)	95.5	7.5	1.2	1.5	3.2	82.1
Whole meat meal	92.0	60.0	16.0	–	–	16.0
Poultry by-product meal	93.4	55.4	13.1	1.6	4.6	18.7
Hatchery waste (dried)	93.7	45.7	30.8	–	4.8	12.4
Feather meal	94.6	87.4	2.9	0.6	–	3.7
Dried whole milk	95.8	25.5	26.5	(–)	37.4	6.4
Dried skimmed milk	89.7	32.8	1.5	–	47.9	7.5
Dried whey	92.2	12.6	1.4	–	70.5	7.7
Fish meal (white)	87.0	61.0	3.5	–	1.5	21.0
Fish meal (menhaden)	93.5	62.1	8.3	0.7	4.2	18.2
Fish solubles (dried)	91.2	71.3	8.5	0.6	0.8	10.0

Source: Tropical Products Institute, London, U.K.

Table 4: Composition of other materials used as feed ingredient

Material		Dry matter per cent	Crude protein (N x 6.25) per cent	Oil (fat) per cent	Crude fibre per cent	Nitrogen free extract per cent	Mineral matter (ash) per cent
Common name	Latin name						
Beet pulp dried	–	91.2	8.8	0.6	18.6	58.7	3.5
Beet molasses	–	80.5	8.4	–	–	62.0	10.1
Beet pulp molasses, dried	–	92.2	8.9	0.5	16.2	61.8	6.8
Cane molasses (blackstrap)	–	73.4	3.0	–	–	61.7	8.6
Carob bean pods	*Ceratonia siliqua*	88.5	4.7	2.5	8.7	70.8	2.7
Carob bean seeds	"	88.5	16.7	2.8	7.6	58.4	3.2
African locust bean seeds	*Parkia* spp	90.0	26.0	10.0	3.0	47.0	–
Dried grass (leafy)	–	90.0	15.0	2.6	20.9	40.7	10.8
Lucerne (alfalfa) meal, dehydrated	*Medicago sativa*	92.7	21.1	3.3	17.5	39.3	11.5
Date stones (crop)	*Phoenix dactylifera*	91.1	6.0	7.2	14.7	60.1	3.1
Yeast, brewers', dried	–	94.0	44.9	0.7	2.7	38.8	6.9
Yeast, torula, dried	–	92.3	46.4	1.2	2.5	34.0	8.2
Sago flour	*Metroxylon sago*	86.0	0.7	0.2	0.2	84.5	0.4

Source: Tropical Products Institute, London, U.K.

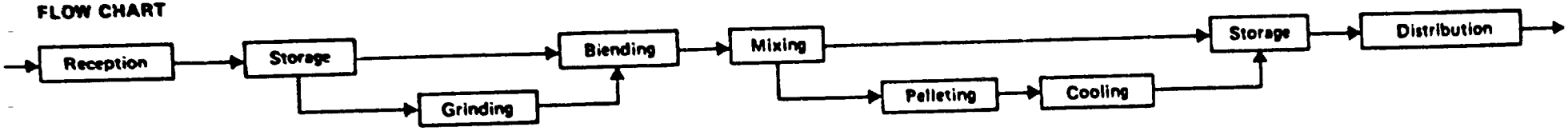
Table 5: Composition of oil seed residues used as feed ingredients

Material		Dry matter per cent	Crude protein (N x 6.25) per cent	Oil (ether extract) per cent	Crude fibre per cent	Nitrogen free extract per cent	Mineral matter (ash) per cent
Common name	Latin name						
Castor bean meal (decorticated)	*Ricinus communis*	90	28.2	1.4	37.1	15.9	6.4
Coconut cake	*Cocos nucifera*	90	21.2	7.3	11.4	44.2	5.9
Cotton seed cake (decorticated)	*Gossypium hirsutum*	90	41.1	8.0	7.8	26.4	6.7
Cotton seed cake (undecorticated)	-	82.4	28.0	5.2	21.4	33.2	4.6
Groundnut cake (decorticated)	*Arachis hypogaea*	90	45.4	6.0	6.5	26.4	5.7
Groundnut cake (undecorticated)	-	90	30.3	8.1	23.0	21.9	5.7
Groundnut extract meal (decorticated)	-	90	48.7	0.7	7.9	28.0	5.7
Kapok seed cake	*Ceiba pentandra*	86	26.8	7.0	25.7	20.1	6.3
Linseed cake	*Linum usitatissimum*	90	31.9	6.9	9.4	36.2	5.6
Mustard seed, extracted meal	*Brassica* spp	88	22.8	2.0	16.0	40.6	6.6
Mustard seed cake	-	88	18.0	7.5	17.5	40.0	5.0
Niger seed cake	*Guizotia abyssinica*	89	32.4	5.8	18.1	23.4	9.3
Palm kernel cake	*Elaeis guineensis*	89	19.2	6.0	13.4	46.5	3.9
Palm kernel, extracted meal	-	90	20.4	0.9	16.0	48.7	4.0
Rape seed, extracted meal	*Brassica napus*	89	36.8	3.1	9.3	32.5	7.3
Rape seed cake	-	91	35.3	9.6	8.3	25.5	12.3
Sesame seed cake	*Sesamum indicum*	91	44.7	11.9	4.5	21.0	8.9
Sesame seed extracted meal	-	94	46.4	2.4	7.7	26.7	10.8
Shea nut cake	*Butyrospermum parkii*	90	12.1	6.5	4.8	60.7	5.9
Soya bean cake	*Glycine max*	89	44.9	5.8	5.3	27.4	5.6
Soya bean extracted meal	-	89	44.8	1.5	5.1	32.1	5.5
Sunflower seed cake (decorticated)	*Helianthus annus*	90	37.2	13.7	12.1	20.3	6.7
Sunflower seed cake (undecorticated)	-	90	18.5	7.2	29.1	28.0	7.2
Sunflower seed, extracted meal	-	90	28.1	1.0	16.3	28.1	6.5

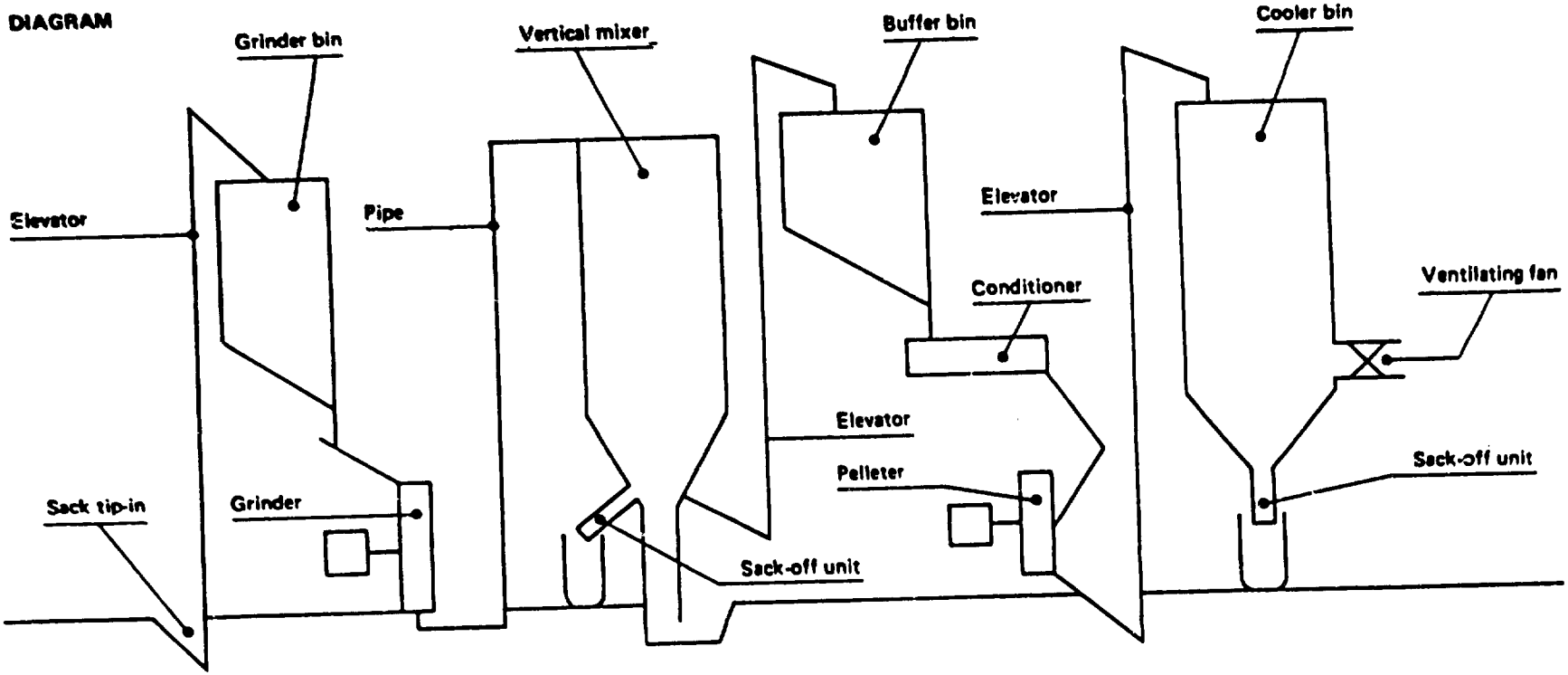
Source: Tropical Products Institute, London, U.K.

Appendix 2 Small-scale compound feed factory

FLOW CHART



FLOW DIAGRAM



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