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UTILIZATION OF SUGAR CANE AND THE BY-PRODUCTS OF ITS
AGRO-INDUSTRY FOR ANIMAL FEEDING

Background paper*

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* The views expressed in this document are those of the author and do not necessarily reflect the views of the Secretariat of UNIDO. This document has not been edited.

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CONTENTS

	Page
1. Utilization of sugar cane and its by-products for animal feed.....	4
2. Direct utilization of sugar cane.....	6
3. Sugar cane juice.....	8
4. Sugar as animal feed.....	8
5. Molasses as animal feed.....	9
- Protein molasses.....	10
- Torula and saccharomyces yeasts.....	12
- Biofermel.....	13
- L-lysine.....	14
- Multinutritional blocks.....	14
- Molasses-urea-pith.....	15
- Zacamel.....	16
6. Bagasse.....	17
- Pre-digested pith (pre-digested medula).....	17
- Hydrolyzed bagasse.....	18
7. Filter mud.....	20
8. Vinasse.....	22
9. Harvest trash.....	23
10. "Saccharina" (Treatcel trash).....	23
11. Plants for animal feeding in the Latin American and Caribbean countries.....	24
Conclusions and recommendations.....	26
Bibliography.....	27

Tables

Table 1:	Amount of by-products that can be obtained from 100 tons of harvested sugar cane.....	4
Table 2:	Biomass and energy production from sugar cane and from other crops.....	6
Table 3:	Typical composition of multinutritional blocks.	14
Table 4:	Zacamel 70:30 composition.....	16
Table 5:	Behaviour of pigs fed with "Melote" and protein nucleus (40% protein).....	21
Table 6:	Nutritional values of saccharina.....	24
Table 7:	Latin America and the Caribbean: Characterization of facilities for animal feed from the sugar cane agro-industry (plants).....	25

Diagrams

Diagram 1:	Utilization of sugar cane and its by-products in animal feeding.....	5
Diagram 2:	Original diagram of protein molasses production	11

Until recently, sugar cane was cultivated world-wide with the fundamental objective of producing sugar. However, for over thirty years, research and development undertaken in many countries, principally in those of the Latin American and Caribbean region, have demonstrated that the by-products of the sugar agro-industry provide a valuable source of raw material for the diversification of the economies of sugar cane producing countries.

This paper has the purpose of offering in a preliminary form, a series of alternatives for the use of sugar cane, its by-products and derivatives for animal feeding, taking as a basis the experience obtained in the Latin American and Caribbean region.

The focus is mainly taken from the viewpoint of the various possibilities offered by the sugar cane agro-industry in animal feed production, without going into an analysis of formulas and diets, nor of the breeding and fattening of the different types of livestock, since this specialization falls outside the scope of this study.

There is a wide spectrum of processes in the production of foodstuffs from sugar cane and its by-products, from the simple use of residues to more sophisticated products, such as lysine, for example.

One of the advantages that can be attributed to the production of animal feed from the sugar cane agro-industry, consists in the low costs of the investment required. In nearly all the countries of Latin America and the Caribbean animal feed has been produced in larger or smaller amount by using the by-products of this agro-industry. It is important to point out that in the production of animal feed from the sugar agro-industry it is necessary to achieve a close relationship between sugar producers and cattle breeders, and to keep in mind that this connection will contribute to the reduction of costs in animal production and in the use of the resources available in each region.

The diversity of products which the sugar cane agro-industry allows, places it in a position to advantageously face the challenge of fluctuating sugar prices in the international market.

In all those countries or regions in which alternatives to the sugar cane agro-industry are utilized or where it is desired to use them for animal feed, the particular conditions prevailing should be analyzed, in order to identify the most profitable among the possibilities offered.

1. UTILIZATION OF SUGAR CANE AND ITS BY-PRODUCTS FOR ANIMAL FEED.

In the process of sugar production various by-products are obtained, which can be grouped according to the stage at which they materialize: those originating during the harvest, which are the cane tops, leaves and trash, and those resulting from the industrial process, such as bagasse, final molasses and filter mud. During the harvest and the technological process of sugar production it is possible to obtain approximately the following:

TABLE 1
AMOUNT OF BY-PRODUCTS THAT CAN BE OBTAINED
FROM 100 TONS OF HARVESTED SUGAR CANE

By-products	Tons
Sugar	12.0
Bagasse (50% moisture)	27.5
Final molasses (88 ° Brix)	3.4
Filter Mud (77% moisture)	3.4
Green leaves	7.8
Dry leaves	6.9
Cane Tops	6.9

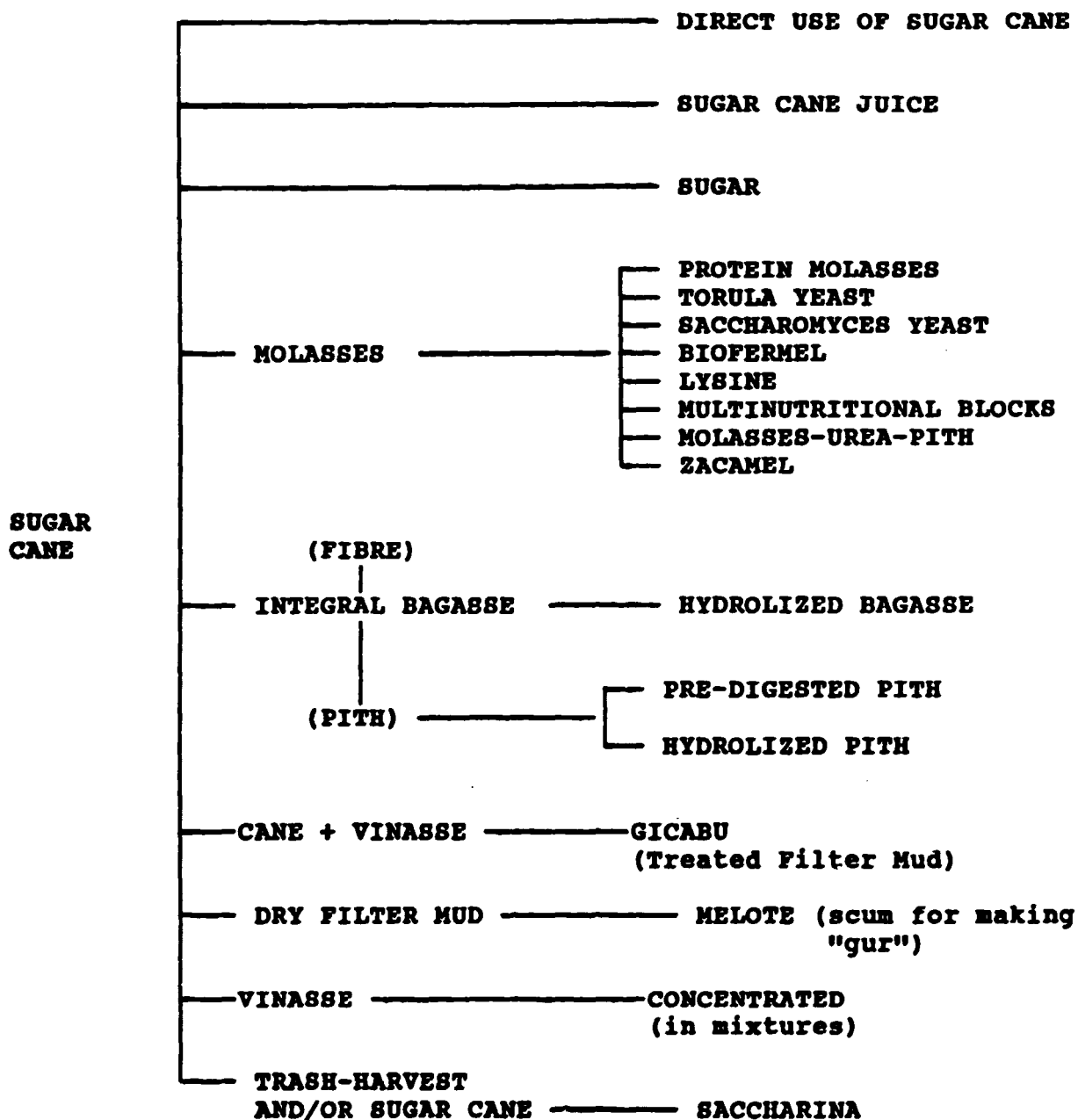
Source : Diversification Project GEPLACTA/UNDP, 1990

The amounts of leaves and cane tops in the sugar cane are noticeably influenced by the varieties, irrigation system, harvest season, and other factors, significantly affecting the final results of sugar production.

For several decades, the sugar cane producing countries of the Latin American and Caribbean region, have pursued numerous research projects in the field of nutrition, through which it is possible today to assert that, particularly in the tropical regions, sugar cane can be the most outstanding crop to substitute cereals advantageously in formulas for fodder to be used mainly to feed cattle, pig and poultry livestock.

Widely known technologies follow the pattern shown in the next diagram, in which the possibilities of animal feeding based on by-products and derivatives of the sugar cane agro-industry are presented.

DIAGRAM 1
UTILIZATION OF SUGAR CANE AND ITS BY PRODUCTS IN ANIMAL FEEDING



SOURCE : Diversification Project GEPLACEA/UNDP, 1990.

This outline shows the relationship that exists among by-products and derivatives. Shredded sugar cane and sugar are used directly, whereas by-products are utilized in various forms, being fed directly to the animals or treated and/or combined with other products.

2. DIRECT UTILIZATION OF SUGAR CANE

Due to its high photosynthesis efficiency and biomass generation, sugar cane is the most productive crop in the world.

Being a product of the tropical and sub-tropical areas, it is a renewable source of energy, which efficiently exploited from its planting to the stage where sugar is obtained, can be an industry that produces its own energy. Biomass and energy production from sugar cane is higher than that of any other crop, as can be observed in Table 2.

TABLE 2
BIOMASS AND ENERGY PRODUCTION FROM SUGAR CANE AND
FROM OTHER CROPS

	TDS/Ha/Year	Thousand MJ/Ha/Year
Whole Sugar Cane	17.2	189.2
Molasses	1.4	18.9
Cane Tops and Leaves	6.0	57.2
Bagasse	6.1	50.5
Sugar Cane Juice	8.8	132.0
Cereals (Grains)	2.1	37.2
Roots and Tubers Fodders	2.7	39.7
Forage Crops	8.0	82.8

Mj/Ha/Year = Mega joule per hectare per year

TDS = Tons of Dry Substance

Source : Figueroa, V. and Iy J., "Non Conventional pig-feeding",
Diversification Series, GEPLACEA/UNDP Collection,
Mexico, 1990.

Historically this crop was exploited exclusively for sugar production; however, in recent years its use has become diversified by manufacturing other products, such as direct alcohol or in formulating diets for animal feeding.

Sugar Cane is a vegetal product, principally composed of sugar, fibres, water, lignin and other materials. The soluble components (sugars) are easily digested, but they require protein supplements and, sometimes, minerals.

This raw material can be integrally utilized when shredded to be used in cattle feeding; it can also be chopped in order to use its juice in pig and poultry feed; the bagasse is also employed in feeding cattle livestock. Important applications of this nature are reported in nearly all the countries of the region, mainly in the Dominican Republic, Colombia, Cuba and Mexico.

One of the advantages offered by the alternative exploitation of sugar cane for animal feeding is its flexibility in terms of the harvest period, since it can remain standing until required when it is destined for livestock production. Once it is cut, sugar cane may be kept stored for around a week without significant deterioration of its properties.

The technical basis for sugar cane exploitation in terms of animal feeding derive from this gramineous plant's physical, chemical and nutritional characteristics, as well as from those of its by-products.

The utilization of sugar cane in animal feeding in commercial undertakings of cattle fattening has been successful in several of the region's countries. Its use is attractive from the point of view of cost when sugar prices are circumstantially low. Besides, in many zones, marginal sugar cane is utilized for feeding purposes.

Direct utilization of sugar cane for animal feeding is preferable when directed to ruminants, due to the high percentage of ligno-cellulose content. It is not highly recommended for pig feed since its digestibility is very low.

Digestibility can be improved between 50% and 60% by means of physical and chemical treatment (hydrolysis, for instance), although protein supplements are required which make this type of forage more expensive. In the future the possibilities for its use could improve applying biotechnological processes to reach an enriched protein content in the solid phase.

Experts on the subject hold that "there exist biological bases to trust sugar cane as a substitute of cereals in intensive systems for the main animal species, which would allow large volumes of foodstuffs to be freed for the human population".

It is also stated that with the sugar cane production of one hectare, at a yield of 90 mt/ha/year, it is possible to yearly increase the live weight of 40 pigs from 30 to 90 kgs., and from 200 to 400 kgs. live weight in the case of 10 yearlings -- levels which are not reached in developed countries by means of cereals.

3. SUGAR CANE JUICE

Sugar cane juice is obtained by chopping the sugar cane in small mills (trapiches). It is a juice diluted by imbibed water incorporated, with around 14° to 16° Brix, an 80% to 88% purity and some non-sugar compounds of the order of 12% to 20%.

Besides utilizing sugar cane juice to obtain sugar crystals or to produce alcohol directly, the case of distilleries, it is used for pig feeding, as an alternative feed source with regard to corn, sorghum or other secondary cereals.

In order to totally or partially substitute sorghum, this utilization of sugar cane was tested in Brazil. Later in the University of Yucatan, Mexico, various tests were made, utilizing sugar cane juice as a substitute for energy sources in pig feeding. Many tests have been run in Haiti, the Dominican Republic and Colombia, and consequently experience has been gained in this field.

Since it does not undergo the industrial operation of the factory, sugar cane juice does not suffer variations in its chemical composition and can, therefore, be used in pig feeding.

Sugar cane juice is a product that is liable to ferment in a short time (8-12 hours), so it is necessary to add some product that will hold back this process such as sodium benzoate, ammonium dioxide and/or formol.

4. SUGAR AS ANIMAL FEED

International sugar prices are unstable with prolonged downward trends, occasionally, below production costs. In these cases, sugar utilization as poultry feed can be considered as an alternative. Several countries have made studies and applied them with encouraging results. In this process of applied research some options are analyzed, such as amorphous sugar, discarded sugars and others.

The dynamics of price variations is a factor that originates changes in the possibility of utilizing sugar. Thus, an increase in the price of sugar has negative repercussion on the feasibility of its utilization in animal feeding. Fodders based on sugar should be complemented with proteins,

vitamins and minerals that are not included in its composition. Such fodders can be utilized for various types of poultry, but the majority of research projects have been made with pigs and poultry, obtaining promising results.

The use of sugar as a component of fodder for laying hens, for fattening poultry and other types of fowl have been studied in several of the region's countries and more satisfactory results are reported than those for the use of molasses.

Between 1984 and 1987, for example, Colombia devoted 336 thousand tons of raw sugar for animal feed (pigs and poultry). Part of this was destined to be used as supplement in a pre-mixed formula in order to permit the addition of complementary nutrients. This allows nearly 438 tons of sugar to be deployed with a saving of around 34 million dollars.

5. MOLASSES AS ANIMAL FEED

During the last few years intense research has taken place for the use of final molasses and other molasses where it is feasible that they be produced in the sugar mills and used for animal feed.

An element to be considered is related to the economic profile of its utilization. In effect, molasses is an exportable product, which causes producing countries to try to export the greatest possible volume in order to obtain a greater amount of foreign currency, provided that prices in the international market are favourable.

In the feed for ruminants, its use is very widespread at world level. Mixed with urea it guarantees the utilization of nitrogen as a simple method in its application and not requiring large investments. In many diets containing molasses, fodders and natural protein are included.

Molasses are used in the formulas for a series of fodders whose use in breeding monogastric animals (pigs and poultry); it has been determined that the percentage should not exceed 40% of molasses in the ration's formula. Larger amounts may cause physiologic diarrheas or an excess that animals will not assimilate adequately.

The sugar industry can produce, besides molasses or final molasses, three other types of molasses : i) syrup or concentrated cane molasses through the process of inversion is known as high test molasses; ii) "A" molasses, which is obtained when 75% of the saccharose is extracted which can be recovered and that is obtained in one pan boiling; and iii) "B" molasses which is extracted when 86% crystallization is obtained in two pan boilings.

The main difference in these types of molasses is in the percentage of reducing sugars and in the ever greater contents of organic non-sugar substances, as the saccharose recuperation process advances. In all cases there is a high percentage of dry substance (+ - 80%) which allows it to be stored for long periods and to manipulate it in a relatively easy manner to be used in animal feeding.

Syrups, "A" and "B" molasses, have greater nutritional value and energy concentration than final molasses, due to their greater saccharose content, but it is obtained in detriment of sugar production. When the price of this product is low, the advisability of producing these molasses within the sugar process, can be analyzed.

Comparing molasses with cereals, the latter have around 20% more brute energy, and besides, the caloric power of sugar (saccharose, glucose and fructose) is lower than that of starches.

For cattle livestock, acceptable results have been obtained by incorporating 4 kg. to 5 kg. of molasses/head and in confined animals this has permitted an increase of around 800 grams/day with rations that contain up to 50% molasses (in the case of livestock for meat production). For milk producing livestock, the use of rations with the same level of molasses has achieved a stabilization in milk production in the order of 10 liters daily.

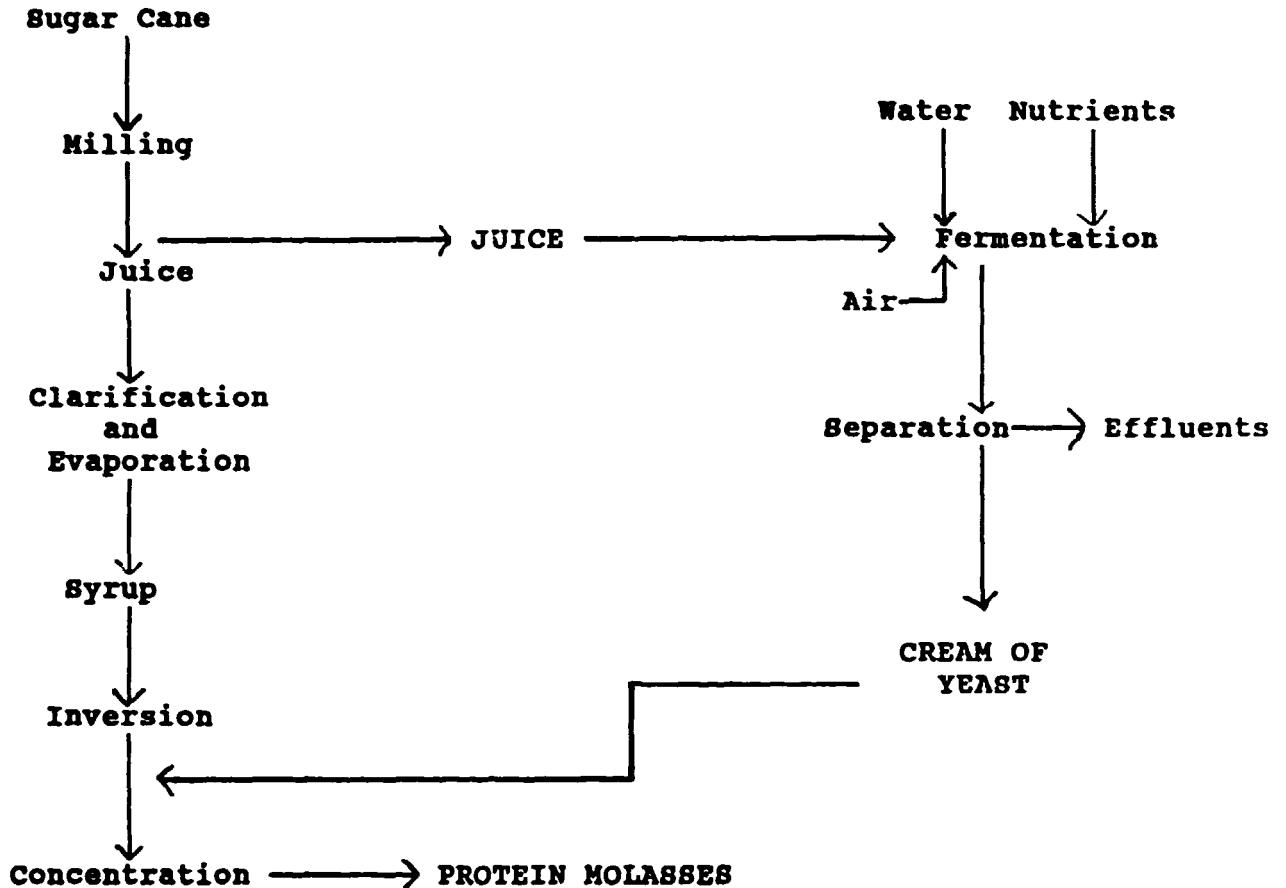
Molasses form part of feed rations, preferably mixed with other materials. Such is the case of nutritional blocks or the mix of molasses-urea-pith.

Protein Molasses

Protein molasses is a mix of proteins and carbohydrates developed in Cuba from research started at the beginning of the seventies. The production of these molasses takes place through a process in which a part of the sugar cane juice is devoted to producing syrup and another enters a fermentation process to obtain yeast cream.

DIAGRAM 2

ORIGINAL DIAGRAM OF PROTEIN MOLASSES PRODUCTION



Later the two parts are mixed, and a concentration is made to 70% of solids, providing carbohydrates and proteins in certain proportions, with a content of around 16% of protein (15.69 + - 4.32%) for the case of enriched protein molasses. For its use, it is diluted to a 40-44% solids concentration. Diluted protein molasses tends to ferment within the 72 hours following its production, which is the reason that development and growth of bacteria must be restricted by adding small doses of a mix of formol and some strong acid. Incorporating lactic bacteria permits the conservation, for 30-day periods, of the protein molasses with no fermentation problems.

The principal use is directed to pigs in their fattening and reproduction diets. It is complemented with vitamins and minerals for the nutritional balance required by the various animal species.

Protein molasses is produced at an industrial scale in Cuba where there are 4 plants in operation and 3 other complexes with small productions. The production capacity is of around 200 thousand tons/year.

At the Jatiboca sugar mill in Minas Gerais, Brazil a plant was set up for the production of protein molasses, where the Cuban technology was adopted.

This type of production is beneficial for tropical or subtropical countries, where weather conditions or technological development do not permit productive crops of cereals to be obtained, which until now had been the principal source for animal feed.

Torula and Saccharomyces Yeasts

Torula yeast is a food product with a high protein content obtained through a process of molasses fermentation. Its protein/carbohydrate rate is higher than forages, and it contains L-lysine, which turns it into an attractive supplement for feeding with cereals that have a low content of this essential aminoacid. This product has 92% of dry substance and 45% of protein.

Torula yeast is rich in L-lysine and in other essential aminoacids, except for methionine and cystine. For the production of a ton of yeast, approximately four tons of molasses are consumed, although other substrates can be used, such as sugar cane juice, vinasse and others.

This yeast can be used for any animal species, but it is most frequently found in preparations of rations for poultry feeding.

In Cuba a process for animal feeding has been developed that allows its recovery with commercial purposes. Torula yeast is rich in the vitamins of B complex, except for B12. When supplementing rations with molasses they are further enriched with elements from the B complex.

Production of this yeast is done in Cuba in eleven plants whose production is destined both for domestic consumption and for export. Its price is related to that of similar products in the international market, taking the protein content as a base. The production capacity of the country is of 120 thousand tons per year.

On its part, saccharomyces yeast is recovered as a by-product of molasses or sugar cane juice fermentation for alcohol production. This yeast has a high percentage of brute protein of the order of 30% to 35%, which allows its use for poultry and pig feeding.

This type of yeast, besides the high protein percentage has a good balance of aminoacids and is rich in complex B vitamins. Production at a commercial scale in Argentina, Brazil, Colombia and Cuba are reported; such productions are destined for domestic consumption.

Saccharomyces yeast is recovered by centrifugation procedures and thermolysis in the fermentation trough and it is commercialized in dehydrated form.

Biofermel

It is a product that is obtained from anaerobic fermentation of molasses mixes, trash from the harvests, urea and bovine manure. Biofermel is a feed containing a large amount of lactic acid producing bacteria that remain active during storage in silos.

Biofermel was developed in the pilot plant of the Biomedical Research Institute of the National Autonomous University of Mexico (UNAM) with the collaboration of the Center for Technical Innovation belonging to the same institution.

The product is obtained in a process of anaerobic fermentation, using lactic acid producing bacteria which have kept active when stored in forage silos. The proportion of raw materials is of 42% of molasses, 24% of trash, 1.8% of urea and 2.2% of manure, all dry based.

Bovine manure is the source for microorganisms with a heterogeneous flora composed of coliforms, streptococci and staphylococci, to which a small amount of lactobacillus is added. Diluted molasses (13° Brix) and urea are added, in order to favour a continuous anaerobic fermentation, at a pH of 5.0 - 5.5 during 24 hours, which originates a change in the original flora, drastically reducing coliforms, streptococci and staphylococci, and increasing in large amounts lactobacillus and volatile fatty acids.

The product that results from the fermentation process is mixed with 85° Brix molasses, in a proportion of 20:80. The next step consists in incorporating maize trash (proportion 4:1) to obtain a product with 80% moisture, which is stored in silos for 15 days, being ready for use in animal feeding.

In Mexico two plants were established in Cotija (Michoacan) in 1985, and in Guanajuato in 1987. Through an agreement for collaboration between the government of the Republic of Honduras and the UNAM, a Biofermel producing plant has gone into operation at the Cantarranas mill in Honduras, which provides the region with three plants that produce this animal feed.

In comparative testing at the industrial scale, it was demonstrated that Biofermel, with a complement of some vegetal protein, is capable of efficiently substituting cereals in animal

feeding. The use of one ton of Biofermel in animal feeding (ruminants) substitutes consumption of 830 kg. of cereals in the fodder.

L-lysine

L-lysine is an essential aminoacid used as a complement of diets lacking in this compound, basically in animal feeding.

The principal uses of L-lysine are in the formulas for fodder for poultry and pig feeding, and in enriching cereals for human consumption and in certain pharmaceutical products.

The best feeding of large livestock tends to favour human nutrition. Part of this can be obtained by incorporating aminoacids in fodder. In this case, incorporating 1.25% of L-lysine permits organisms ingesting them to metabolize 60% to 70% of food based on corn, wheat or agricultural residues, trash, instead of 25% to 30%, which is the normal amount. This reference is of great importance when it concerns to animal feeding.

Multinutritional Blocks

Multinutritional blocks are feed products based on a mix of molasses and urea, complemented with salt and pith as the fibrous element. Caustic soda is used as a linking agent. It is a feed supplement with a high level of proteins that come from the urea homogenized with molasses, and it is slowly fed into the animals organism for a better utilization of the ammonia by the bacteria in the rumen. The typical composition can be observed in Table 3.

TABLE 3

TYPICAL COMPOSITION OF MULTINUTRIONAL BLOCKS

	%
Urea	10
Salt (Sodium Chloride)	3
Dicalcium Phosphate	5
Lime (CaO)	8
Molasses	50
Wheat Bran	6
Pith	18

Source : Providence Mill, Inc. (Information of PROVIGAN-BLOCK)

This type of multinutritional feed are proteic-energetic supplements that are considered of easy obtainment and consumption, based on FAO experiences in 15 countries of three continents, to which the contribution of the Interinstitutional Agreement for Livestock Production in the Valley of the Cauca River (CIPAV), in Colombia is added.

These blocks are more easily utilized by the small manufacturers than the urea-molasses mixes or those of urea-molasses-pith. Their consumption is in relation to the urea percentage, the hardness of the block and the type of livestock; there is no risk of poisoning. It is easily digestible, making the increase in live weight larger than that obtained with other feed rations. No sophisticated equipment is required to form the block. The components can be mixed by hand or using a cement mixer or a horizontal paddle mixer. With the mix a paste is formed that is poured into molds where it begins to harden, an operation requiring 3 to 7 days.

Its easy handling is a great advantage for transportation, storing and final administration to the animals. It must be prevented that the blocks become overly hard, since the animals would no longer consume them. Also, if they are too soft, they would be consumed in excess which might lead to toxic risks caused by the high urea consumption.

Numerous test have been made in Colombia, Australia, India, Belize, Pakistan, the Philippines and Ethiopia, supervised by FAO, which has eight projects underway and 11 other under control of UNDP/FAO, basically in Africa. There are eight countries in the Latin American Region that have requested assistance to implement multinutritional blocks. Currently they are produced at an industrial scale in Colombia

Molasses-Urea-Pith

Molasses-Urea-Pith is the result of the first attempts at bovine feed using the sugar cane by-products. As indicated by their name, it is a mix of urea, in a 3% proportion, with molasses. The resulting product is mixed with pith at a 30:70 proportion, with a possible increase in the molasses content in order to have a better nutritional value.

The final mix generally has 9% of brute protein and its digestibility is in the order of 50%. No great investments are required to manufacture this product. Molasses is the component that has the greatest influence in the production cost.

Nutritional value of the molasses-urea-pith mix can be increased or decreased according to the percentage of molasses incorporated, but it must be considered that excessive molasses causes problems in the mixes handling (a viscose material is then formed), or when the amount of molasses added is low, animals do not care to ingest it.

Zacamel

Zacamel is a feed supplement for ruminants produced at the Emiliano Zapata Sugar Mill in Mexico, through a mix of 70% molasses and 30% dry pith. It also offers a variation on the product that is considered to be a concentrate, produced by a mix of Zacamel, fowl manure, malt roots, malt "sabadilla", sorghum, barley and a pre-mix of vitamins and minerals. The content of a 14% raw protein is guaranteed by the manufacturers.

Zacamel can also be utilized in its simple form, carefully controlled, for pig and poultry feeding. Current production is of 100-110 mt/shift of Zacamel and 20 mt/day of the concentrate.

A typical analysis of Zacamel is shown on Table 4.

The mineral-vitamin complex incorporated in the mix is of 2.5 kg per 800 kg of molasses, providing 8 million units of vitamin A and 500 thousand units of Vitamin D3. To this can be added traces of bromide, cobalt, nickel, iodine, copper magnesium, zinc, iron, sulfur and magnesium sulfate.

TABLE 4
ZACAMEL 70:30 COMPOSITION

	%
Free nitrogen extract	65.9
Raw fiber	7.55
Moisture	15.65
Raw Protein	2.10
Raw Fat	1.01
Ashes	7.75

=====
Source : Zacamel Manuals, Zacatepec Sugar Mill,
Morelos, Mexico

The moisture content must be controlled, for with a high percentage, fermentation is produced and the free nitrogen elements are reduced, as well as the total digestible nutrients.

Owing to its low molasses content, Zacamel can be stored for 90 to 120 days, without fermentation risks. To aid in its preservation, 500 grams of sodium benzoate are added per ton of molasses.

6. BAGASSE

Bagasse is utilized in animal feeding, in its integral form as well as in a fraction of it known as pith, medula or marrow. This fraction is the by-product of the depithing operation that takes place in pulp and paper as well as board plants. This discarded material, composed of pith and refines of bagasse constitutes between 25% and 35% of integral bagasse.

Pith composition is similar to that of bagasse, with a slightly higher percentage of moisture and ashes. Morphologically, there are great differences. Pith is preferably employed after some treatment, originating products such as pre-digested pith, hydrolyzed pith or ammonium treated pith.

Pre-digested pith (pre-digested medula)

Pre-digested pith is obtained from treating pith with caustic soda (sodium hydroxide), at moderate temperatures, in order to increase the cellulosic material's pre-digestibility. This product, mixed with molasses and urea is used as feed for ruminants since they are the only ones with a capacity to convert cellulose into energy; it is preferably administered to those animals that are used with milk producing purposes, in doses according to the results desired, that is, in function of growth, reproduction, maintenance, meat or milk.

Digestibility increases with a greater percentage of NaOH (sodium hydroxide), but within a certain limit, since an error in default may be counter-productive and give scarce digestibility to the product.

It is not advisable to decrease moisture of pith, since the degree in which it comes out of the depithing process is that required to obtain an adequate product. If moisture is increased, a decrease in the product's conservation results.

Pith is mixed with caustic soda in a mixing equipment, leaving them in contact for at least five minutes. This mixture receives an incorporation of molasses and urea, and a product with around 55% of moisture is obtained. The product maintains its stability for 24 to 48 hours. However, when it is pre-digested, digestibility increases up to 60%, and the content of brute protein by 12%.

The mix can be made manually with a primitive system of sprinkling caustic soda upon a layer of pith extended in an open courtyard. The production process is very simple, and the basic equipment consists on transporters, tanks, chutes and a mixer.

Technically, pre-digested pith presents advantages over the molasses-urea-pith, since it substitutes it efficiently. Besides, it has a higher feeding value with regard to the molasses savings reported. A ton of molasses-urea-pith consumes 300 kg. of molasses, while a ton of pre-digested pith can substitute from 1.2 to 1.3 tons of molasses-urea-pith

One of the good things about this process consists on its flexibility to convert plants that produce molasses-urea-pith to the production of pre-digested pith. This permits a decrease of up to 50% of the final molasses used per ton of the product, which can be utilized in dry seasons for milk cows.

Until a short time ago, pre-digested pith was displacing molasses-urea or molasses-urea-pith products. However, lately, due to the increase in the international price of caustic soda and because the presence of sodium pollution was determined in the ruminants excretions, the interest for this product was reduced in favor of pith and/or hydrolyzed bagasse.

Hydrolyzed bagasse

Considering the surplus bagasse from the alcohol industry and the need to attend animal feeding, in Brazil a process has been developed for hydrolyzed bagasse. This development took five years to enter the industrial phase. After observing results obtained in laboratory tests, pilot plants and a semi-industrial scale.

Bagasse constitutes a potential source of energy for nutrition of bovine and other ruminants, but, in its natural form, its use is not efficient, partly due to its fibrous lignified composition.

Lignin interferes with digestibility due to its resistance to chemical degrading under the conditions that prevail in the animals' digestive tract. On the other hand, lignin surrounds the fibres, preventing the access of enzymes to them in order to permit digestion to take place.

The process happens through an auto-hydrolysis treatment, basically in two forms: in a continuous operation or by loads, which in turn, have two phases:

- i) **auto-hydrolysis phase**, in which sugar cane bagasse (or any other lignocellulosic residue) is conditioned in a chamber where it is submitted to high pressure (17 atmospheres) and temperature (200° C) through the injection of steam in reactors designed for this purpose. Under these conditions, the division of acetylic radicals takes place in the hemicellulose, with the formation of acetic acid, which promotes acid hydrolysis of the hemicellulose itself reaching its constituent part which include dextroses and pentoses.

- ii) **rapid decompression phase**, at which level the steam contained in the chambers is liberated suddenly and the water contained in the bagasse fragments is suddenly vaporized, the volume of these fragments softens the material considerably, and its digestibility as a result of the treatment will have increased 84%, compared to natural bagasse. This level of digestibility is equivalent to natural green grass.

Once hydrolyzed, bagasse is a voluminous product with a high acidity level, a characteristic that makes its conservation possible for several months and provides a substantial reduction of losses by waste at the drinking containers. Its color is brown, its aroma is agreeable, and its density is 2 to 3 times higher to that of natural bagasse.

Hydrolyzed bagasse makes it possible an integral production of sugar, alcohol and animal protein, if in the same agro-industrial unit, facilities are established for confined livestock. A result of utilizing this feed provides profits of 0.9 to 1.5 kgs/day in the live weight of the confined animals in a lapse of 120 days. Ration's consumption oscillate between 17 and 30 kg of the original material/head/day each, for the beginning and the end of confinements. The most significant developments of this technology for animal production were obtained in Brazil, where in 1987 36 thousand heads of livestock were fed in confinements annexed to 13 distilleries.

Furthermore, similar research has been conducted to hydrolyze bagasse with satisfactory results in Argentina, Colombia and Cuba, while in Mexico, a pilot plant was set up in the La Abeja sugar mill (Casasano).

7. FILTER MUD

Filter mud is a by-product whose characteristic properties and chemical components are very varied. Until now, few practical uses have been found for it. Information is available concerning its use in the field of animal feeding, in the sense that it can be used as an additive in ruminants' diets, in molasses-urea mixes and in other fodders.

In the composition of brute protein there is around 4% of glutamic acid, 2.5% of L-lysine, 0.5% methionine, 5.4% aspartic acid and other amino-acids.

In Cuba, filter mud is used for animal feed through the Gicabú formulation of a product that receives the name of Gicabú, which results from a mix of filtered mud, some 75% of moisture, with vinasse (6% of dry substance). 50 tons of filter mud and 10 tons of vinasse are used, which after drying give place to 12.5 tons of final product with 85% dry substance and 8% brute protein.

Drying through solar heat takes two days. Studies are under way to use the flue gasses from the steam boilers, which would prevent the use of a large surface of land for drying and would optimize the process.

In Cuba 84 plants have been installed, in which Gicabú is produced, with a capacity of 100 tons per day, operating 150 days/year. Production in 1986 was estimated at 384 thousand tons.

In Colombia the non centrifugal sugar ("gur") industry offers a product called "melote" (dry scum) which is used for pig feeding and yearling fattening. In this case, fresh filter mud is pre-dried to a 50% solids, which permits its storage in stable form without fermentation occurring. When it is used for pig diets, "melote" should be supplemented with protein for better results.

Table 5 presents the behaviour of pigs fed with "melote" supplemented by a protein nucleus.

TABLE 5

BEHAVIOUR OF PIGS FED WITH "MELOTE" AND PROTEIN NUCLEUS
(40% Protein)

INTERVALS (Days)	0	34	84	112	124	AVERAGE
LIVE WEIGHT	15.00	30.00	57.00	83.00	93.00	
INCREASE (g/d)		440.00	530.00	920.00	840.00	629.00
CONSUMPTION						
Melote [*] (Dry Scum)		2.55	3.62	4.43	5.63	3.84
Protein Nucleus		.61	.56	.56	.56	.58
Dry Substance		2.08	2.68	3.17	3.89	2.83
CONVERSIONS **		4.73	5.06	3.45	4.63	4.50

* "Melote", with 60% dry substance and a protein nucleus with 90% of dry substance

** Dry Substance Consumption/weight increase (kg/kg)

SOURCE : ASOCAÑA, Santander, CIPAV, 1987 and

Animal Feed Systems in the Tropics Based on Sugar Cane, page 90;

GEPLACEA Collection, Diversification Series, 1989.

8. VINASSE

Vinasse is the effluent of distilleries that represents, on an average, evacuation of 13 litres for each liter of alcohol produced. The total solid contents in the vinasse varies from 4% to 10%, with pH valued between 3 and 5. This by-product is made up of organic material (non-fermentable sugar and dead yeast), mineral salts, and water. Its composition varies from one distillery to another, according to whether molasses or direct juice is used, and according to the process employed.

One way of controlling the pollution generated by vinasse discharged is using it in ferti-irrigation, as it is successfully done in Brazil, although special conditions of the land are required. More than a hundred years ago it was started to be used in animal feeding. This practice is currently favoured by the use of concentrated vinasse, especially in European countries.

In Mexico, interesting studies have been made in this direction, and vinasse has been successfully concentrated in the Independencia, San Cristobal and Santa Clara Sugar Mills. In the latter, concentrated vinasse is produced at a commercial scale. Vinasse is first evaporated to 60% of its solids, consuming steam at one ton per hour of evaporated water, using a three stage system. The next step consists in drying the concentrate by aspersion, at the same time that pith is mixed in to absorb vinasse.

The product obtained, known as "Vinapith", contains between 17% and 19% of dry protein and around 6.5% to 7% moisture. Besides, it contains potassium, phosphorus, magnesium and calcium salts.

Vinapith was tested on poultry and cattle with encouraging results that allow its commercial scale production to be foreseen. It is suggested that in its concentrated form it partially or totally substitutes molasses in certain feed rations, and tests have begun to substitute vinasse for molasses in Biofermel obtainment.

Vinasse drying has implied some problems that are gradually being overcome. In the aspects of feeding, work continues under zootechnical and dietetic controls in the Mexican states of Veracruz and Michoacan.

In Venezuela, the production of pellets made up of a mix of pith and concentrated vinasse was initiated.

HARVEST TRASH

The harvest trash, made up by cane tops, green leaves and dry leaves or pieces of stalk, in the majority of cases are dispersed in the sugar cane fields. However, they represent a great potential for animal feeding and other products. In virtue of all this, lately important efforts are being directed towards their utilization, mainly in formulating fodder to feed animals or as power sources.

Particularly in Cuba, integral sugar cane is processed in the gathering and cleaning centers, succeeding in making 70% of sugar cane produced pass through these centers. In this manner, it is prevented that this waste be sent to the mills, as well as any foreign materials. In the fields many residues are left that can be easily gathered by sugar cane combines, dragging and packing machines and silo-harvesters.

Gathering the residues presents some difficulties, but when it is achieved it means that it will be possible to utilize a by-product that has many practical applications. Harvest residues should be treated by processing and then mixing with urea and molasses and stored in silos. This method, which is similar to that employed for hay, is the most widely used in order to improve the quality of fodder and utilize harvest residues. Untreated residues have a 3% protein and a 35% digestibility. Once treated, the protein content increases to over 9% and digestibility to 50%. Several processes have been developed to obtain products that are adequate for feeding animals from sugar cane residues which are normally done in simple facilities.

10. "SACCHARINA" (Treatcel trash)

In the search for feed rations for cattle, pig, caprine and poultry livestock in Cuba, a new product has been developed, based on agricultural trash (cane tops and leaves) that have been obtaining quite satisfactory results.

It was begun at a rustic scale and has now passed into the industrial scale. Its characteristics are the following : the cane tops and leaves of the sugar cane are ground without extracting the juice, until a finely shredded product is obtained. Mineral salts and urea are then added, mixing homogeneously; it is extended in a courtyard to be dried, forming a layer of 3-5 centimeters. The average density is of 68-70 tons per hectare. The mass is stirred to favour airing which originates fermentation between the sugar cane trash and the additives.

After 24 hours it can serve as feed for the animals or dried for storage. The product is kept for up to 180 days without losing its nutritional qualities or spoiling.

The first Saccharina producing plant was set in operation at the Empresa 14 de Julio Sugar Mill in Cuba, with a production of 11 thousand tons, and steps have been taken to reach 24 thousand tons with increased capacity. In Table 6 the nutritional values of the Saccharina are shown.

TABLE 6
NUTRITIONAL VALUES OF SACCHARINA

	Range
% Dry Substance (D.S.)	87.1 - 89.6
% Brute Protein	8.7 - 13.5
Energy (MJ/kg)	14.5 - 16.5
% Calcium (Ca)	0.3 - 0.4
% Phosphorous (P)	0.2 - 0.3

Source : Bohemia Magazine, 23-3-1990.
Weekly publication, Havana, Cuba

Saccharina is also obtained from integral sugar cane.

11. PLANTS FOR ANIMAL FEEDING IN THE LATIN AMERICAN AND CARIBBEAN COUNTRIES

Table 7 shows the plants that produce animal feed in the Latin American and Caribbean countries.

In Latin America and the Caribbean, 345 facilities produce animal feed from the sugar cane agro-industry by-products: 12 of them produce torula yeast; 8 saccharomyces; 8 protein molasses; 13 saccharina; 48 molasses-urea-pith; 88 pre-digested pith; 8 hydrolyzed pith; 3 Biofermel; 84 Gicabú; 3 melote; 4 concentrated vinasse; 5 harvest trash; 9 pajumel; 6 molasses-urea.

TABLE 7

LATIN AMERICA AND THE CARIBBEAN : CHARACTERIZATION OF FACILITIES FOR ANIMAL FEED FROM THE SUGAR CANE AGRO-INDUSTRY
(Plants)

PRODUCTS	ARGENTINA	BRAZIL	COLOMBIA	CUBA	GUATEMALA	HONDURAS	JAMAICA	MEXICO	PERU	VENEZUELA	TOTAL
TORULA YEAST				11				1			12
SACCHAROMYCES YEAST	1	2	2	3							8
PROTEIN MOLASSES				7							8
SACCHARINA		1		13							13
MOLASSES-UREA-PITH			1	42			1	2	1	1	48
PRE-DIGESTED BAGASSE				85	1					2	88
HYDROLIZED BAGASSE	1	4	2					1			8
BIOFERNEL						1		2			3
GICABU				84							84
MELOTE			3								3
CONCENTRATED VINASSE								3		1	4
HARVEST TRASH				5							5
PAJUNEL				9							9
MOLASSES-UREA				60							60
TOTAL	1	5	8	319	1	1	1	9	1	4	353

SOURCE : Prepared by GEPLACEA/UNDP with data from various different national and international sources, 1990

CONCLUSIONS AND RECOMMENDATIONS

Sugar cane has exceptional characteristics that may provide an answer to the problems of animal feeding. Latin America and Caribbean countries have had over 30 years of experience in this specialized area, including research and development, and establishing a total of 345 facilities. Sharing this accumulated knowledge may allow other regions or countries to adapt these technologies to animal feeding and establish such strategies according to their specific conditions in every case.

Feed obtained in the Latin American and Caribbean countries from the sugar agro-industry have been basically utilized to feed cattle, pigs and poultry under tropical conditions, with advantageous results, since investments - in the majority of cases - are not high, and facilities need not be complex.

Sugar cane and the sugar factories are dispersed in areas where there are various types of animals, or where they can easily be bred, since the combination of existing factors provide flexibility for the production of sugar/feed.

The GEPLACEA/UNDP Diversification Project for the Sugar Cane Agro-Industry has published a series of books where the experiences in animal feeding obtained in the countries of Latin America and the Caribbean region have been presented. These books are available to developing countries interested in this alternatives for the diversification of sugar cane.

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