EFFECT OF PROCESSING ON THE NUTRITIONAL VALUE OF FEEDS

Proceedings of a Symposium
Gainesville, Florida
January 11-13, 1972

Sponsored by

Committee on Animal Nutrition
Agricultural Board
National Research Council

Center for Tropical Agriculture
University of Florida

Department of Animal Science
University of Florida

NATIONAL ACADEMY OF SCIENCES / WASHINGTON, D.C. / 1973

INCAP I-690

R. BRESSANI

Effect of Processing on the Nutritional Value of Feeds in Central America

INTRODUCTION

The efficient development of animal industry requires, among other things, knowledge of the chemical composition and nutritive value of feedstuffs utilized in the preparation of mixed feeds. Such knowledge becomes even more important when it is recognized that the composition of such diets varies according to the needs of the animal to meet satisfactorily specific functions, such as growth, production, maintenance, and reproduction.

In Central America such diets are, in many cases, not easily balanced, because of the lack of sufficient kinds of feedstuffs containing adequate levels of essential nutrients. Besides the limited number of feedstuffs and their low availability, present problems with most of them include a lack of uniformity in raw materials, which introduces significant variations in composition as well as improper processing, resulting in products of low nutritional value. Furthermore, most products are not defined or classified, which makes possible their adulteration.

Knowledge of the effect of processing on the nutritive value of feedstuffs is very limited in Central America. It appears that the main concern is to find and make available various kinds of feedstuffs manufactured through primitive processing techniques in most cases. There are several reasons for this:

- The area is generally underdeveloped.
- With a few exceptions, processing industries are just beginning to appear.
- Intensive animal production is rather new in the area.
- There is a general lack of knowledge concerning the effect of processing on the concentration and availability of nutrients.

This report summarizes some of the research findings carried out by the Division of Food and Agricultural Sciences of the Institute of Nutrition of Central America and Panama (INCAP). Some of the work has been carried out at the laboratory level; however, research has also been done with industries, particularly those processing cottonseed. While this work has been in progress, it has been found that interest in producing good-quality feedstuffs is constantly increasing.

VARIATION IN CHEMICAL COMPOSITION OF PROCESSED FEEDSTUFFS

Interest in feedstuffs is relatively new in Central America. Those interested have used as a reference the well-known feed-composition values of Morrison's book (Morrison, 1959). However, production was often very poor. To remedy the situation, work was started on a survey of feedstuffs in Central America. Samples were collected and attempts were made to define the conditions under which they were produced. The samples were analyzed for their proximate chemical composition, and, in some cases, analysis included amino acid content, mineral and vitamin concentration, and biological assays for protein quality and nutritive value in general (Braham *et al.*, 1969; Bressani *et al.*, 1968a; Elías and Bressani, 1970; Gómez Brenes and Bressani, 1970; Zaghi and Bressani, 1969).

Products from Vegetable Origin

Oilseed Meals Among oil-containing seeds, the one that is most available in Central America is cottonseed (Bressani *et al.*, 1968b). Sesame is processed to a limited extent (Zaghi and Bressani, 1969). Other oil-bearing seeds processed include the fruit of the African palm, corozo nuts, and copra (De la Fuente *et al.*, 1971). Because of the problems encountered in the production of cottonseed and the increasing demand for fats and oils, other oil-containing seeds are beginning to be exploited. For example, peanuts will be processed in 1972, although peanut meal is still not available in the area.

In most cases, oilseed processors in Central America pay little attention to nutritive value, particularly with respect to protein. They are concerned only with oil extraction. Processing plants include hydraulic pressing, prepress solvent, and solvent procedures (Bressani *et al.*, 1968a). Because of this, the quality of the material available is variable. Table 1 summarizes chemical results on 128 cottonseed meal samples from Central America and on 7 for sesame meal (Bressani *et al.*, 1968a; Zaghi and Bressani, 1969). The results on cottonseed meal reveal significant differences in oil content, differences that can be traced to poor extraction procedures, to method of extraction, or to the addition of soap stocks to the extracted seed.

Crude fiber and total protein content are variable. Both depend on the amount of hulls left with the kernel before processing and on the amounts added back to the meal. Free gossypol is highly variable. The low values, correlating well with low available lysine content and low nitrogen solubility, suggest that the meal was produced by screw-pressing operations, while samples with a high free-gossypol level suggest a material coming from a solvent-extraction plant. Variability in chemical composition is also evident in sesame meal.

From these data it can be concluded that very little attention is given to nutritive quality, that processing conditions are, in general, not well

TABLE 1 Variation in Composition of Oilseed Meals in Central America (%)[a]

	Cottonseed Meal		Sesame-Oil Meal	
Component	Minimum	Maximum	Minimum	Maximum
Dry matter	89.0	93.7	90.4	96.6
Crude fat	2.5	9.1	0.6	13.2
Crude fiber	4.2	14.2	5.2	7.0
Crude protein	35.8	51.3	38.0	45.1
Ash	6.1	7.7	9.5	13.2
Free gossypol	0.036	0.126	–	–
Total gossypol	0.76	1.22	–	–
Available lysine g/16 g N	2.4	4.1	–	–
N solubility	39.5	83.2	–	–
Number of samples	128		7	

[a]Bressani *et al.* (1968a).

controlled, mainly because of the use of old equipment, and that there is a need to standardize the product. This problem is now being worked out by agencies of the various governments.

Cereal Grain By-Products The problem with cereal grain by-products is similar to that with oilseed meals. Table 2 summarizes data for corn gluten and for two rice by-products (Elías and Bressani, 1970). In the case of corn gluten, the variability is not as great, probably because the number of processing plants is rather small.

It can be seen, however, that starch extraction carried out by wet-milling is very inefficient. The rice by-products show a relatively high variability in chemical composition. This variability has been traced to the operating conditions used and to the machinery employed. In many instances, the machinery is rather old; therefore, definition or classification of products is very poor. For example, rice bran-samples with a high fat content suggest a material containing rice polishings and germ.

The variability in chemical composition of wheat by-products is lower than in other cereal grains (Table 3). The wheat-milling industry is well advanced in technology and in new machinery, which help significantly in standardizing the chemical quality of the by-products. Furthermore, the wheat processed in most countries, with the exception of Guatemala, is from the United States or Canada, with the result that by-products have lower variability in chemical constituents.

Products of Animal Origin

The variation in chemical composition found in cereal grain by-products and in oilseed meals is also evident in the composition of some animal by-products (Gómez Brenes and Bressani, 1970). Table 4 summarizes

TABLE 2 Variation in Composition of Cereal Grain By-Products in Central America (%)[a]

	Corn Gluten		Rice Polishings		Rice Bran	
Component	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Dry matter	84.3	91.2	86.7	90.1	85.1	89.0
Crude fat	4.9	10.2	7.7	20.3	3.8	19.3
Crude fiber	1.2	3.9	3.6	11.9	3.7	24.9
Crude protein	13.6	19.8	8.6	14.2	6.8	14.2
Ash	0.6	2.4	6.5	9.6	5.6	12.4

[a]Elías and Bressani (1970).

TABLE 3 Variation in Chemical Composition of Cereal Grain By-Products in Central America (%)[a]

	Wheat Middlings		Wheat Bran	
Component	Minimum	Maximum	Minimum	Maximum
Dry matter	86.3	88.0	85.0	87.5
Crude fat	3.6	7.1	4.0	6.4
Crude fiber	3.4	9.4	6.0	12.6
Crude protein	14.8	21.6	13.2	20.8
Ash	2.3	4.5	3.4	6.6

[a]Elías and Bressani (1970).

the proximate composition of three products. Meat meal, for example, shows a very high variation in protein and ash content, which suggests not only poor processing in terms of raw materials but also lack of a clear definition of the composition standards of this type of product. Blood meal on the other hand is less variable, probably because of the physical characteristics of the material before processing.

Fish meal is produced in three or four places in Central America. Panama is the main supplier. The variation in composition is rather high, as indicated by the maximum and minimum values for fat, protein, and ash. The low values probably represent adulterated samples because of the high cost of this feedstuff in Central America.

The information presented suggests a significant lack of uniformity in the feedstuffs available in Central America, a situation that is changing because of a better understanding by the consumer of the reasons why such feedstuffs should have a constant composition and because of the competition among producers of such feedstuffs. Although only

TABLE 4 Variation in Chemical Composition of By-Products of Animal Origin (%)[a]

	Meat Meal		Blood Meal		Fish Meal	
Component	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Dry matter	90.4	93.7	86.8	92.6	78.0	94.5
Crude fat	9.8	13.2	0.1	0.8	0.3	12.5
Crude protein	36.3	60.1	72.6	81.4	29.4	66.7
Ash	7.0	35.1	2.4	5.1	9.3	54.6
Number of samples	5		7		9	

[a]Gómez Brenes and Bressani (1970).

TABLE 5 Partial Chemical Composition and Protein Quality of Meat Meal and Blood Meal from Central America

	Composition			Protein Quality		
Sample	Crude Fat (%)	Crude Protein (%)	Ash (%)	Average Weight Gain[a] (g)	Protein Efficiency Ratio	Available Lysine (g/16 g N)
Meat meal (10133)	13.6	39.6	25.0	22	0.96	3.55
Meat meal (10134)	10.9	35.2	43.7	13	0.58	2.79
Blood meal	0.6	85.1	2.3	-8	–	7.70
Casein	–	–	–	117	2.75	–

[a]Average initial weight, 42 g.

major chemical components were discussed, the variability shown serves to indicate what can be expected in the minor components, such as calcium, phosphorus, amino acids, and vitamins.

Some of these materials have been fed to rats as the only source of protein to learn of their protein quality. Table 5 summarizes the results of two samples of meat meal and one of blood meal. The table shows partial chemical composition, weight gained by the animals in 28 days, protein efficiency ratio, and available lysine values.

The protein quality of the two meat-meal samples is rather low, and the values are different from each other, as corroborated by the low levels of available lysine. The blood-meal sample contained a high level of available lysine in the protein although this is rather poor in nutritive quality, since the animals lost weight. This was expected since it is known that blood-meal protein is deficient in isoleucine. The data indicate that the quality of such feedstuffs is poor. As indicated before, the low quality of these feedstuffs could be due to poor-quality raw materials improperly selected as well as to poor processing. On the other hand, the high available lysine in blood meal suggests care in the preparation of the material.

Results on fish meal are presented in Table 6. The level of fat in the samples ranged from 3.4 to 10.5 percent. A wide variation was also found in ash content, and protein content ranged from 56.8 to 62.5 percent. Two fish protein concentrate samples were used as controls. The protein efficiency ratio values showed a wide variation (not necessarily because of available lysine, which was relatively constant) among the fish-meal samples.

In summary, much of the variation found in feedstuff samples in Central America is due to the poor quality of raw materials, which are

TABLE 6 Partial Chemical Composition and Protein Quality of Fish Meal from Central America

Sample INCAP Number	Composition: Crude Fat (%)	Crude Protein (%)	Ash (%)	Protein Quality: Average Weight Gain[a] (g)	Protein Efficiency Ratio	Available Lysine (g/16 g N)
10138	9.5	58.8	19.0	87	2.18	6.71
10139	10.5	58.4	21.3	107	2.47	6.45
10140	3.4	56.8	25.3	127	2.58	6.32
10141	5.5	62.5	13.3	116	2.67	6.36
Fish protein concentrate	0.6	85.0	10.4	154	3.13	7.70
Fish protein concentrate	0.6	91.1	4.7	152	3.23	7.06
Casein	–	–	–	69	2.82	–

[a]Average initial weight, 42 g.

inefficiently selected, and poor processing is probably affecting nutritive quality in some cases.

PROCESSING OF COTTONSEED

As indicated previously, cottonseed is the most important source of protein in Central America. Because of its high availability and the need to develop a high-protein food for people, efforts were made to modify processing operation that could yield a cottonseed flour acceptable for human consumption. This was achieved in 1959, and today about 1.5 million lb of cottonseed flour are used for the preparation of Incaparina (Bressani *et al.*, 1966). The modifications introduced for the production of a high-grade cottonseed flour are now also used to produce a cottonseed meal that has applications in poultry and swine diets.

Results from a relatively large number of studies carried out in five oil mills in Central America confirmed that temperature of processing was extremely important in controlling the protein quality of cottonseed through a significant decrease in available lysine (Bressani and Elías, 1968). Some representative results are shown in Table 7. The values are average results of two runs. The samples were obtained after the processing stages indicated. The results demonstrated that fat content decreases at the screw-pressing stage, as expected, causing changes in other components. Gossypol changes, however, occur at the drying stage where temperatures increase as high as 260 °F (126.6 °C). Avail-

TABLE 7 Changes in Chemical Composition of Cottonseed during Processing by Screw-Pressing[a]

Stage in Processing	°C	Fat (%)	Crude Fiber (%)	Nitrogen (%)	Gossypol Free (%)	Gossypol Total (%)	Available Lysine (g/16 g N)
Seed	–	31.8	8.5	4.60	1.12	1.36	3.29
Cooking	93	31.2	7.9	4.63	1.05	1.32	3.20
Drying	93–127	33.6	7.1	4.89	0.29	1.23	2.86
Conditioning	115–138	37.1	6.7	4.69	0.22	1.16	2.61
After expeller	<138	6.4	10.7	6.36	0.047	1.47	2.38
Meal	–	6.4	10.7	6.36	0.047	1.47	2.38

[a]Bressani and Elías (1968).

able lysine also decreases. Conditioning of the seed before pressing does not alter free gossypol, but decreases lysine content further. A further decrease takes place in both lysine and free gossypol when the oil is being extracted from the seed during pressing. At this point, temperatures also increase to relatively high levels.

These studies indicated that the moisture content of the seed being processed had an effect on free gossypol and lysine. The results are shown in Table 8. The treatment differences between the two studies are related to moisture in the material during drying and conditioning and to the temperature of the specific processing step. In both studies, free gossypol and lysine decreased in the final product; however, the decrease was higher in the material produced in Study II. The results show that the composition of the materials in both studies is similar up to the drying stage. During drying, however, in Study I, temperature was increased from 200 to 260 °F (93.5 to 126.6 °C), with a moisture drop from 10.3 to 5.9 percent. In Study II, temperature was decreased from 230 to 200 °F (110 to 93.5 °C), while moisture decreased from 9.4 to 3.4 percent. The processing conditions used in Study II were capable of inducing higher decreases in free gossypol as compared with the processing conditions applied in Study I. Conditioning of the seed in Study I was carried out at a temperature of 240 °F (115 °C), with 4.1 percent moisture, while in Study II this operation was carried out at a temperature of 280 °F (138 °C), with 2.9 percent moisture. The different treatment caused no change in free gossypol and lysine content in Study I, but it caused a significant decrease in these two substances in Study II. Finally, expelling decreased the levels of free gossypol and of lysine further, but less in Study I than in Study II. From

TABLE 8 Changes in Free Gossypol and Available Lysine of Cottonseed in Relation to Moisture and Temperature during Screw-Pressing[a]

	Study I				Study II			
Processing Step	°C	H_2O (%)	Free Gossypol (%)	Available Lysine (g/16 g N)	°C	H_2O (%)	Free Gossypol (%)	Available Lysine (g/16 g N)
Seed	–	8.7	1.12	3.29	–	8.7	1.12	3.29
Cooking	93	10.3	1.02	3.41	93	9.4	1.08	2.99
Drying	93–127	10.3–5.9	0.40	2.94	110–93	9.4–3.4	0.17	2.80
Conditioning	115	4.1	0.36	3.04	138	2.9	0.09	2.61
Expeller	<138	4.8	0.05	2.60	<138	4.2	0.04	2.16

[a]Bressani and Elías (1968).

these studies, it was concluded that the moisture of the material going through the presses is very important in controlling available lysine and free gossypol content in the final product.

This finding was studied further with prepress solvent procedures that are less damaging to the organic components of cottonseed. The results are shown in Figure 1, in which moisture level in the crushed seeds at the screw-press level is related to free gossypol, ε-amino lysine,

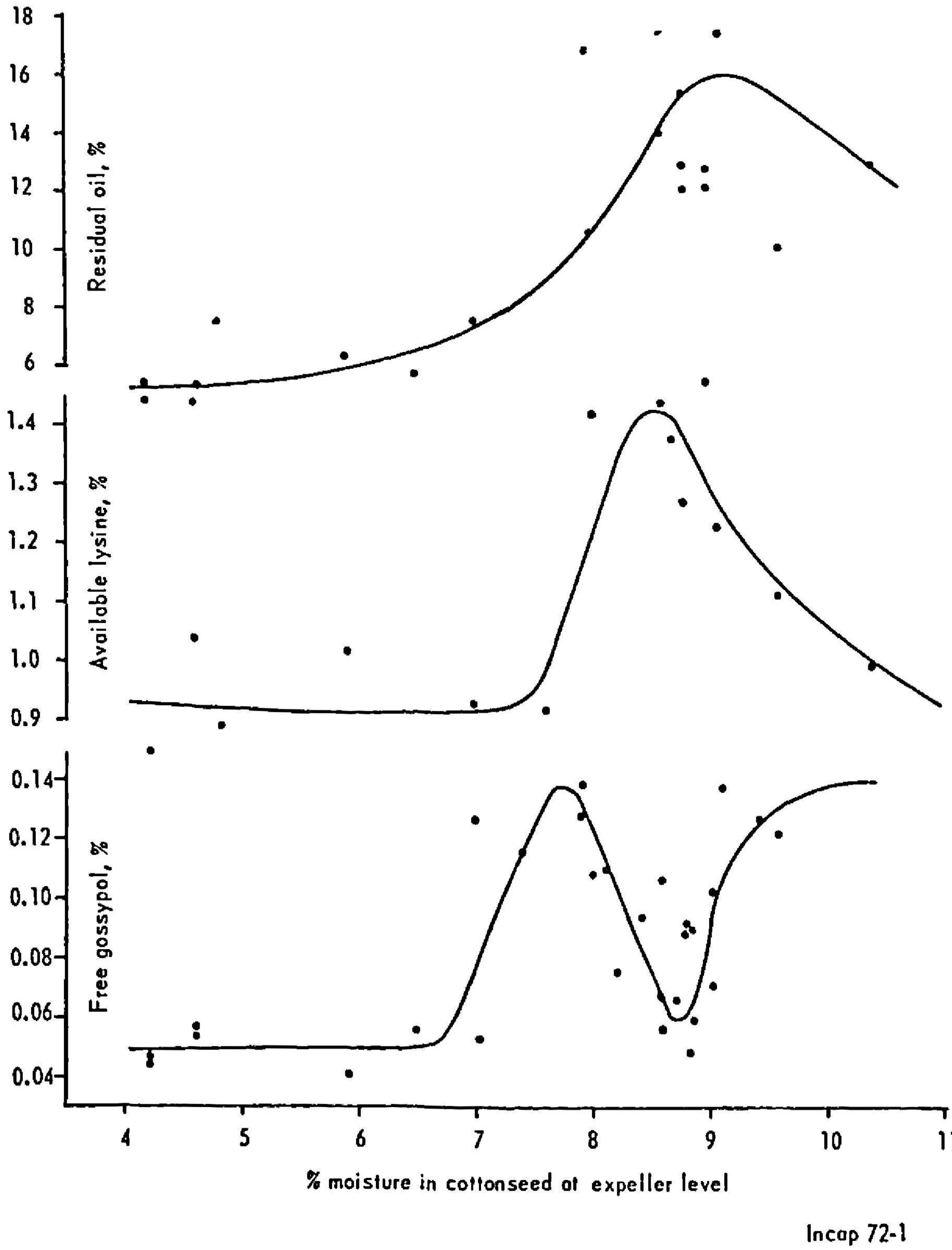


FIGURE 1 Relationship between percentage of moisture in cottonseed at expeller level and free gossypol, available lysine, and residual oil content.

and fat content. The data indicate that when moisture in the crushed seed is around 9 percent, it leads to the production of a cottonseed meal with acceptable levels of free gossypol, high available lysine, and high nitrogen solubility. Even though oil content is high, solvent extraction decreases the values to about 1.5 percent.

The changes in chemical composition, nutritive value, and disappearance of toxicity of cottonseed processed by prepress solvent are shown in Table 9. Changes in fat and protein content begin to occur only at the oil-expelling operation level as previously shown. The same takes place with respect to gossypol. Available lysine does not change. The animals lost weight when the level of free gossypol was above 0.97 percent, but mortality of the young rats started to decrease from the moment the seed was cooked.

Differences in protein quality between the three processes commonly used in Central American oil-extraction plants are summarized in Table 10. This table shows the concentration of other chemical components together with the growth performance of rats fed the three types of cottonseed meal and their protein efficiency ratio (Elias *et al.*, 1969).

The data show that prepress solvent processes yield cottonseed meals with free gossypol levels as low as those resulting from screw-pressing, with the difference that the protein is of higher quality, as indicated by the higher available lysine value and the biological results with rats. Even though solvent-extracted meals have a higher lysine content, the higher levels of free gossypol obviously affect the utilization of the protein, as indicated by the lower weight gain and protein efficiency ratio in comparison with the prepress solvent meals.

From these and other studies it was found that protein quality was highly correlated with lysine and N solubility, but not with free gossypol. On the other hand, weight gain was negatively correlated with total gossypol as well as with residual oil in the meal (Braham *et al.*, 1965).

The prepress solvent meal has been fed to broilers, layers, and swine, with acceptable results, particularly if supplemented with synthetic or natural lysine. Cottonseed meals produced even under the conditions indicated are deficient in lysine for most animal species (Elías and Bressani, 1971). This amino acid is deficient in native cottonseed protein, and processing increases the deficiency by binding the amino acid with gossypol and sugars.

Representative results for chicks are shown in Table 11. Growth of the chicks increased with increasing levels of cottonseed meal in the diet, which was the only source of protein. This increase was observed up to the 56 percent level. Higher levels in the diet decreased final weight. Addition of lysine was effective only at the 40 and 48 percent

TABLE 9 Changes in Some Chemical Components and in Protein Quality of Cottonseed Processed by a Modified Prepress Solvent-Extraction Method[a]

Processing Stage	Fat (%)	Protein (%)	Gossypol		Available Lysine (g/16 g N)	Average Weight Gain[b]	Protein Efficiency Ratio	Mortality (%)
			Free (%)	Total (%)				
Kernel	31.8	31.9	1.10	1.11	3.14	–	–	100.0
Cooking	33.9	33.3	1.10	1.19	3.19	-12	–	83.3
Drying	33.9	32.1	1.02	1.14	3.19	-13	–	83.3
Conditioning	35.6	33.0	0.97	1.11	3.07	-13	–	47.2
Expeller	8.6	42.0	0.058	0.73	3.31	+82	1.99	0
Solvent	2.0	46.0	0.057	0.74	3.12	+81	1.91	0
Flour	2.4	49.3	0.066	0.85	3.33	+89	1.93	0

[a]Bressani and Elías (1968).

TABLE 10 Protein Quality of Cottonseed Meals Produced by Three Different Industrial Processes[a]

Type of Processing	Gossypol Free (%)	Gossypol Total (%)	E-NH_2 Lysine (g/16 g N)	Soluble N (%)	Average Weight Gain[b] (g)	Protein Efficiency Ratio
Screw press	0.051	0.99	2.78	39	62	1.47
Prepress solvent	0.051	0.90	3.33	71	105	1.96
Solvent	0.131	0.98	3.75	74	85	1.79
Casein	–	–	–	–	112	2.86

[a]Elías *et al.* (1969).
[b]Duration of test: 28 days (rats).

cottonseed levels in the diet. These results indicate, therefore, that properly processed cottonseed can be used in feeding broilers with good results, and a better performance is obtained if lysine is added.

Representative results on the use of prepress solvent-extracted cottonseed meal fed to young swine are shown in Table 12. The level of free gossypol was increased from 0 to 0.08 percent, and all diets also contained 1 percent calcium hydroxide and 0.1 percent ferrous sulfate, which in other studies were found effective in detoxifying cottonseed meals (Bressani *et al.*, 1964; Jarquín *et al.*, 1966, 1968). The results indicate a poorer performance on cottonseed than on soybean meal. However, these results are not necessarily due to gossypol level; they may be due to a deficiency of lysine in cottonseed-meal diets. There is a slight tendency for a lower performance as the level of free gossypol increases in the diet, but no mortality was found in the study. Similar

TABLE 11 Growth of Baby Chicks Fed Various Levels of Prepress Solvent-Extracted Cottonseed Meal with and without Lysine

Cottonseed-Meal Level in Diet	Without Lysine Average Final Weight[a,b] (g)	With Lysine: Lysine Added (%)	With Lysine: Average Final Weight[a,b] (g)
40	372	0.42	517
48	473	0.51	535
56	568	0.58	563
64	535	0.68	567
72	525	0.76	516
80	472	0.84	423

[a]Average initial weight, 63 g.
[b]At 5 weeks.

TABLE 12 Performance of Swine Fed Prepress Solvent-Extracted Cottonseed

Protein Source	Free-Gossypol Level in Diet (%)	Average Initial Weight (kg)	Average Weight Gain[a] (kg)	Feed Efficiency
Soybean meal	0	9.5	32.6	2.25
Cottonseed meal[b]	0.02	9.6	29.1	2.63
Cottonseed meal	0.05	9.6	24.7	2.69
Cottonseed meal	0.08	9.8	25.2	2.68

[a]After 10 weeks.
[b]Level of cottonseed meal, 42 percent.

results have been obtained in other experiments, and swine weighing 65 kg have been produced on prepress solvent-extracted cottonseed meal in about 20 weeks (Jarquín *et al.*, 1968).

This type of cottonseed meal further processed to eliminate fiber has been used in the feeding of 3-day-old Holstein calves. Representative results are shown in Table 13. In this example, the milk replacer formulations contained from 12 to 20 percent prepress solvent-extracted cottonseed flour.

The control group was fed a commercial milk replacer and a second group received a formula based on soybean flour. The results obtained after 44 days showed similar performance from all formulations submitted to test. In further studies, levels up to 40 percent cottonseed flour have been used. However, the response obtained is not as high as that shown in Table 13, unless lysine is added.

Prepress solvent-extracted cottonseed flours have been used for about 10 yr in high-protein foods for children, with good results.

TABLE 13 Growth of 3-Day-Old Male Holstein Calves Fed Various Milk Replacers Based on Vegetable Proteins

Milk Replacer	Level of Cottonseed Flour (%)	Average Initial Weight (kg)	Average Final Weight[b] (kg)	Weight Gain (kg/day)
ASL	12	39.97	62.91	0.52
SL	0	39.20	58.59	0.44
AL	20	40.14	62.70	0.51
Control[a]	0	36.81	55.44	0.42

[a]Commercial milk replacer.
[b]44 days.

EFFECT ON THE NUTRITIONAL QUALITY OF VARIOUS PRODUCTS

Poultry Manure

The countries of Central America have a shortage of sources of nitrogen, and, because of the relatively large amounts of poultry manure available, interest has developed in the utilization of this source in animal feeding. Various processing plants are in operation in which dehydration of poultry manure is carried out with heated air. In order to help in the diversification of uses of this material, studies are being conducted to test the quality of this waste in ruminant feeding.

Table 14 describes the chemical composition of samples from the same poultry farm. One sample was processed at the laboratory and one was processed industrially. The difference between the two samples is indicated by the lower protein content of the industrially processed sample. Not only were there differences in composition but the material collected for dehydration in the industrial process was obtained disregarding the designated use to be made of it when dried (Figure 2). The industrial sample was incorporated into a feed for ruminants at levels ranging from 8 to 24 percent. The results of the study are summarized in Table 15. It can be seen that the animals did not refuse to consume such a feed even with 24 percent poultry manure in it. The quality of the material, however, was rather poor, since weight gain decreased as the level of manure increased in the feed offered to the animals. These results, as well as those showing the chemical composition, indicate poor processing conditions, which started with the improper selection of the material to be processed. There is no doubt that materials such as these have a potential as feedstuffs, although they must be properly processed if they are to be used. However, those interested understand little about the effects of high temperatures on nutritive quality or are under the impression that processing will upgrade the quality of the processed material. What is really needed is the dissemination of knowl-

TABLE 14 Chemical Composition of Poultry Manure (%)

Component	Laboratory Processed	Industrially Processed
Dry matter	87.9	87.9
Crude fat	1.2	2.0
Crude fiber	10.6	11.0
Crude protein	21.4	13.2
Ash	31.8	38.0

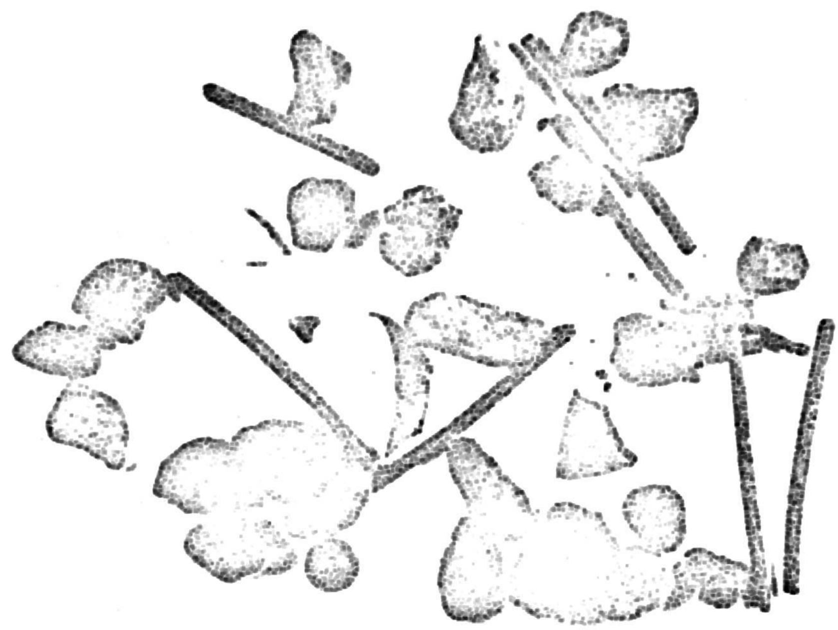


FIGURE 2 Materials found in industrially dehydrated poultry manure.

edge on the significance and implications of proper versus improper processing.

Leaf Meals

Similar results have been obtained in the dehydration of leaf meals. The equipment used is the dehydrator developed for alfalfa but not for tropical forages high in protein. An example is shown in Table 16 for ramie dehydrated at the laboratory scale and ramie dehydrated by a heated air dehydrator (Figure 3).

TABLE 15 Weight Changes of Holstein Calves Fed Diets Containing Processed Poultry Manure

Poultry Manure (% of Diet)	Average Initial Weight (lb)	Average Weight Gain[a] (lb)	Feed Intake (lb/Animal)
0	217.8	105.4	561.4
8	216.0	89.2	545.2
16	215.8	65.3	467.8
24	215.0	62.3	493.2

[a]Six weeks.

last 3 yr to use them as feedstuffs for ruminant feeding (Bressani *et al.*, in press; Bressani *et al.*, 1972; Jarquín *et al.*, in press). The composition of coffee pulp, the more abundant of the two by-products from coffee, is shown in Table 17. In various experiments conducted with various animal species, including rats, it became evident that coffee pulp contains some undesirable components that cause lower weight gains than those achieved by control groups fed diets free of coffee pulp. In attempts to eliminate such factors or to decrease their effect, fresh pulp containing 65 percent moisture was ensiled. After 4 months it was dehydrated and fed to young steers in a mixed feed. The results of one study are shown in Table 18. They indicate that ensiling decreased the quality of the pulp. The animals ate less feed, resulting in lower weight gain in 12 weeks. Studies are under way to characterize the responsible factors, and processes are being developed to eliminate them.

Coffee bran, the second by-product of coffee processing (Figure 4), is a feedstuff containing about 72 percent crude fiber. This material is well tolerated by ruminants up to levels of 40 percent of the feed. Recently, it has been subjected to pelleting with good results, as shown by the pellets in Figure 4. Studies are under way to learn if the pelleting process improves the utilization of this material by ruminants.

Legume Grains

In recent years interest has developed in utilizing some species of leguminous seeds in feeds. Table 19 summarizes some of the work carried out with *Cajanus indicus* (Braham *et al.*, 1965). The seed, not always used for human consumption, was cooked in water at 16-lb pressure for various periods of time, then dried and ground. The various flours were then added to a basal diet and fed to groups of rats for a 28-day period. The results shown in the table indicate that the seed is relatively nontoxic when fed raw. It is well known that leguminous seeds contain trypsin inhibitors and hemagglutinin compounds that to a large

TABLE 17 Chemical Composition of Coffee Pulp (%)

Component	Fresh and Dried	Fresh, Ensiled, and Dried
Dry matter	85.8	93.4
Crude fat	2.4	3.2
Crude fiber	24.0	21.0
Crude protein	11.7	10.1
Ash	5.9	8.3

TABLE 18 Effect of Anaerobic Fermentation on the Nutritive Value of Coffee Pulp Fed to Holstein Calves

Coffee Pulp in Diet	Type of Coffee Pulp	Average Initial Weight (kg)	Average Weight Gain[a] (kg)	Average Feed Consumed (kg)
None	–	143.9	115.1	911.4
30	dried	144.4	90.4	774.5
30	ensiled	144.5	78.6	718.2

[a]Twelve weeks.

extent are heat labile. In the present case, cooking for 30 min improved the quality of the material, but prolonged cooking time decreased weight gain and protein efficiency ratio. Studies have indicated that this is due to a decrease in lysine (Bressani *et al.*, 1963). The addition of lysine, methionine, and tryptophan significantly increased the quality of the material.

Another seed studied is *Enterolobium cyclocarpum.* The seed without hulls contains, on a dry-weight basis, between 33 and 41 percent crude protein. It is highly toxic and allergenic when fed raw.

The cooked seed was fed to young rats or chicks (Bressani *et al.*, 1966). Representative results for chicks are shown in Table 20. In one phase of the test, it replaced the protein from soybeans in the basal diet; in the other, it replaced the protein from cottonseed. The results show that its quality is not as good as that of the sources it replaced; the chicks lost weight as its amount was increased in the diet. As with most leguminous seeds, the results were attributed to a relatively large deficiency in sulfur-containing amino acids in the protein.

FIGURE 4 A: Coffee hulls. B: Mixed feed with coffee hulls. C: Pellets containing 40 percent coffee hulls.

TABLE 19 Effect of Cooking Time on the Protein Quality of *Cajanus indicus*[a]

Cooking Time (min)	Average Weight Gain (g)	Protein Efficiency Ratio
0	11	0.46
10	41	1.37
20	40	1.52
30	44	1.39
40	35	1.34
60	38	0.94
Casein	121	2.80
C. indicus + L-lys + DL-met + DL-try	140	2.83

[a]Braham *et al.* (1965).

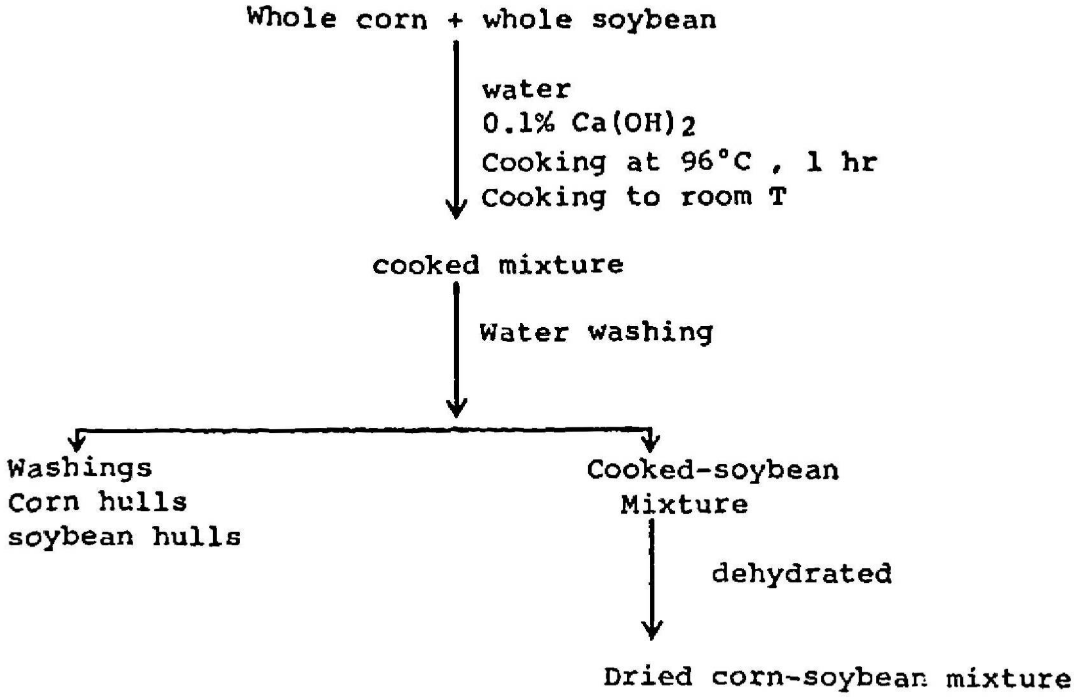
Corn–Soybean Mixtures

Studies have also been conducted to develop a system for using soybeans in feeding swine. Since soybean meal is a costly protein concentrate and not available, the approach being developed consists of using whole soybeans. Previous results indicated that mixtures of corn and soybean flour proteins in a protein ratio of 2:3 had the highest protein quality. On this basis, corn and whole soybeans mixed in various proportions were cooked by the traditional lime-cooking process (Figure 5) used for tortilla manufacture. The process requires 1 hr of cooking in

TABLE 20 Effect of Replacing Soybean or Cottonseed Meal by *Enterolobium cyclocarpum* on Chick Growth[a]

Soybean Meal (%)	Cottonseed Meal (%)	*E. cyclocarpum* (%)	Average Weight Gain[b] (g)	Feed Efficiency
19.00	19.00	–	422	1.78
14.25	19.00	7.42	397	1.86
9.50	19.00	14.84	415	1.83
4.75	19.00	22.26	281	1.96
–	19.00	29.70	198	2.11
19.00	14.25	7.42	464	1.76
19.00	9.50	14.84	420	1.58
19.00	4.75	22.26	334	1.54
19.00	–	29.70	204	1.62

[a]Bressani *et al.* (1966).
[b]28 days.



Incop 72-2

FIGURE 5 Processing scheme for processing whole corn–whole soybean mixtures.

the presence of 0.1 percent calcium hydroxide. The corn–soybean mixtures produced were then dried and fed to young rats. The results are shown in Table 21. The data indicate that all corn–soybean mixtures had a high protein quality. The mixture in the 2:3 ratio was the best; it was similar to a mixture of corn and soybean flour. This system will now be applied to swine, from weaning to market weight. Studies have been conducted on cooking time and on the level of lime needed. This process was able to destroy trypsin-inhibitor factors in soybean, and the presence of corn during cooking decreased losses of solids. Soybean proteins are highly soluble in alkaline conditions, which could explain the large loss observed when soybeans were processed by themselves.

Fungi-Infected Corn

It is well recognized that in developing countries, significant losses of food crops take place because of poor processing and storage after harvest. In a survey conducted in Guatemala, it was found that corn used mainly for human consumption was highly contaminated with about 20 species of fungi (Figure 6). Infection ranged from 0.02 per-

TABLE 21 Effect of Lime Cooking of Mixtures of Corn and Soybean on the Protein Quality of the Mixture

Protein Distribution in Diet (%)		Weight of Components (g)				Protein Efficiency Ratio
Soybean	Corn	Soybean	Corn	Yield (%)	Average Weight Gain (g)	
0	100	0	100	80.0	12	0.69
50	50	21	79	81.1	81	2.08
60	40	28	72	80.0	81	2.54
70	30	39	61	72.0	99	2.37
100	0	100	0	62.7	101	2.03
60	40	38	58	–*	80	2.48
Casein	–	–	–	–	120	2.87

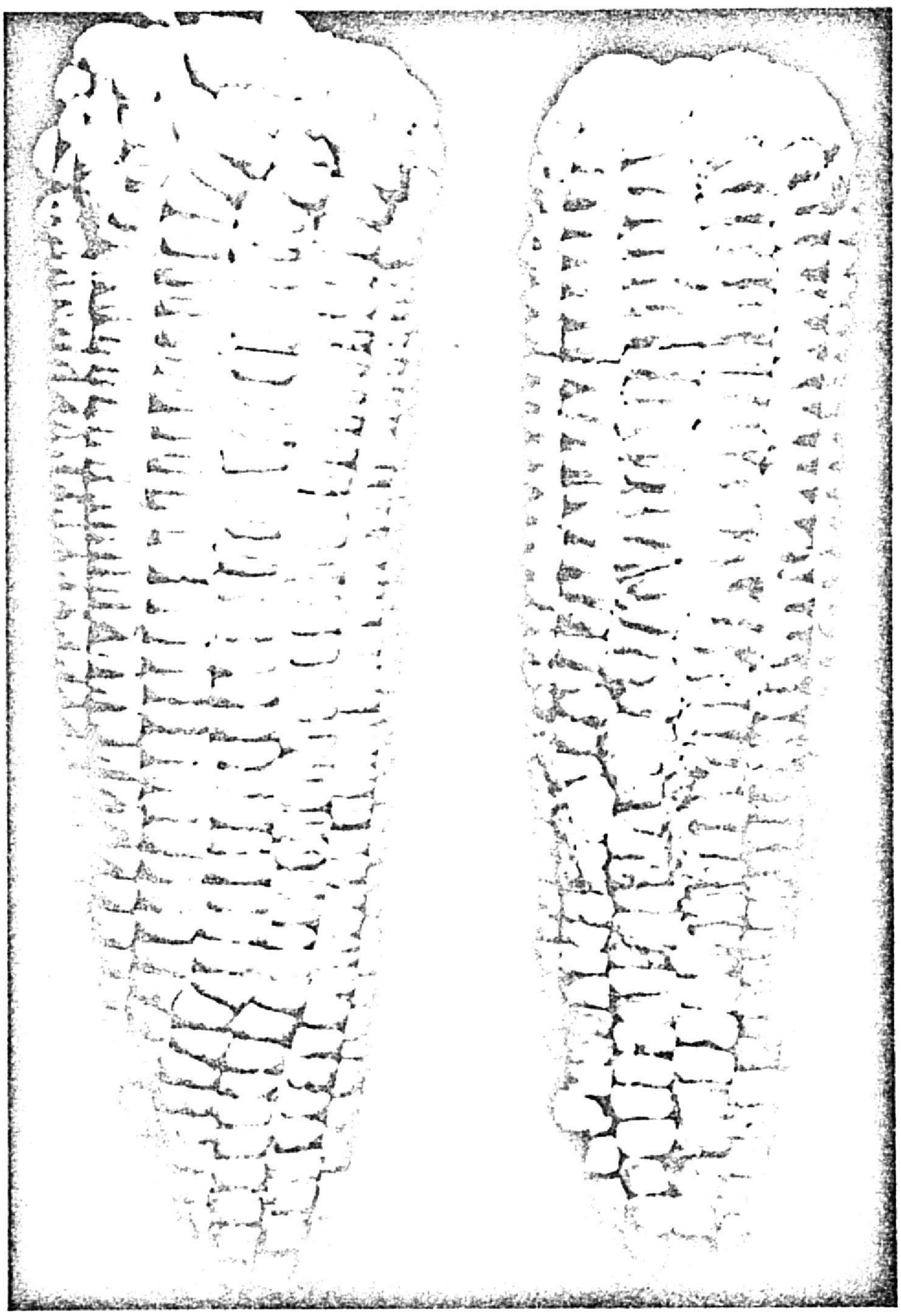


FIGURE 6 Ears of corn infected with *Fusarium moniliforme*.

cent with *Aspergillus candidus* to 43.8 percent with *Penicillum* species. Furthermore, it was found that about 2.5 percent of the samples were infected with *Aspergillus flavus.* Corn infected with a variety of fungi when fed to growing chickens resulted in poor growth and relatively high mortality.

Studies were conducted to learn whether lime cooking could eliminate the toxic compounds in corn infected with *Aspergillus flavus.* Yellow corn was inoculated with *A. flavus* and incubated for 30 days. A second sample was sterilized twice at a temperature of 125 °C and 16 lb pressure. Both samples were then cooked in limewater; the process commonly used to prepare tortillas was followed. After drying, the material was ground and added to a 10 percent casein basal diet in the amount of 80 percent of the diet. These diets were then fed to groups of weanling rats for a 6-week period. The results are shown in Table 22. The weight gains of the rats fed the sterilized corn and of those fed the lime-cooked corn prepared from it were essentially the same. The infected corn caused a high mortality, and the one surviving rat gained 24 g in the 6 weeks the study lasted. Finally, the rats fed the *A. flavus* infected corn, which had been subjected to lime cooking, induced a slightly lower growth when compared with its control, with no mortality. The feed intake and feed efficiency correlated with weight gain. The results were interpreted to mean that lime cooking reduced to a very large extent the aflatoxins produced by *A. flavus,* and it was concluded that the process could be used to decrease losses of corn infected with toxin-producing fungi (Martínez *et al.*, 1970a,b).

Industrial Milk By-Products

There are industries in Central America with sufficient knowledge to process materials labile to excessive heat. In relation to work carried out at INCAP on the development of milk replacers for calf feeding, it appeared advisable to use by-products of the milk industry in the formula to reduce the cost of the milk replacer. Two products were used—one called Solilac 65-35-15, made from skim milk, cheese whey, and butter whey, and one called Solilac 70-30, made from skim milk and cheese whey. The materials were blended in the liquid form and then dehydrated by spray-drying techniques. These two materials and skim milk powder, processed by the same technology, were included in a milk-replacer formulation in an amount of 40 percent of the diet. The other protein components were soybean and cottonseed flour.

The calves consumed 177 g of replacer per liter of water per day at the rate of 4 liters the first week and 6 liters the remaining 6 weeks.

TABLE 22 Effect of Lime Cooking on the Nutritive Value of *Aspergillus flavus*-Infected Corn[a]

Corn Sample	Average Weight Gain[b] (g)	Feed Intake (g)	Feed Efficiency	Mortality (%)
Sterilized	228	719	3.2	0
A. flavus-infected	24[c]	211	8.8	87.5
Lime cooked from sterilized	221	708	3.2	0
Lime cooked from *A. flavus*-infected	186	651	3.5	0

[a]Martínez *et al.* (1970a).
[b]After six weeks.
[c]The weight gain of one rat that survived.

Records were kept of the frequency and intensity of diarrheas and of feed intake and weight changes.

Table 23 summarizes the results. The three by-products had a similar protein content, although the two Solilac samples had a higher available lysine value, which was expected because of the protein of whey by-products. The three formulations did not differ in lysine values and induced a similar weight gain. None of the animals developed diarrhea, and general appearance of the calves at the end of the study was good.

CONCLUSION

The results presented indicate that some knowledge is available in Central America on the effects of processing on nutritive value; as the demand for feeds increases, their quality is expected to increase also. The The major problem with respect to the quality of some feeds is the lack of appropriate equipment, the uncontrolled processing conditions under which they are made and the inadequate attention paid to the raw mate-

TABLE 23 Growth of 3-Day-Old Holstein Calves Fed a Milk Replacer Containing Three Types of Milk By-Products

Milk By-Product	Protein (%)	Available Lysine (g/16 g N)		Average Weight Calves (kg)		
		By-Product	Replacer	Initial	Gain[a]	Gain (%)
Skim milk	31.6	5.68	5.44	38.7	28.8	74.4
Solilac 65-35-15	27.4	7.05	5.28	45.2	32.5	71.9
Solilac 70-30	31.1	7.53	5.23	41.5	31.5	75.9

[a]42 days.

Bressani, R., R. Jarquín, L. G. Elías, and C. Albertazzi. 1968b. Composición química de variedades de semilla de algodón y efecto del medio ambiente sobre su contenido de gosipol. Turrialba 18:133-138.

Bressani, R., R. Jarquín, L. G. Elías, and J. E. Braham. 1966. Análisis químico de la harina de almendra de conacaste (*Enterolobium cyclocarpum*) y su evaluación biológica en ratas y pollos. Turrialba 16:330-339.

De la Fuente, G. 1972. Composición química y valor proteico de la torta de palma africana y corozo. *In* Memorias de la Segunda Reunión Centroamericana en Tecnología de Aceites, Grasas y Proteínas. Celebrada en Guatemala el 28 y 29 de octubre de 1971 bajo los auspicios del Instituto Centroamericano de Investigación y Tecnología Industrial (ICAITI). Guatemala, ICAITI, p. 47-55 plus 9 tables.

Elías, L. G., and R. Bressani. 1970. Uso de recursos alimenticios centroamericanos para el fomento de la industria animal. V. Composición química de algunos subproductos derivados de la industria de los cereales: trigo, arroz y maíz. Turrialba 20:166-170.

Elías, L. G., and R. Bressani. 1971. Amino acid and protein supplementation of defatted cottonseed flour. Arch. Latinoam. Nutr. 21:149-167.

Elías, L. G., S. Sanchez Loarca, and R. Bressani. 1969. Estudio comparativo de diferentes métodos para evaluación del valor proteínico de harinas de semilla de algodón. Arch. Latinoam. Nutr. 19:279-297.

Gómez Brenes, R. A., and R. Bressani. 1970. Uso de recursos alimenticios Centroamericanos para el fomento de la industria animal. IV. Concentrados proteínicos de origen animal de uso común en el área. Turrialba 20:45-52.

Jarquín, R., R. Bressani, L. G. Elías, C. Tejada, M. González, and J. E. Braham. 1966. Effect of cooking and calcium and iron supplementation on gossypol toxicity in swine. Agric. Food Chem. 14:275-279.

Jarquín, R., J. M. González, J. E. Braham, and R. Bressani. 1973. Pulpa y pergamino de café. II: Utilización de la pulpa de café en la alimentación de rumiantes. Turrialba 23:41-47.

Jarquín, R., M. González, R. Oliva, L. A. Lamm, L. G. Elías, and R. Bressani. 1968. Estudio del uso de harina de semilla de algodón en el crecimiento y engorde de cerdos. Arch. Latinoam. Nutr. 18:39-63.

Martínez, M. L., L. G. Elías, J. F. Rodríguez, R. Jarquín, and R. Bressani. 1970a. Valor nutritivo del maíz infectado con hongos en pollos y de tortilla de maíz fungoso en ratas. Arch. Latinoam. Nutr. 20:217-240.

Martínez, M. L., E. Schieber, R. Gómez Brenes, and R. Bressani. 1970b. Prevalencia de hongos en granos de maíz (*Z. mays*, L.) de Guatemala. Turrialba 20:311-319.

Morrison, F. B. 1959. Feeds and feeding. 22nd ed. Morrison Publishing Co., Clinton, Iowa.

Zaghi, S. de, and R. Bressani. 1969. Uso de recursos alimenticios centroamericanos para el fomento de la industria animal. II. Composición química de la semilla y de la harina de torta de ajonjolí (*Sesamum indicum*). Turrialba 19:34-38.