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DRAWINGS ATTACHED

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(54) PRODUCTION OF LIVESTOCK FEED FROM SUGARCANE

(71) We, CANADIAN CANE EQUIPMENT, LTD., a company incorporated under the Laws of Canada, of 800 Dorchester Boulevard, W., Montreal 2, Quebec, Canada, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particular described in and by the following statement:—

This invention relates to the manufacture and use of feeds for livestock and to feed compositions containing sugarcane pith for use as livestock feed and to processes for the preparation, preservation and use thereof.

To feed the burgeoning world population, it is of importance that the efficiency of feed production systems be improved through more efficient use of existing facilities, introduction of new types of crops and livestock, and development of new feed processing techniques.

Present trends of feeding livestock which are used for human food production are of concern because of the direct competition between feed for livestock and food for man, as illustrated by the large amounts of grain usually incorporated in livestock rations. Despite this competition, there is an almost indispensable place for livestock agriculture in the overall pattern of food production. Whereas in some instances, livestock do seriously compete with man, in many others they may not. This latter situation is exemplified by herbivorous animals, particularly ruminants, such as cattle, which possess digestive abilities that man does not.

A digestive characteristic of ruminants, which sets them apart from man, is their ability to digest cellulose. Critical to this ability is the presence of a multi-compartment complex stomach which through the presence of various micro-organisms hydrolyzes the chemical linkages of cellulose eventually producing energy and releasing plant cellular components which are also utilized by the animal.

[Price 25p]

Cellulose is the structural component of all plant cells and is the most widely distributed single organic compound in the plant kingdom. Despite this abundance, only herbivorous animals, particularly ruminants, can utilize cellulose as a source of energy, since other species do not possess digestive facilities for the degradation of cellulose. Cellulase, the enzyme responsible for this degradation, is produced by microorganisms which reside in the complex stomach of ruminants. The volatile fatty acids produced by these micro-organisms serve as the actual energy source for the host animal.

In the tropics, competition between man and livestock for food is not as severe as in temperate countries because the cereals have been grown essentially for human consumption and livestock such as cattle have been left to procure their requirements from other sources, including whole sugarcanes and sugarcane by-products.

Sugarcane, a giant member of the grass family, is widely grown in tropical countries for the production of sugar, mainly for export. This crop provides one of the cheapest forms of energy food, with the lowest unit of land area required per unit of energy produced. Although sugar does not provide a complete diet for man, it represents about one seventh of his total energy intake. As an efficient energy producer, it has been estimated that the energy produced by one acre under sugarcane is equivalent to that produced by seven acres under wheat, twenty acres under milk production and over one hundred acres under beef production. Despite the energy potential of sugarcane, however, its use in livestock feed has not been widely advocated and past attempts to utilize sugarcane and sugarcane by-products in livestock feed have been somewhat unsuccessful.

Whole mature sugarcanes have been used in limited amounts for feeding to cattle. However, due to the high lignin content substantially increasing the rigidity of the outer rind,

the digestive tract of the ruminant may be seriously harmed, e.g., punctured, by the sharp coarse nature of whole sugarcane stalks. Sugarcane tops have also been consumed by draft animals in the sugarcane fields, but the year-round efficiency of their utilization alone is questionable since the nutritive values in the tops fall to significantly lower levels during the dry season in the tropical countries as compared to their levels during the wet season.

Bagasse, the coarse fibrous residue of certain sugarcane juice extraction processes, is primarily used at the sugar factory as fuel for plant operations. Depending on the efficiency of the crushing operation, bagasse may vary in its content of sugars, although in any event such sugars represent a relatively small fraction of the bagasse. To livestock, bagasse is an unpalatable feedstuff when used alone but intake and energy content have been increased by the addition of molasses, another of the sugarcane by-products. Bagasse utilization by livestock is primarily limited by its high content of highly lignified material, e.g., the hard outer rind fibers, which disrupts the digestive systems of the livestock. Further, investigations have shown that it takes more energy to digest the bagasse than is obtained from it by the livestock.

Bagasse pith, another sugarcane by-product, is obtained by expressing the sugar juice from the sugarcane and screening out the hard outer rind fibers. Again, because it may take more energy to digest bagasse pith than is obtained from it, molasses has been mixed in with the bagasse pith. See, for example, U.S. Patent 707,113.

Whether sugarcane or sugarcane by-products be used, additional nitrogenous ingredients are usually added to the feed as supplementary protein substituents, urea being the most common nitrogenous protein substitute used. A drawback, however, is that urea has been reported to have a toxic effect on ruminant livestock where too high a proportion is used in the feed.

Accordingly, a primary object of the present invention is to provide an improved livestock feed from sugarcane which feed substantially prevents or alleviates one or more of the disadvantages of the prior art as discussed above.

Another object is to provide a process for sustaining livestock with a feed composition which has a high energy content and is adequate as a sole dietary constituent, which is highly palatable, and which is easily digestible.

A further object is to provide a ruminant livestock feed composition which allows higher levels of urea to be incorporated therein without toxic effects on the ruminant livestock.

According to the present invention, a process is provided for sustaining livestock with a feed composition comprising sugarcane pith which contains substantially all of its

naturally present sugar juice, i.e., a substantial amount of the sugar juice originally occurring in the pith, the feed being substantially free from outer rind fibers. This sugarcane pith contains the fine, inner fibers of the sugarcane interior but is substantially free from the highly lignified outer rind fibers of the sugarcane and has been found not to be disruptive of the digestive system of livestock. Further, the voluntary intake of this pith by livestock has been found to be comparable to commercial dairy ration.

This sugarcane pith feed may be combined or mixed with nitrogenous protein substituents such as urea to provide an even better feed for ruminants. Surprisingly, it has been found that nitrogenous protein substituents such as urea may be mixed with the sugarcane pith in higher proportions than in previous feeds without toxic effects on ruminant livestock.

This sugarcane pith feed may be combined or mixed with chopped sugarcane tops to provide an even better feed for ruminants. It has been found that ruminants such as cattle seem to prefer even more a feed comprising a mixture of pith and tops as compared to a feed containing pith but no tops. A feed comprising a mixture of pith and tops is also beneficial from the standpoint that such a mixture has a higher level of nutritive values than pasture grasses in the tropics during the dry season.

The present invention also includes a process for preparing or producing ruminant livestock feed compositions from sugarcane comprising longitudinally opening or splitting the sugarcane stalk without expressing a significant amount of sugar juice from the pith, separating the pith from the highly lignified outer rind or rind fibers while retaining substantially all of the sugar juice in the pith, and then adding to the separated pith a nitrogenous protein substitute such as urea.

The processes may include preserving the livestock feed compositions by drying the sugarcane pith to a substantially moisture-free condition, and then storing the dried material in an airtight container, or placing the feed compositions in a silo with at least one lower alkyl carboxylic acid producing a microorganism such as *Lactobacillus*.

In order that the invention may be more clearly understood and readily carried out into effect reference is now directed to the accompanying drawing given by way of example and which pictorially illustrates a section of sugarcane and its various components.

The drawing shows a typical section of sugarcane stalk. This portion of the stalk has two nodes 12, the part therebetween being an internode. The outer rind fiber region 14 of the internode is hard, highly lignified, and is comprised primarily of interconnected fibrovascular bundles. A thin epidermis, mostly thin, fine fibers, covers the rind and clings loosely to the stronger and larger fibrovascu-

lar bundles. The interior 15 of the stalk is mainly soft pith that contains most of the sweet natural sugar juice. The soft pith inside the stalk also contains or is interspersed with thin, fine inner fibers which are not as highly lignified as the outer rind fibers. Surprisingly, these fine inner fibers have been found not to be disruptive or injurious to the digestive systems of livestock. When separated from the outer rind 14, the interior 15 of the stalk is sometimes referred to as pith. The exterior of the mature internode is usually covered with a thin film of waxy bloom or cutical wax, as it is frequently called. Wax is also found throughout the rind as well as on the surface. A ring 16 beneath the node 12 contains a high concentration of wax. A band 17 above the wax ring 16 is called the leaf scar. A root band 18 is a small section of the node just above the leaf scar 17 that usually differs in color from the internode and has many small dots. Under favorable moisture conditions, a root may develop at each dot, should the section of the stalk 10 be placed in the ground. Just above the root band 18, and not usually clearly distinct from it is a transition area known as the growth ring 19. Elongation and growth of the internode takes place in this area. A bud 20, when exposed to favorable moisture and temperature conditions and with proper stimulus, can develop into a new shoot. Expansion of the diameter of the stalk 10 may result in growth cracks 21 which may extend inwardly through the rind. Smaller barely distinct, corky cracks may develop along the internode and separate the fibrous material of the rind for short distances.

The particular composition of sugarcane may vary according to the particular species, as well as soil conditions, climate, and modes of cultivation. For example, sugarcane stalk may average from about 8 to 16 percent dry fiber and from 84 to 92 percent water and soluble solids (mostly sugars). Further, the pith may constitute from 75 to 80 percent of the cane stalk and may contain about 12 to 18 percent sugars (mostly sucrose, with some with glucose and fructose).

As stated above, the separated sugarcane pith utilized in the present invention contains a substantial amount of naturally present sugar juice and is substantially free from highly lignified outer rind fibers. It should also be understood that the separated sugarcane pith utilized in the present invention also contains the thin fine inner fibers as discussed above.

Preferably, the separated sugarcane pith has retained enough of the sugar juice such that the pith comprises more than 10 percent sugars. Most preferably, the sugarcane pith contains substantially all of its original sugar juice. Over a period of time, the separated pith may lose some of its water content due to evaporation and some of its sugar content

due to chemical decomposition. These losses, however, are normally negligible with respect to the function of the pith as a feed for livestock.

The sugarcane pith utilized in the present invention is preferably separated from the hard outer rind of the sugarcane stalk by longitudinally opening or splitting the stalk without expressing a significant amount of sugar juice from the pith, and thereafter separating the pith from the outer rind fibers while retaining substantially all of the sugar juice in the pith.

The splitting of the stalk and separation of the pith is preferably achieved using the methods and apparatus described in one or more of the following United States patents and patent applications, all of which are incorporated herein by reference: U.S. Patents 3,424,612, 3,464,881, and 3,567,511 and British Patents Nos. 1,126,491, 1,126,492, 1,126,493, 1,225,849 and 1,226,254. As described therein, the splitting of the stalk and separation of the pith involves handling the sugarcane stalks individually rather than in bulk as is done in conventional whole cane milling operations where masses of randomly oriented sugarcane are delivered in bulk to massive machinery that cuts, crushes, shreds and breaks the whole cane stalk, and under high pressure forcefully squeezes out the natural sugar juices.

For example, the sugarcane pith utilized in the present invention may be obtained by positively feeding an aligned stalk against a stalk splitting or cutting edge which opens the stalk up longitudinally, and then brushing, scraping, scooping, or milling the pith away from the exposed inner portion or side of the split stalk. These operations are performed without any effective squeezing or compressing of the pith so that the sugar juice may be retained in the pith. The means or apparatus for performing these operations are not a part of the present invention and thus for sake of brevity are not described further herein. For a more detailed discussion of the separation process and apparatus, reference may be made to the above listed U.S. patents and patent applications.

Because of the high-energy content of the uncompressed sugarcane pith, it may be suitably used in accordance with the instant invention as the sole feed to sustain or maintain livestock, e.g., ruminants such as cattle and sheep, and non-ruminants such as swine.

Additional dietary supplements, however, may be added to the sugarcane pith to enhance its use as a livestock feed. When such dietary supplements are used, the pith may comprise, for example, at least about 10 percent, and preferably from about 20 to 99 percent, and most preferably from about 50 to 80 percent, of the feed, on an as-fed weight basis, depending upon the amount of supplement incorporated into the feed.

5 An example of a particular nutrient which
may be added to the uncompressed sugarcane
pith to increase the nutritive value of the pith
in a ruminant livestock feed is a nitrogenous
protein substitute which can be converted into
protein by the livestock. That is, a limiting
factor in the utilization of roughage by rumi-
nants such as cattle may be an inadequate
supply of nitrogen with which to satisfy the
growth requirements of the microbial popula-
tion of the ruminant's complex stomach.
Although many non-protein nitrogenous com-
pounds may be useful to fulfill this need, urea
is most frequently used.

15 Cases of urea toxicity have been reported to
result where high concentrations of urea were
used in the ruminant livestock feed ration. The
present invention, however, allows higher
levels of urea to be incorporated into the feed
in amounts of about 1 to 5 percent, preferably
1 to 2 percent, and most preferably about 1.5
to 2 percent, on an as-fed weight basis. The
use of biuret (carbamylurea) is also contem-
plated in the present invention as a substitute
for all or a portion of the urea in the feed.

25 Another example of a particular nutrient
which may be added to the uncompressed
sugarcane pith to increase the nutritive value
of the pith in a ruminant livestock feed is
chopped sugarcane tops, i.e., the upper 20 to
40 percent, typically about 30 percent, by
weight, of the sugarcane plant, which upper
portion has been chopped or reduced into
smaller pieces to facilitate ingestion by the
livestock. Such chopped sugarcane tops may
be incorporated into the feed in amounts of
about 20 to 40 percent, preferably about 25 to
35 percent, and typically about 30 percent, on
an as-fed weight basis.

40 An example of a particular nutrient which
may be added to the sugarcane pith to increase
the nutritive value of the pith in a non-rumi-
nant, e.g., pigs and poultry, livestock feed are
the non-vegetable protein sources such as fish
meal or blood meal. Such non-vegetable pro-
tein sources may be incorporated into the feed
in amounts of about 1 to 40 percent, prefer-
ably about 20 to 30 percent, on an as-fed
weight basis.

50 Other protein supplements may also be
added to the livestock ration. For example,
brewery by-products or vegetable protein sup-
plements such as soybeans, clover, alfalfa, peas,
peanuts, beans, cottonseed and coconut oil
may be added as a meal or in some other
suitable form, and in amounts of about 1 to
90 percent, preferably about 40 to 80 percent,
on an as-fed weight basis.

60 Mineral supplements may also be added
to the livestock ration, for example, as salts
in a dry mix to facilitate ease and convenience
of handling and use. These mineral supplying
salts may include necessary anions such as
the chlorides, bromides, iodides, sulphates,
phosphates, nitrates, carbonates and the like,

of various elemental substances necessary to
promote proper growth and function. Simi-
larly, the necessary metallic and non-metallic
elements such as sodium, potassium, calcium,
iron, copper, phosphorous, sulfur, nitrogen, and
the like may also be added in an appropriate
form. The mineral supplement may be present
in the feed in amounts of about 1 to 20 percent,
and preferably from 1 to 5 percent, on an
as-fed weight basis. For example, a suitable
mineral mix may contain 10 to 20 percent
calcium, 5 to 10 percent phosphorous, 25 to
50 percent sodium chloride, and from about
.001 to 2 percent iodine.

Additional nutrients which may be mixed
with or added to the composition of the instant
invention include vitamins which are bio-
chemically necessary to maintain growth and
functioning of organic tissue. Particular vita-
mins include, among others, vitamin A, neces-
sary to maintain the integrity of epithelial
tissue, vitamin B, which aids in preventing
pernicious anemia, vitamin B₁₂, riboflavin,
thiamin, and vitamins C, D, and E, to name
only a few.

Of course, other ingredients may be added
to the livestock feed composition of the pre-
sent invention to modify it without departing
from the spirit and scope of the invention.
For example, various liquid or semi-liquid
additives can be used to enable the feed to be
pressed into pellets, bars, or cakes to facilitate
handling. If desired, additional natural or
artificial flavors may be added to further in-
crease the palatability of the feed. Various
other curative or preventive compounds or
compositions may also be added to the feed,
such as drugs or medicines in the form of
powders, granules, tablets, or liquids of varying
viscosity. Similarly, other compounds may also
be added to or mixed with the feed to obtain
desired effects on the livestock.

The above described livestock feed composi-
tions may be preserved over a period of time
by several different processes or methods. One
of these methods includes drying the sugarcane
pith to a substantially moisture free condition,
e.g., a moisture content of less than 10 percent,
and then storing or placing the dried material
in an airtight container or enclosure. For ex-
ample, the sugarcane pith may be dried in a
conventional suspension type hot air dryer,
and the dry material may then be stored in
sealed polyethylene bags. Drying temperatures
may vary, but usually they are within the
range of from 25°C to about 125°C. If de-
sired, the sugarcane pith material may be
milled or ground after drying to produce a
free flowing powder which may be pelletized
to increase the bulk density of the material.

Yet another way that the above-described
livestock feed compositions may be preserved
is an ensiling process which involves placing
or storing in contact in a silo the sugarcane
pith material and at least one lower alkyl

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carboxylic acid-producing microorganism. The term "silo" is used in its conventional sense and includes trenches, pits, and vertical or horizontal containers, e.g., cylinders, sealed to exclude air and used for storing silage. As stated above, the sugarcane pith material is placed in a silo in contact with lower alkyl carboxylic acid-producing microorganism.

The sugarcane pith material may be placed in a silo in contact with an amount of lower alkyl carboxylic acid producing microorganisms sufficient to produce a pH of the material of less than about 4, e.g., about 3 to 4, within an initial ensiling period of 7 days. Typically, the sugarcane pith material as separated from the outer rind material contains a sufficient amount of these lower alkyl carboxylic acid producing microorganisms to preserve the pith in the ensiling process. The presence of these lower alkyl carboxylic acid producing microorganisms is believed to result from infestation of the growing sugarcane in the field by the microorganisms. However, if needed or desired, about 0.1 to 10 percent of an actively fermenting culture of the appropriate microorganism may be added to the pith before ensiling.

Suitable microorganisms include *Lactobacillus*, e.g., *Lactobacillus delbrueckii* and *L. pentosaceticus*, and *Acetobacter*, e.g., *Acetobacter melanogenum*. Production of lower carboxylic acids by microorganisms is well known *per se*. See, for example, the production of acetic acid using *Acetobacter*, the production of lactic acid using *Lactobacillus* and the production of citric acid using *Citromyces*, and the description of actively fermenting cultures in the *Encyclopedia of Chemical Technology*, Kirk and Othmer, Interscience Inc., New York, 1951, Vol. 6, pages 317 to 375. It is thought that these microorganisms react with the sugar in the pith to produce these lower carboxylic acids which act as preservatives for the sugarcane pith.

The invention is further illustrated by the following examples; all parts and percentages in the examples and throughout the specification and claims are by weight unless otherwise indicated.

EXAMPLE I.

The following example was conducted at an altitude of approximately 1200 feet above sea level with the temperature during this period varying between an average minimum of 72°F and average maximum of 88°F. The average monthly rainfall was 5.28 inches with the highest 6.65 inches.

Six of the cattle used in this run were Senepol steers (derived from breeding 3/4 Senegal and 1/4 Red Poll) which represent livestock with beef producing potential, cross-bred for tropical conditions. The Senepol

steers were in good condition at the beginning of the run and ranged in weight from 200 to 402 pounds. The remaining steers used in the run were Holstein and represent livestock essentially bred for milk production under tropical conditions. These Holstein steers were from four to eight months old and weighed from 160 to 206 pounds with a physical condition somewhat below that of the Senepol steers.

The steers used in this run were housed individually to enable separate feeding and watering.

The first portion of the run involved an intensive feeding period consisting of 77 days. Two different rations were tested on the steers. Four steers of each breed were placed on a supplemented fresh sugarcane pith feed or ration, and two others of each breed were placed on a control consisting of a dairy ration and a citrus pulp ration. During these 77 days, the steers were penned separately and individually fed and watered. Initially, the steers were fed once a day but during the last month of the period, the steers consuming the most feed were fed twice a day. The sugarcane pith leftover from the previous day's feeding was always discarded. The weight of each steer was determined during the entire 77-day period.

The second phase of the run involved an extended feeding period of 21 days wherein the pen partitions in the livestock shelters were removed and the ten steers, i.e., the eight formerly on the sugarcane pith supplemented ration, plus the two Senepol steers formerly on the control ration, were group fed the sugarcane pith supplemented ration for the entire time. This extended feeding period was used to determine what effect individual versus group feeding might have on livestock performance. The steers were weighed at the beginning and the end of the 20-day interval although no data was collected on individual feed consumption during this period.

The sugarcane pith used in the supplemented feed ration was obtained daily from mature sugarcane stalks which normally would be used for sugar production. The stalks were first split down the middle into halves and each fed through a separator similar to that disclosed in British patent No. 1,225,849. Using this particular method and apparatus, the pith was milled away from the split stalk portions and obtained with substantially all of the sugar juice originally contained therein and was in the form of a fluffy or flocculant mass free from the highly lignified outer rind fibers and any waxes but containing the fine, inner fibers of the pithy interior of the sugarcane stalk.

A supplement of the following compositions was fed to the livestock at a rate of 2 pounds

and 1 pound per animal per day to the Senepols and the Holsteins, respectively.

	Percent
5 Soybean Meal (44% Protein)	67
Urea (42% Nitrogen X 6.25=262% Crude Protein)	13
10 Mineral Mix (Purina)	20

The approximate composition of the mineral mix as noted by the manufacturer was substantially as follows:

15 Calcium	13—15
Phosphorous (not less than)	6.5
Iodine (not less than)	0.0006
Sodium Chloride	40—45

20 A Vitamin A pre-mix (10,000 International Units/gram) was added at a rate of 0.50 grams per 450 grams of supplement. The supplement was prepared fresh daily and mixed into the top one-third of the sugarcane pith which was fed *ad libitum* to the steers, 25 i.e., the steers were fed as much sugarcane pith as they desired.

The control animals were fed a combination of a commercial dairy ration at 4 pounds per animal per day and a dried citrus pulp which was fed *ad libitum*, i.e., as desired. The commercial dairy ration comprises 16% minimum crude protein including not more than 5% equivalent crude protein from urea, 2.3% minimum crude fat and 14% maximum crude fiber according to the manufacturers specification.

For the greater part of the period, the weights of the two largest Senepol steers were estimated with a calibrated tape measure (e.g., a Weight Band, distributed by Cooper, McDougall and Robertson, Ltd., Berkhamstead, Herts, England) because of their large size which precluded the use of an available weighing scale. The body weight changes of the steers during the first 77-day period of the test are summarized in Table I and Table II. The body weight gain of the Senepol steers was almost twice the rate gain of the Holstein steers when fed the sugarcane pith supplemented ration. A possible explanation for the difference in rates of gain between the two breeds might be attributed to the heavier initial weight of the Senepol steers as well as the reduced intake of ration by the Holstein steers (Table I) and their generally poorer pre-trial condition.

TABLE I

	Sugarcane Pith		Control	
	Holstein	Senepol	Senepol	Holstein
Number of steers	4	4	2	2
Av. Initial Wt. (lbs.)	181	277	301	179
Av. Final Wt. (lbs.)	236	383	340	291
Av. Total Gain (lbs.)	55	106	39	112
Av. Daily Gain (lbs.)	0.71	1.38	0.51	1.45
Daily Feed Consumed				
Sugarcane Pith, lbs.	16.4	25.2	—	—
Supplement, lbs. (as fed)	1.0	1.9	—	—
Citrus Pulp, lbs. (as fed)	—	—	3.0	3.0
Dairy Ration, lbs. (as fed)	—	—	3.4	3.9
Total (as fed)	17.4	27.1	6.4	6.9
Feed Efficiency				
(As Fed)	26.7	19.9	12.4	4.7

TABLE II

Liveweight changes of steers during 77-day period (pounds)

Steer No. ^{1,2}	Ration	Initial Wt.	Final Wt.	Total Gain	Daily Gain
S1	Sugarcane Pith	354	489	135	1.75
S2	Sugarcane Pith	234	318	84	1.09
S3	Sugarcane Pith	246	356	110	1.42
S4	Sugarcane Pith	274	370	96	1.25
S5	Control	200	208	8	0.10
S6	Control	402	472	70	0.91
H1	Sugarcane Pith	178	248	70	0.91
H2	Sugarcane Pith	170	208	38	0.49
H3	Sugarcane Pith	172	208	36	0.47
H4	Sugarcane Pith	206	282	76	0.98
H5	Control	198	320	122	1.58
H6	Control	160	262	102	1.32

¹S — Senepol steers²H — Holstein steers

Table III and Table IV illustrate the body weight changes of the animals during the second phase of the trial, i.e., the additional 21-day period. Values show that steers fed the sugarcane pith supplemented ration under feed-lot conditions achieved even higher rates of gain than when individually pen fed.

TABLE III

Weight changes during additional 21-day period (pounds)

	6-Senepols	4-Holsteins
Av. Initial Wt. (Aug. 31st)	369	236
Av. Final Wt. (Sept. 20th)	407	254
Av. Total Gain	38	18
Av. Daily Gain	1.81	0.86

TABLE IV

Weight changes of steers on sugarcane pith ration over additional
21-day feeding period (pounds)

Steer No. ^{1,2}	Initial Wt.	Final Wt.	Total Gain	Average Daily Gain
S1	489	538	49	2.29
S2	318	348	30	1.43
S3	356	389	33	1.56
S4	370	413	43	2.05
S5	208	248	40	1.89
S6	472	507	35	1.66
H1	248	270	22	1.05
H2	208	238	30	1.43
H3	208	230	22	1.05
H4	282	280	-2	

¹S — Senepol steers

²H — Holstein steers

For purposes of comparison, tropical cattle under grazing conditions, on good feed at the best time of year, generally realize satisfactory weight gains of approximately 0.75 pounds per day.

Thus, it can be seen that fresh sugarcane pith is very satisfactory when used in a ration as the main source of energy for livestock.

In summary, comparing the daily average weight gains made by the Senepol steers in both the 77-day and 21-day periods, with that obtained under existing systems of cattle rearing in the tropics, it can be seen that production on a sugarcane pith based ration is superior to that normally obtained.

EXAMPLE II.

This example was conducted under substantially the same climate conditions as Example I.

Eight mature indigenous male sheep weighing between 40 and 60 pounds were used in this example. The animals were kept in individual cages to enable total excrement collection and voluntary intake determinations.

The first phase of the run consisted of feeding the sheep the same composition as that fed to the steers in Example I; namely, sugarcane pith fed *ad libitum* and 200 grams of supple-

ment. The actual 7-day test period employed to obtain the desired values followed a five-week adaptation period wherein the animals were all fed the sugarcane pith *ad libitum* with an increasing supplement mix which eventually attained the 200 gram level. The second phase consisted of the *ad libitum* feeding of sugarcane pith and 100 grams of supplement to the test animal for seven days. Immediately following a 7-day adaptation period during which the animals were given time to accustom themselves to the dietary variation, the supplement level was reduced in the second phase of the run in order to determine whether the nutrients other than those supplying energy were limiting the utilization of the sugarcane pith. Digestibility and voluntary intake values for the ration were determined for both phases of the test.

The sugarcane pith and supplement were prepared as described in Example I, with the supplement mix for each sheep pre-weighed and individually packaged. Both feed and water were constantly available to all of the sheep. Feed consumption was determined daily wherein the amount of feed available on each successive day was 10% in excess of the previous day's consumption per animal. Feed

samples were also chemically analyzed on a daily basis. Provisions were also made for collection of animal excrement daily during each of the 7-day test periods for chemical analysis. The animals were weighed before and after excrement collection to obtain data for calculating the Relative Intake of the ration. The sheep became adapted to their new environment and feed rather quickly and did not exhibit any ill effects during the trial.

Chemical analyses (Table V) were conducted for dry matter and crude protein content of both the feed and the excrement samples according to procedures of the Association of

Official Agricultural Chemists (Official Methods of Analysis—10th Edition, 1965). The crude protein content was calculated after a determination of nitrogen by the Kjeldal method followed by multiplying the value obtained by 6.25. The cellulose content of both the feed and the excrement was determined by a method as described by Donefer et al, *Journal of Animal Science*, 19, 545. An oxygen bomb calorimeter was used to determine the gross energy content of the feed and the excrement samples.

The chemical analysis of the feed used is set forth below in Table V.

TABLE V

Chemical analysis of components of ration

Ingredient	Dry Matter	Gross Energy k.cal/gm	Crude Protein	Cellulose
	%		%	%
Sugarcane pith	91.9	4.25	1.5	17.5
Supplement mix	87.3	3.44	70.9	8.0

From Table V it may be noted that the cellulose content of the sugarcane pith is higher than that normally found in grain seeds, such as corn, barley, oats, etc.

The relatively low gross energy value of the supplement mix is a result of the addition of mineral components which are non-energy containing materials. The high crude protein content reflects the urea contained in the supplement which has the equivalent of over 250% crude protein. The value for the cellulose content is somewhat higher indicating a contribution by the soybean meal which contains about 10% cellulose.

The apparent digestibility coefficients of dry matter, gross energy, crude protein and cellulose were calculated using the following formula:

Coefficient of digestibility (%) =

$$\frac{(F_o X A_o) - (F_i X A_i)}{(F_o X A_o)} \times 100$$

where

F_o = grams of feed consumed

F_i = grams of excrement

A_o = percentage nutrient in feed

A_i = percent nutrient in excrement

(nutrient relates to dry matter, crude protein, cellulose or kilocalories of gross energy per gram, with all data converted to dry matter basis).

The digestibility coefficient is a function of

the efficiency of the animals' digestive system, while the gross energy is that total energy theoretically available for digestion from a feed ration.

The Relative Intake of each feed was calculated from the following formula:

$$\text{Relative Intake} = \frac{\text{Observed intake}}{80(W_{kg}^{0.75})} \times 100$$

where $(W_{kg}^{0.75})$ is the metabolic body size of the animal which takes into account the animal's weight.

The Nutritive Value Index (NVI) for feeds is then calculated by multiplying the Relative Intake of the feed by its percent gross energy digestibility.

N.V.I. = Relative Intake $\times$ gross energy digestibility, %.

Relative Intake (RI) is a measure of voluntary intake and is compared to that of standard high-quality forage. The Nutritive Value Index (NVI) is an index of feed nutritive value, which is the product of the relative intake and the gross energy digestibility of a particular feed composition. It is used as a measure of the digestible energy intake potential of the ration.

Values for the Apparent Digestibility of dry matter, gross energy, crude protein and cellulose, as well as Relative Intake and Nutritive Value Index, are summarized in Table VI.

TABLE VI

Summary of apparent digestibility values, Relative Intake, and Nutritive Value Index of sugarcane pith supplemented ration fed to sheep

	Level of Supplementation	
	100 gm	200 gm
	Apparent Digestibility (%)	
Dry matter	77.2	77.6
Gross energy	76.1	76.8
Crude protein	71.8	80.8
Cellulose	57.1	59.6
Relative Intake	84.9	99.2
Nutritive Value Index	64.7	76.2

5 These values indicate that all the components under investigation are adequately digested and that the metabolic utilization of the energy from the sugarcane pith was not limited by nutrient deficiency. The high value of cellulose digestibility is of particular interest in that it suggests the cellulose utilization was not appreciably limited by a lignin complex.

10 Further, the Relative Intake Value of 99.2 observed for the sugarcane pith feed at the 200 gm. supplement level is essentially the same as that of high quality legume forage such as alfalfa or clover hay.

15 The slight increase in cellulose digestibility at higher supplementation levels may be attributed to increased microbial activity in the animals digestive system. This is based on the assumption that the increased nutrient contribution at a higher supplementation level may have acted as a stimulant to the micro-organisms responsible for cellulose degradation.

20 The availability of the gross energy of the sugarcane supplemented ration (approximately

75%) is on the order of that observed for high-quality grain such as barley. It should be noted, however, that the digestibility values presented represent contributions by both the sugarcane pith and the supplement components of the ration. In spite of this, these energy values can be largely attributed to the sugarcane pith since it comprises approximately 85% of the entire ration. In fact, the energy availability of the sugarcane pith alone should be higher than that reported for the mixture since the supplement to which it is added would not be considered a good source of energy.

The weight gains of the sheep on each of the feeding schedules over the 7-day trial periods are tabulated in Table VII. The results indicate that the animals gained more on the higher level of supplementation. The results also indicate the effect of a superior nutrient contribution resulting in increased weight.

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TABLE VII

Live weight changes¹ of sheep on rations over 7-day test periods

	Level of Supplementation	
	100 gm	200 gm
Av. Total Gain (grams)	269	766
Av. Daily Gain (grams)	38.4	109.4

¹ Values represent average of eight sheep.

EXAMPLE III.

Under substantially the same climate conditions as in Example I, a young Holstein bull was over a period of about 4 weeks feed *ad libitum* nothing but sugarcane pith. The pith was prepared as described in Example I except that no supplement whatsoever was used. The bull remained healthy and suffered no noticeable ill effects during the feeding period. When the bull was butchered, the digestive tract looked healthy and normal, with no signs of punctures or other ill effects.

EXAMPLE IV.

Under substantially the same climatic conditions as in Example I, an ensiling process was used to preserve fresh sugarcane pith over a period of several months.

A pit silo was constructed 30 feet long, 8 feet wide and 6 feet deep at one end and 3 feet deep at the other end with a sloping bottom. A sump was constructed at the deep end to collect any effluent. The whole of the silo was lined and covered with polyethylene sheeting.

The silo was filled with fresh sugarcane pith in contact with naturally present *Acetobacter melanogenum* and *Lactobacillus delbrueckii*, compressed by tamping and covered for a period of 6 weeks. The silo was then opened at the shallow end and samples of the ensiled material analyzed and the following results were obtained.

Dry Matter 35.04 per cent
pH 3.20
Acids Present acetic; lactic

The ensiled pith material was fed to the animals used in Example II to determine its palatability. From observations made, the animals consumed this material just as readily as they had the freshly prepared sugarcane pith.

EXAMPLE V.

Several pounds of freshly prepared sugarcane pith were completely dried in a conventional suspension type hot air dryer at 100°C. A portion of the dried material was first milled to increase its bulk density and was then stored in sealed polyethylene bags for approximately 1 year, after which the material was examined and analyzed showing that no deterioration had taken place during storage.

EXAMPLE VI.

Under substantially the same climatic conditions as in Example I, several pigs including both adults and weaned piglets were fed a similar ratio to that used in Example I, except that fish meal was substituted for the urea. In addition, the animals received household slops. All of the animals appeared to thrive well and suffered no noticeable ill-effects during the feeding period.

EXAMPLE VII.

Under substantially the same conditions as in Example I, cattle were fed *ad libitum* a mixture of about 70 percent sugarcane pith and 30 percent chopped sugarcane tops. The cattle appeared to prefer this mixture over a feed of sugarcane pith alone, and all of the animals appeared to thrive well and suffered no noticeable ill-effects during the feeding period.

WHAT WE CLAIM IS:—

1. A process for feeding livestock, which comprises providing the livestock with a livestock feed comprising sugarcane pith containing substantially all of its naturally present sugar juice and the fine inner fibers of the interior of sugarcane stalk, and substantially free from outer rind fibers.

2. A process according to claim 1 wherein the sugarcane pith contains more than 10 percent by weight of naturally present sugars.



TABLE VII

Live weight changes¹ of sheep on rations over 7-day test periods

	Level of Supplementation	
	100 gm	200 gm
Av. Total Gain (grams)	269	766
Av. Daily Gain (grams)	38.4	109.4

¹ Values represent average of eight sheep.

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EXAMPLE IV.

Under substantially the same climatic conditions as in Example I, an ensiling process was used to preserve fresh sugarcane pith over a period of several months.

A pit silo was constructed 30 feet long, 8 feet wide and 6 feet deep at one end and 3 feet deep at the other end with a sloping bottom. A sump was constructed at the deep end to collect any effluent. The whole of the silo was lined and covered with polyethylene sheeting.

The silo was filled with fresh sugarcane pith in contact with naturally present *Acetobacter melanogenum* and *Lactobacillus delbrueckii*, compressed by tamping and covered for a period of 6 weeks. The silo was then opened at the shallow end and samples of the ensiled material analyzed and the following results were obtained.

Dry Matter 35.04 per cent
pH 3.20
Acids Present acetic; lactic

The ensiled pith material was fed to the animals used in Example II to determine its palatability. From observations made, the animals consumed this material just as readily as they had the freshly prepared sugarcane pith.

EXAMPLE V.

Several pounds of freshly prepared sugarcane pith were completely dried in a conventional suspension type hot air dryer at 100°C. A portion of the dried material was first milled to increase its bulk density and was then stored in sealed polyethylene bags for approximately 1 year, after which the material was examined and analyzed showing that no deterioration had taken place during storage.

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Under substantially the same climatic conditions as in Example I, several pigs including both adults and weaned piglets were fed a similar ratio to that used in Example I, except that fish meal was substituted for the urea. In addition, the animals received household slops. All of the animals appeared to thrive well and suffered no noticeable ill-effects during the feeding period.

EXAMPLE VII.

Under substantially the same conditions as in Example I, cattle were fed *ad libitum* a mixture of about 70 percent sugarcane pith and 30 percent chopped sugarcane tops. The cattle appeared to prefer this mixture over a feed of sugarcane pith alone, and all of the animals appeared to thrive well and suffered no noticeable ill-effects during the feeding period.

WHAT WE CLAIM IS:—

1. A process for feeding livestock, which comprises providing the livestock with a livestock feed comprising sugarcane pith containing substantially all of its naturally present sugar juice and the fine inner fibers of the interior of sugarcane stalk, and substantially free from outer rind fibers.

2. A process according to claim 1 wherein the sugarcane pith contains more than 10 percent by weight of naturally present sugars.



3. A process according to claim 1 or 2 for sustaining ruminants, which comprises providing the ruminants with a livestock feed comprising additionally nitrogenous protein substitute.
4. A process according to claim 3 wherein the nitrogenous protein substitute is urea.
5. A process according to claim 3 or 4 which further includes providing the ruminants with chopped sugarcane tops along with the sugarcane pith.
6. A process according to claim 1 for sustaining non-ruminants, which process comprises providing the non-ruminants with a livestock feed comprising additionally a natural protein source.
7. A process according to claim 6 wherein the natural protein source is blood or fish meal and wherein the sugarcane pith contains more than 10 percent by weight of naturally present sugars.
8. A livestock feed composition for use in the process of claim 1, comprising sugarcane pith which pith contains substantially all of its naturally present sugar juice and the fine inner fibers of the interior of sugarcane stalk and is substantially free from outer rind fibers.
9. A composition according to claim 8 for feeding ruminants and which further includes chopped sugarcane tops.
10. A composition according to claim 8 or 9 for feeding ruminants and which further includes a nitrogenous protein substitute or a natural non-vegetable protein source.
11. A composition according to claim 8 for use as a ruminant livestock feed, comprising a mixture of a) sugarcane pith containing substantially all of its naturally present sugar juice and the fine inner fibers of the interior of sugarcane stalk, and substantially free from outer rind fibers; b) a vegetable protein source; c) a nitrogenous protein substitute, and d) a mineral mix.
12. A process for producing the livestock feed claimed in claim 8 comprising:—
- longitudinally opening sugarcane stalks without expressing a significant amount of sugar juice from the pith; and
 - separating the pith from the outer rind fibers while retaining substantially all of the sugar juice in the pith and substantially all of the fine inner fibers of the interior of sugarcane stalk.
13. A process according to claim 12 and further comprising adding to the separated pith a nitrogenous protein substitute or a natural protein source.
14. A process according to claim 13 wherein the nitrogenous protein substitute is urea, and wherein the process further comprises adding a vegetable protein source and a mineral mix to the separated pith.
15. A process according to claim 12 which further comprises drying the pith to a substantially moisture free condition, and thereafter enclosing the pith in an airtight container.
16. A process for producing a ruminant livestock feed from sugarcane, which comprises:
- longitudinally opening sugarcane stalks without expressing a significant amount of sugar juice from the pith;
 - milling the pith from the outer rind fibers while retaining substantially all of the sugar juice in the pith and substantially all of the fine inner fibers of the interior of sugarcane stalk;
 - chopping the tops of the sugarcane; and
 - adding to the separated pith:
 - urea;
 - a meal selected from soybean, clover and alfalfa;
 - a mineral mix; and
 - chopped sugarcane tops.
17. A process according to claim 16 wherein a microorganism selected from *Lactobacillus* and *Acetobacter* is added to the feed.
18. A livestock feed product produced by the process of claim 16.
19. A process of feeding livestock according to claim 1 substantially as hereinbefore described.
20. A livestock feed composition according to claim 8 substantially as hereinbefore described.
21. A process for producing a ruminant livestock feed from sugarcane according to claim 16 substantially as hereinbefore described.

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