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UTILIZATION OF COFFEE PULP AS ANIMAL FEED

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I. INTRODUCTION

Coffee beans have been for a long time one of the most important crops in several countries in Latin America and other parts of the world. Because of the nature of the coffee processing industry and the economic value of the coffee beans, very little attention has been given to the by-products in the past. However, due to various problems, such as disposal, pollution of the environment, economy of coffee production, and the need for feed ingredients has stimulated renewed interest in the utilization of coffee-processing by-products in Latin America.

Until very recent, research activities were very limited in scope, emphasizing the use of coffee pulp as an animal feed. As early as 1944, research reports were published on the use of coffee pulp as a feed ingredient for dairy cattle, with apparent good results (1). Since then, other reports on the use of coffee pulp as an animal feed have been published (2-9). Many of these reports are contradictory in nature, however, the potential of coffee pulp as an animal feed was suggested in some of them, although problems were encountered in its use. Reports on other uses have also been published, however, economic uses are still to be developed (10).

The present report attempts to review the advances made on research being carried out by INCAP and sponsored by IDRC to utilize coffee cherry by-products as components of animal feeds. The first part of the manuscript reviews the chemical aspects of the by-products; it is followed by the nutritional evaluation of coffee pulp as a feed component in rations for broilers, swine and cattle and ends by describing the alternatives so far available for processing and how it affects its nutritional value.

II. THE BY-PRODUCTS OF COFFEE CHERRIES

Even though the two main coffee cherry by-products, namely coffee pulp and hulls, are well known in coffee-producing countries, it was deemed of interest to describe them before going into their potential uses.

A cross section of the coffee cherry is presented in Figure 1. The pulp is made of a relatively thick layer of spongy cells. Immediately next to the pulp a layer of mucilage is found, and then next to the mucilage the hulls enclose the coffee beans.

During harvesting, the cherries are taken to coffee mills, which in some countries are located at the coffee plantation while in others are centralized in town or cities. They are then dumped into a water tank to be washed with running water which transports the cherries to the pulping machines as shown in Figure 2. This operation removes the pulp from the beans which remain covered by mucilage and hulls. The beans are allowed to ferment for 48 to 72 hours, or are treated chemically to remove the mucilage, and then partially sun-dried before subjecting them to drying with hot air in a revolving drum. After drying the beans are threshed to remove the hulls.

The pulp removed from the fruit is disposed off either by throwing it into rivers or by composting and later use as a fertilizer in the coffee plantation. In centralized mills the pulp is returned to the coffee plantation at a relatively high cost, to be disposed off due to the cost of transportation.

The process described above is commonly used in coffee processing plants that have abundant water supplies, which is not the case for all centralized plants. In these, when water is limiting, it is used several times to wet-mill the cherries, operation which suggests the possibility of using the washing waters as a substrate for microbial growth. This possible use will not be discussed at this time, and is still a subject of much research.

When coffee cherries are processed the material balance obtained is shown in Table 1. The process is described on the left of the Table. The information includes the moisture content of the whole cherry and of the fractions obtained. From 1 kilo of cherries, 432 grams of coffee pulp are obtained which on a dry weight basis represent about 29% of the weight of the whole cherry. Further processing of the beans yields 61 g of wet coffee hulls or 41 g dry hulls, equivalent to about 13% of the cherry. The other by-product of interest is the mucilage which amounts to about 5% of the dry weight of coffee cherries (11). Very little differences have been found in fraction distribution between coffee varieties, localities and harvest time, except in mucilage content, which has varied from as low as 4.9% to as high as 13.7%. These variation may be due also to efficiency of system of processing.

On the basis of the entire Latin American coffee production, it is estimated that there are approximately over 1.5 million metric tons of dry coffee pulp available, and about 0.5 million metric tons of hulls. Likewise, the quantities of mucilage are quite large. Obviously, these quantities have some economic significance and should serve a useful purpose in coffee producing countries. It would appear that the limiting factors in the effective use of the by-products from coffee are in the processing of the fruit which has not changed over the years to produce coffee beans, and in the lack of continuous research on the by-products.

Table 2 shows the gross chemical composition of coffee pulp. Three groups of analyses are shown corresponding to fresh and dry pulp, and to a sample of pulp as found two to three days after being obtained by separation from the beans. Attention is called to the high water content which for purposes of utilization constitutes a problem in its handling, transportation, processing and direct use as an animal feed. When dried, the material contains around 10% crude protein, 21% crude fiber, 8% ash and 44% nitrogen-free extract. These values would change, of course, with variety, soil composition, altitude, and agricultural practices.

Table 3 summarizes the average content of other organic compounds in coffee pulp which may determine its potential as an industrial raw material or as a feedstuff. It is noteworthy the content of tannins, caffeine and chlorogenic and caffeic acids. All of these chemicals may have untoward effects on the performance of animals fed feed-stuffs containing them. On the other hand, some of these substances can be extracted for specific applications. For example, studies have been carried out by us to extract caffeine from coffee pulp with success (12). Results of the fractionation of cellular walls and structural polysaccharides in coffee pulp are shown in Table 4. A cellular content of 63% suggests that the material has a relatively high level of nutrients. The levels of lignocellulose, hemicellulose, cellulose and lignin indicate that the product is superior to various types of feeds. Of the protein, about 3% is found in a lignified form, probably not readily available (13). The mineral breakdown of the ash fraction is shown in Table 5. The Ca/P ratio leans toward calcium, however, the availability of either is not known. Attention should be drawn to the high potassium concentration, which could very well have important implications in the uses given to coffee pulp. Levels of minor elements are quite low (11).

Table 6 summarizes the average amino acid content of two samples (11). For purposes of comparison, the amino acid content of other agricultural by-products is also presented. It is of interest to note the relatively high level of lysine present in coffee pulp, which is as high as that found in soybean meal on a per gram of nitrogen basis. Coffee pulp protein is deficient in sulfur-containing amino acids. At present, the biological availability of these amino acids is not known. This is an aspect which requires some investigation because of the relatively high tannin content in coffee pulp, and the known fact that tannins react with protein making its amino acids biologically unavailable to the animals. Amino acid content accounts for about 60-65% of the total nitrogen in coffee pulp. Likewise, caffeine accounts for about 15% of the total, while niacin, trigonelline and nitrogen bases make the difference to 100%. This factor has not been appreciated in the past and studies are now underway to elucidate the nutritional significance of this fact. Therefore, the true protein of coffee pulp has also been obtained from the other two fractions, the hulls and the mucilage. These, however, will not be discussed at this time, except to indicate that our results demonstrate very little potential of coffee hulls as a feedstuff. On the other hand, the mucilage could be useful as a raw material for pectins and some research along these lines is underway.

II.1 Coffee Pulp as an Animal Feedstuff

Experimental feeding trials

a. Coffee pulp in swine feeding

The chemical composition and amino acid content of coffee pulp suggest that it has good possibilities as a source of nutrients for swine feeding, although its major limitation is its high crude fiber content.

Studies designed to learn of the possibilities of using coffee pulp in swine feeding were carried out with diets containing 18, 15 and 12% protein. These were fed to growing swine from 12-30, 34-60 and 65-90 kg body weight, respectively.

At each level of protein, the diets contained 0, 8.2, 16.4 and 24.6% sun-dried and ground coffee pulp, which replaced equal amounts of protein from a basic soy:maize blend. Crude fiber was equalized between diets. The same animals were used throughout the study, although at each stage, the animals were randomized into new groups. The results of the study are summarized in Figure 3. It can be seen that at each growth stage daily weight gain and feed efficiency were inversely related to coffee pulp level in the diet. However, the overall performance was relatively good. The high coffee pulp level showed a significantly lower performance. This was attributed to a decrease in total true protein on the one hand and to the low levels of true protein in coffee pulp, which became more important as protein content decreased from 18 to 12%. Likewise, the higher levels of coffee pulp also carried with it higher levels of fiber, thus decreasing feed conversion efficiency. Metabolic studies with swine (14, 15) as well as of other growth studies suggested that coffee pulp can be safely used in swine rations in amounts of 10-16% in place of corn. The economic advantages are very promising as well as the significance of reducing the competition for corn between animal and man. Commercial trials with swine are underway using 10% coffee pulp, with results highly acceptable at present.

b. Coffee pulp in poultry feeds

As with other animal species, chick performance decreases as coffee pulp concentration in the diet increases. This is clearly shown in Figure 4. Feed efficiency also decreases as more coffee pulp is present in the diet. Likewise, as it was the case for other species there is a definite tendency for chickens to consume more water as coffee pulp increases in the diet. This is probably due to the diuretic effect of caffeine. As with swine some of the effect on growth and feed efficiency is due to an increase in crude fiber which is found in higher amounts as coffee pulp in the diet is raised, as well as to the problem of the low levels of true protein in coffee pulp, not recognized in the past. Results of a larger feeding trial with chicks is summarized in Figure 5 in which coffee pulp replaced 10 and 20% corn in a standard corn:soybean mixture. The results shown confirm previous findings in that weight gain and feed conversion efficiency are inversely related to coffee pulp level. Furthermore, there is a significant increase in feed intake as shown, suggesting that the animal is trying to compensate nutrient intake, particularly energy at the higher levels of dietary coffee pulp, which are providing higher levels of crude fiber. At present, field commercial trials with 10% coffee pulp are being conducted in our experimental farm with acceptable results so far.

c. Nutritional value of coffee pulp in ruminants

A material such as coffee pulp whose dry matter contains around 10% crude protein and less than 25% crude fiber, has a great potential as a feed for ruminants, and it is with this animal species where most studies have been conducted.

The majority of studies on the nutritive value of coffee pulp have been carried out using dry pulp to learn of its effects on growing and fattening cattle (16-22) and all have given similar results. In these studies, coffee pulp has been given to the animals in various ways. In some cases coarsely ground as part of the roughage, in others finely ground as part of a supplement and in others as silage, as will be indicated later.

Representative results of feeding coarsely ground coffee pulp as part of the ration is shown in Table 7. Levels of 0, 10, 20 and 30% were used to replace cottonseed hulls. In this 84-day trial, there is an inverse relationship in daily weight gain and coffee pulp level in the ration. Total feed intake remained relatively constant up to 20% coffee pulp in the diet and decreases with a 30% level.Feed efficiency followed a similar trend, with respect to dietary coffee pulp level. Results using higher levels with older animals are shown in Table 8. In this case the trial also lasted 84 days and levels of coffee pulp were 0, 20, 40 and 60%. As before, daily weight gain, dry matter intake, and feed efficiency were negatively correlated with coffee pulp level. Obviously, dry matter intake from coffee pulp increased which resulted in increased intakes of caffeine and tannins. However, other chemical components in coffee pulp also increased, making it difficult to indicate which are the factors responsible for the performance observed. One aspect of interest observed in all experiments performed is the benefits of high protein content diets and adaptation of the animal to coffee pulp level.

Up to the present time the factors responsible for the adverse effects are not known. As indicated previously, coffee pulp has relatively high quantities of caffeine which are able to decrease feed intake and the growth of the animals. This is indicated by representative results shown in Table 9. In the example shown, the two levels of synthetic caffeine added were equivalent to 30 and 60% dehydrated coffee pulp. The results show that 30% coffee pulp decreased animal performance, although not statistically so, when compared to the control. On the other hand, 0.12% caffeine, which is the amount found on the average in 30% coffee pulp did not cause any adverse effect on performance. However, when the level was duplicated, daily weight gain decreased as well as feed intake and feed conversion efficiency. In nitrogen balance and digestibility studies carried out, it was observed a high urine output in animals fed coffee pulp or caffeine. These high urine levels carried high amounts of nitrogen, which could explain the results observed.

A similar study carried out with additions to the control diet of tannic acid in amounts of 0.75 and 1.50% was also carried out. None of the two tannic acid levels affected animal performance significantly, even though the ones that received 1.5% tannic acid in the diet were slightly less efficient. In both of these studies -caffeine and tannic acid addition- coffee pulp always resulted in lower performance than the chemicals individually, suggesting that other substances alone or in combination are effective in decreasing performance of the animals. Therefore, a study was carried out in which caffeine and tannic acid were fed together. The results are shown in Figure 6. They show progressive decrease in weight gain when the animals consumed diets with a constant level of tannic acid and levels of caffeine up to 0.24%. Feed intake and feed conversion efficiency also were affected as shown. It is known that tannins bind protein, therefore, this effect as well as the higher N excretion in urine could very well be responsible for the poor animal performance observed upon feeding high levels of coffee pulp.

Metabolic trials with ruminants carried out in our laboratories permitted the estimation of some nutritional characteristics of coffee pulp (23). These are shown in Table 10. The values obtained for dry matter, organic matter, crude fiber and energy digestibility are comparable to values from other forages. However, protein digestibility is lower than that found for grasses and feeds of such a nature. The low protein digestibility value is probably due to free phenols which are oxidized, and to tannins binding protein and making it unavailable to the rumen flora of the animals. Various other studies have been carried out which have permitted to recommend not more than 30% coffee pulp in the feeding of ruminants. The general observations made in the course of the studies performed when feeding 30% and over of coffee pulp are shown in Table 11. These are, reduced dry matter intake, feed efficiency, daily weight gain, and nitrogen retention due to a high urine output accompanied by high water intake. These may be the reasons for the beneficial effects of high protein diets. Of much interest is the observation made by several workers as well as by our studies on the beneficial effects of feeding green forages or grass silage with coffee pulp. Although advances have been made, it is essential to continue the research in the utilization of coffee pulp.

III. PROCESSING OF COFFEE PULP AS A FEED

The main problem in the utilization of coffee pulp before its use as an animal feed is its high water content which interferes with its transportation, handling and preservation. Therefore, the aspects related to the stabilization of coffee pulp before its use as an animal feed are of great practical importance, which may affect its chemical composition and nutritive value, its acceptability and its economics. Attention has thus been given to the problem, and two approaches have been considered. These are presented schematically in Figure 7.

The wet coffee pulp is ensilaged and used as such or mixed with other silages or green chopped forage, in one case, or it is dehydrated and used in the other, as such, mixed with other forages or as an ingredient in compounded feeds. A combination of the two approaches is also recommended.

III.1 Ensilaging

Coffee pulp silage is an adequate and a practical solution to the problem of high moisture content and its implications of coffee pulp. This method of preservation and utilization has been studied extensively by INCAP, however, many more studies must be performed to be able to understand the process, and to recommend appropriate technologies to develop an improved product.

The steps for making coffee pulp silage as practical in our Experimental farm are described in Figure 8. The variations in this process which have been studied include the addition of 3-6% sugar cane molasses, or molasses with 4-6% wheat bran, the above with brewer's yeast, or in combination with green forages such as grass or corn.

Coffee pulp containing about 80% water is transported to the site where the silos are located. About 4-5% of the water is lost, this amount representing the water carried by the pulp during removal from the coffee grains. Additional moisture may or may not be removed before placing the pulp into the silos. Every 12 inch layer of pulp is then sprayed with sugar cane molasses with or without the other additions, and then it is pressed. When the material is well packed into the silo, each cubic foot weighs 64-67 lbs (24). The silo is then sealed air-tight and the material ensilaged can be preserved very well for long periods of time.

III.1.1 Chemical composition

The gross chemical composition of coffee pulp silage made with the addition of sugar cane molasses as shown in Table 12, is practically the same as that of fresh coffee pulp, however, levels of tannins and of caffeine usually decrease. Consistent changes have not been observed in crude fiber fractionation.

Using pilot plant silos, studies have been carried out to measure changes in pH, soluble sugars, protein and mucilage from three types of silage, the control, with added sugar cane molasses, and with wheat bran. Representative results are shown in Table 13. The pH increased in the control, remained relatively constant in the silage with molasses and decreased in the silage with molasses and wheat bran. Soluble sugars decreased in all three cases, while protein within silage type remained constant. Of particular interest is the behavior of the material analyzed as mucilage which tended to increase in all cases, up to 90 days, and decreased at the end of 120 days. The significance of these findings is still being investigated. Changes in volatile fatty acids are shown in Table 14. Lactic acid decreased in all cases, but slower when wheat bran was included. In other studies a high lactic acid content was found during the second and third week after ensilaging. Acetic and propionic acid increased with respect to time in all three types of coffee pulp silage with some differences in the end. As was indicated before, additional studies are needed to understand, influence and control the process to insure quality in the final product.

III.1.2 Nutritional value

In spite of the changes observed during ensilaging of coffee pulp, its nutritional value remains for all practical purposes similar to that of fresh coffee pulp. An example is shown in Table 15 for coffee pulp ensilaged for 4 and 14 months, fed at a 30% level to young ruminants. Animal performance was essentially the same between dehydrated fresh coffee pulp and dehydrated coffee pulp silage as judged by weight gains and feed conversion efficiency. Therefore, the advantage of ensilaging is to be found in the convenience it offers to preserve the pulp for long periods of time, to be used when needed.

III.2 Dehydration

Two method of dehydration have been studied. One is solar dehydration and the second mechanical hot air dehydration.

III.2.1 Solar dehydration

For sun dehydration, the material is spread on a clean surface to a thickness of about 5-8 cm. It is mixed 3 to 4 times daily and in about 24 to 30 hours moisture has been reduced to almost 12%, moisture level adequate for storage and preservation. During dehydration the color of coffee pulp changes from the dark red to a dark brown color. This, however, can be controlled by spraying with solutions of sodium metabisulfite at 1.5 - 2.0% solutions. Most of the studies carried out by INCAP have been with sun-dehydrated coffee pulp. Results indicate that storage time decreases the antiphysiological effects, at least in respect to mortality rates in rats. It has been observed that caffeine concentration decreased to about 0.45%.

Sun-drying represents the cheapest way to dehydrate pulp, however, there are various disadvantages, such as large area to spread the pulp, time involved, and color changes. Large lots have been commercially produced in El Salvador at a price of $2.50/100 lbs. As indicated before, when coarsely ground, it can be mixed with other forages and fed mixed with molasses, or it can be ground more finely to be included in compounded feeds to be used as a supplement.

III.2.2 Mechanical hot air dehydration

A second approach to dehydration is by means of heated air. Figure 9 describes the events taking place. The coffee pulp is transported to the plant and mixed with lime to favor water removal upon a continuous pressing operation. The pressed material is then disintegrated and transferred to a rotating tunnel drier yielding the dry pulp. This can be left as such or ground, and stored. With heated air, results of our studies indicate that by using 1.5 lbs of coffee pulp per square foot, with an air temperature of 90°C and 604 lb of air/min coffee pulp can be dehydrated in 60 minutes.

The mixing of coffee pulp with calcium hydroxide followed by a continuous pressing step to reduce moisture levels significantly is shown in Table 16. Maximum amounts of lime vary between 0.6 and 1.0% of the fresh weight of the pulp. Up to the present time nothing has been done with the press liquor. This is then followed by dehydration in a drum dryer or in a tunnel dryer. The material resulting from this type of processing has the best appearance of all products with some highly desirable characteristics, particularly if treated previously with sulfite.

These processing operations served to a very large extent in making possible the development of an industrial plant built in San José, Costa Rica by the firm Pulpa de Café, S. A. This plant operated early in 1980 for the late coffee harvest and will start again in August 1980. Samples from the January 1980 dehydration trials have been analyzed with results not different than those previously shown for sun-dehydrated pulp, except for a slightly lower protein content, around 9.0%, and for a pH of 9.5 as it would be expected. Feeding trials will be conducted as soon as the product becomes available.

In summary, it has been shown that coffee pulp can be used as a feed for poultry, swine and cattle, at levels not greater than 10, 10 and 30% of the diet with present types of materials. There are gaps of information still needed to make better use of this by-product for the purposes discussed. These are knowledge on the non-protein nitrogen components, fate of mucilage during digestion, and the identification of the compounds which are constraints to good animal feeding performance. Processing includes silage production and dehydration, by solar energy or hot air. More information should be obtained on both processes to optimize the nutritional quality of this important by-product.

IV. BIBLIOGRAPHY

1. Choussy, F. La pulpa de café como alimento del ganado. Anales del Instituto Tecnológico de El Salvador. 1:265-280, 1944

2. Work, S.H., Lewy van Severen y L. Escalón. Informe preliminar del valor de la pulpa seca de café, como sustituto del maíz en la ración de vacas lecheras. Café de El Salvador. 16:773-780, 1946

3. Osegueda Jiménez, F.L., R.A. Quiteño, R.A. Martínez y M. Rodríguez. Uso de la pulpa de café seca en el engorde de novillos en confinamiento. Agricultura de El Salvador. 10:3-9, 1970

4. Echavarría, G. La pulpa del café como alimento para ganado. Revista Cafetalera de Colombia. 8:3310-3313, 1947

5. Madden, D.E. The value of coffee pulp silage as feed for cattle. Thesis (Magister Scientificae). Instituto Interamericano de Ciencias Agrícolas. Turrialba, Costa Rica, 1948

6. Squibb, R.L. Present status of dried coffee pulp and coffee pulp silage as an animal feedstuff. Boletín mimeografiado, Instituto Agropecuario Nacional. Guatemala, 1950

7. Bolaños, J. R. La pulpa de café como alimento para ganado. Café de El Salvador. 23:217-218, 1953

8. Rogerson, A. Nutritive value of coffee hulls. E. African Agron. J. 20:254-255, 1955

9. Van Severen, M.L. y R. Carbonell. Estudios sobre digestibilidad de la pulpa de café y de la hoja de banano. Café de El Salvador. 19:1619-1624, 1949

10. Aguirre, F. La utilización industrial del grano de café y de sus subproductos. Investigaciones Tecnológicas del ICAITI #1-1966. ICAITI, Guatemala, C. A.

11. Bressani, R., E. Estrada y R. Jarquín. Pulpa y Pergamino de Café. I. Composición química y contenido de aminoácidos de la proteína de la pulpa. Turrialba. 22:299-304, 1972

12. Molina, M., G. de la Fuente, M. A. Baten and R. Bressani. Decaffeination. A process to detoxify coffee pulp. Agr. & Food Chem. 22:1055-1059, 1974.

13. Murillo, B., E. Estrada, M. T. Cabezas, E. Vargas, L. Daqui y R. Bressani. Composición de carbohidratos estructurales en diferentes muestras de pulpa y pergamino de café. In preparation

14. Rosales, F. Uso de la pulpa de café deshidratada en la alimentación de cerdos. Thesis (Magister Scientificae). INCAP/CESNA, Universidad de San Carlos de Guatemala, Guatemala, noviembre, 1973

15. Jarquín, R., F. A. Rosales, J. M. González, J. E. Braham y R. Bressani. Pulpa y pergamino de café. IX. Uso de la pulpa de café en la alimentación de cerdos en la fase de crecimiento y acabado. Turrialba, 24:353-354, 1974

16. Jarquín, R., J. M. González, J. E. Braham y R. Bressani. Pulpa y pergamino de café en la alimentación de rumiantes. Turrialba 24:41-47, 1973

17. Bará, M., F. M. Espinosa y M. S. Guevara. Determinación del nivel adecuado de pulpa de café en la ración de novillos. Boletín informativo. Instituto Salvadoreño de Investigaciones del Café. 92:1-8, 1970

18. Flores Recinos, F. Respuesta bio-económica de novillos en engorde alimentados con diferentes niveles de pulpa de café ensilada y proteína. Thesis (Magister Scientificae), IICA. Centro Tropical de Enseñanza e Investigación. Depto de Ganadería Tropical, Turrialba, Costa Rica, 1973.

19. Braham, J. E., R. Jarquín, J. M. González y R. Bressani. Pulpa y pergamino de café en la alimentación de terneros. Thesis (Magister Scientificae), INCAP/CESNA, Universidad de San Carlos de Guatemala, 1973

20. Estrada, Eugenia. Cafeína y taninos como factores limitantes en el uso de la pulpa de café en la alimentación de terneros. Thesis (Magister Scientificae), INCAP/CESNA, Universidad de San Carlos de Guatemala, 1973

21. Cabezas, M. T., J. M. González y R. Bressani. Pulpa y pergamino de café. V. Absorción y retención de nitrógeno en terneros alimentados con raciones elaboradas con pulpa de café. Turrialba 24:90-94, 1974

22. Cabezas, M. T., B. Murillo, R. Jarquín, J. M. González, E. Estrada y R. Bressani. VI. Adaptación del ganado bovino a la pulpa de café. Turrialba 24:160-167, 1974

23. Vargas, E. Valor nutritivo de la pulpa de café. Thesis (Magister Scientificae), INCAP/CESNA/Universidad de San Carlos de Guatemala. Guatemala, noviembre, 1974

24. González, J. M. Boletín informativo de la División de Ciencias Agrícolas y de Alimentos del INCAP. VIII. Preparación de ensilaje de pulpa de café. AGA, 16:16-19, 1973

Fig. 1 CROSS SECTION OF COFFEE CHERRY

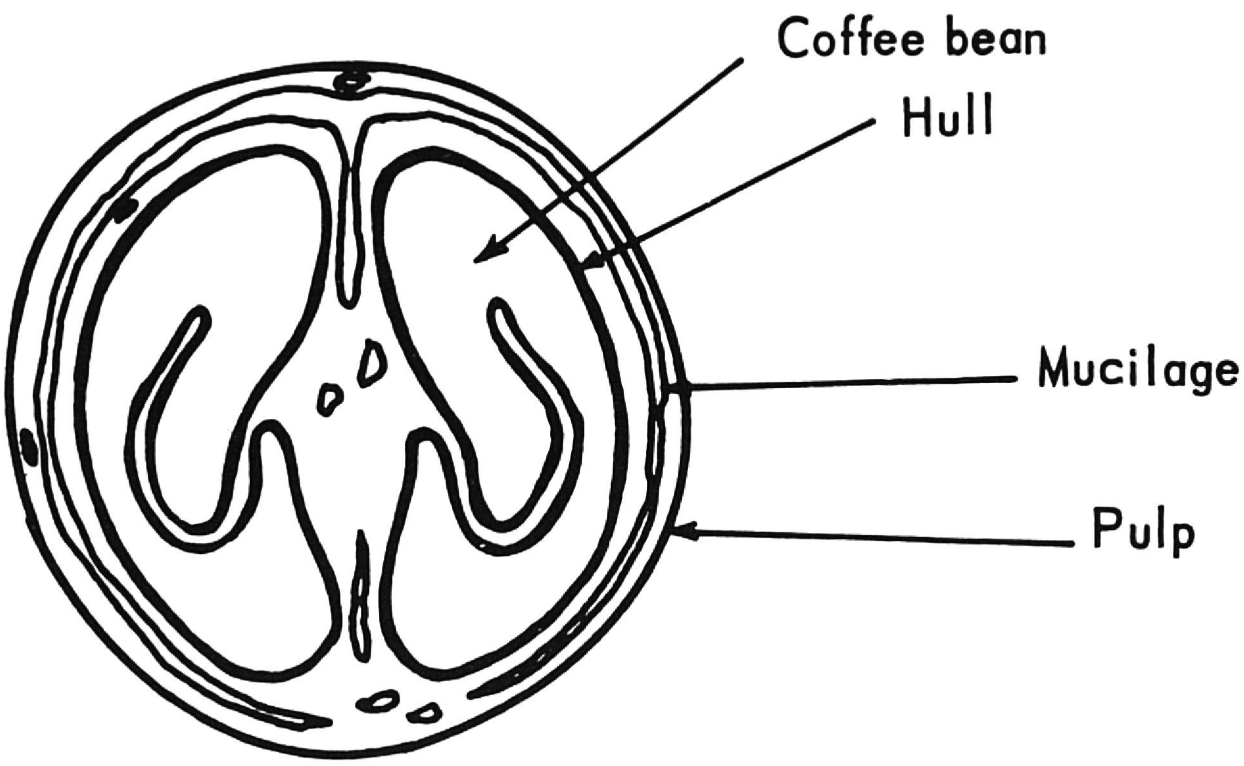

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Fig. 2 WATER USAGE IN SOME CENTRAL COFFEE MILLS IN CENTRAL AMERICA

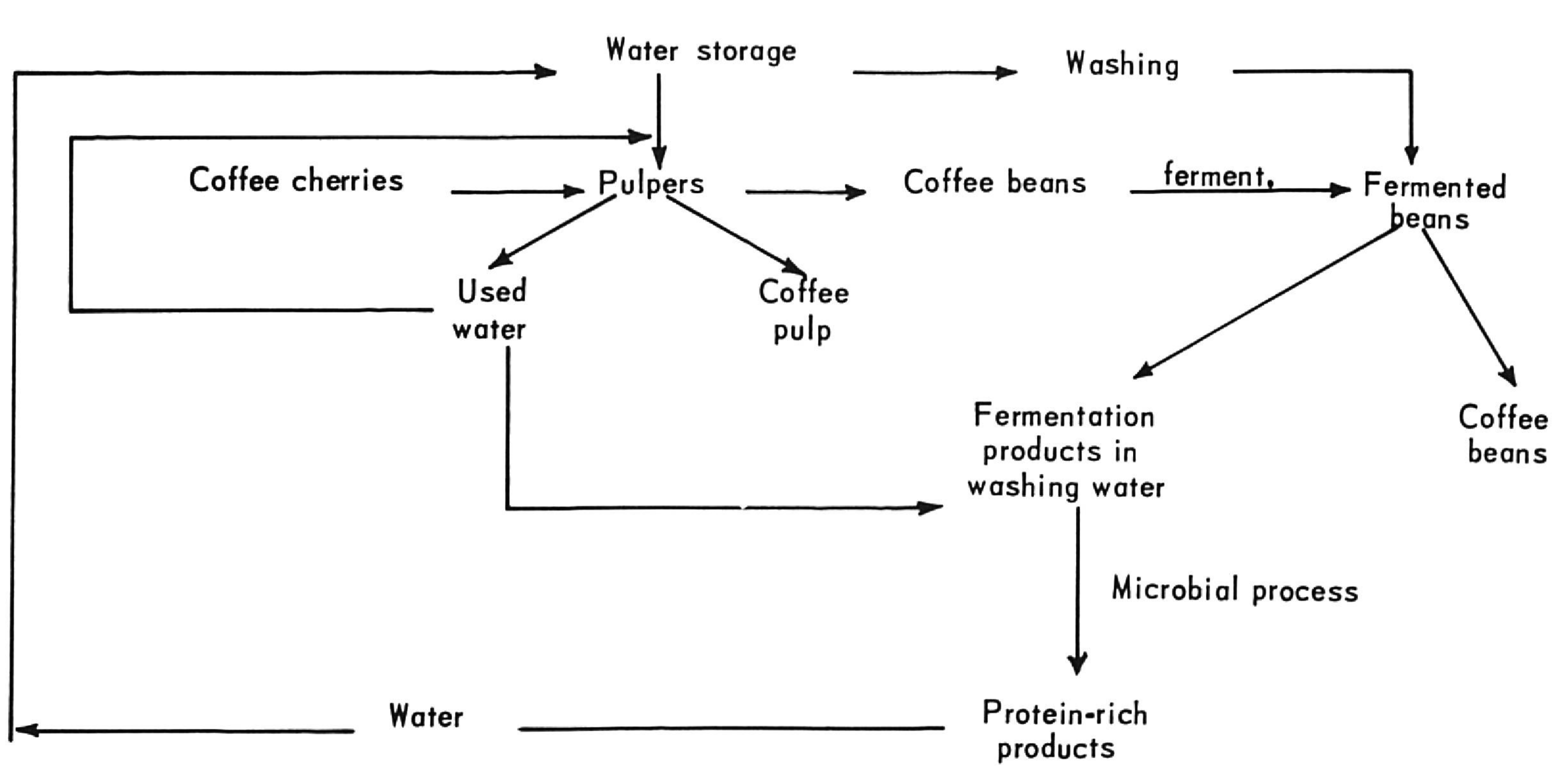

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Fig. 3 PERFORMANCE OF SWINE FED DIFFERENT LEVELS OF COFFEE PULP

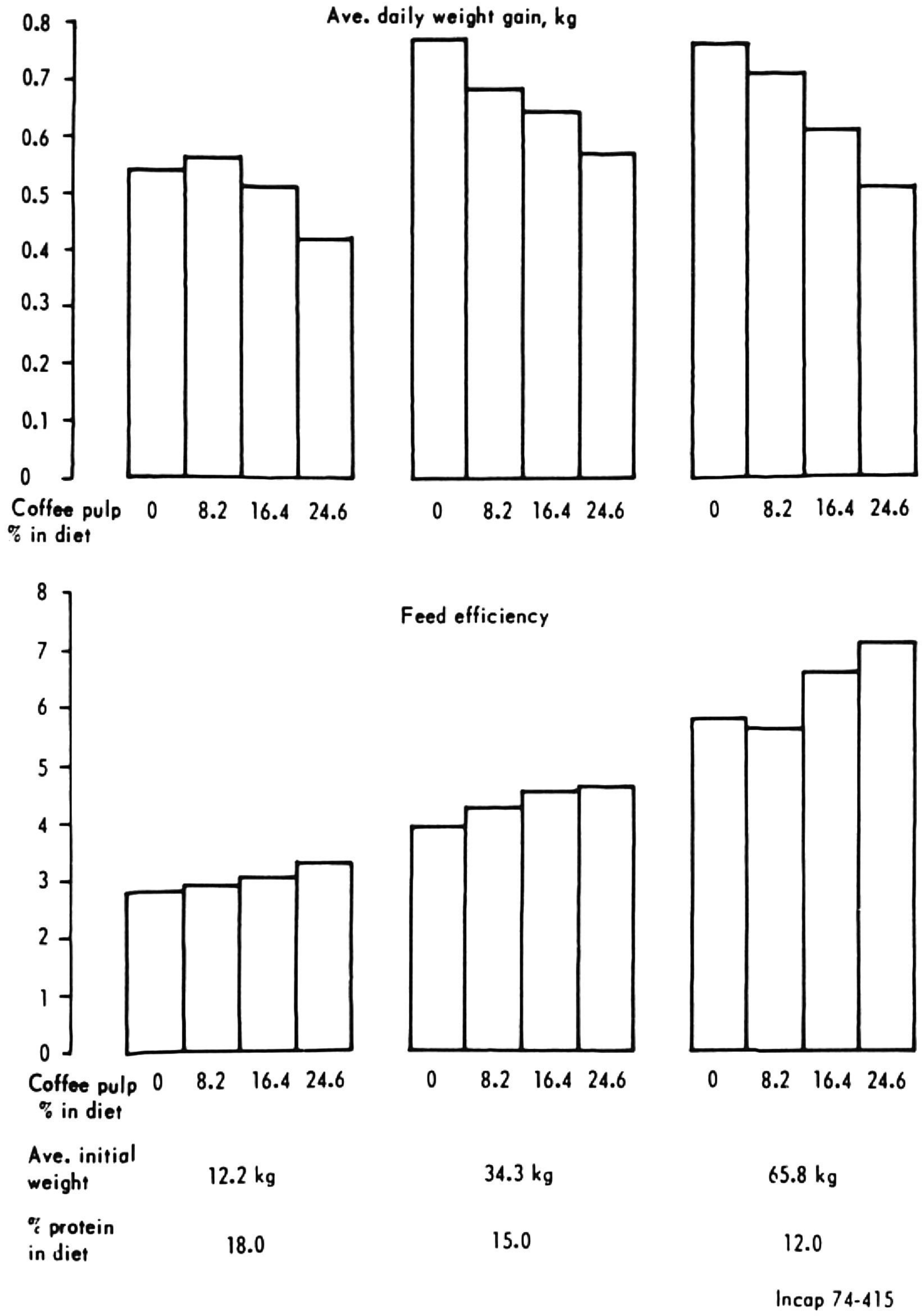

Fig. 4 EFFECT OF COFFEE PULP IN DIETS FOR CHICKENS

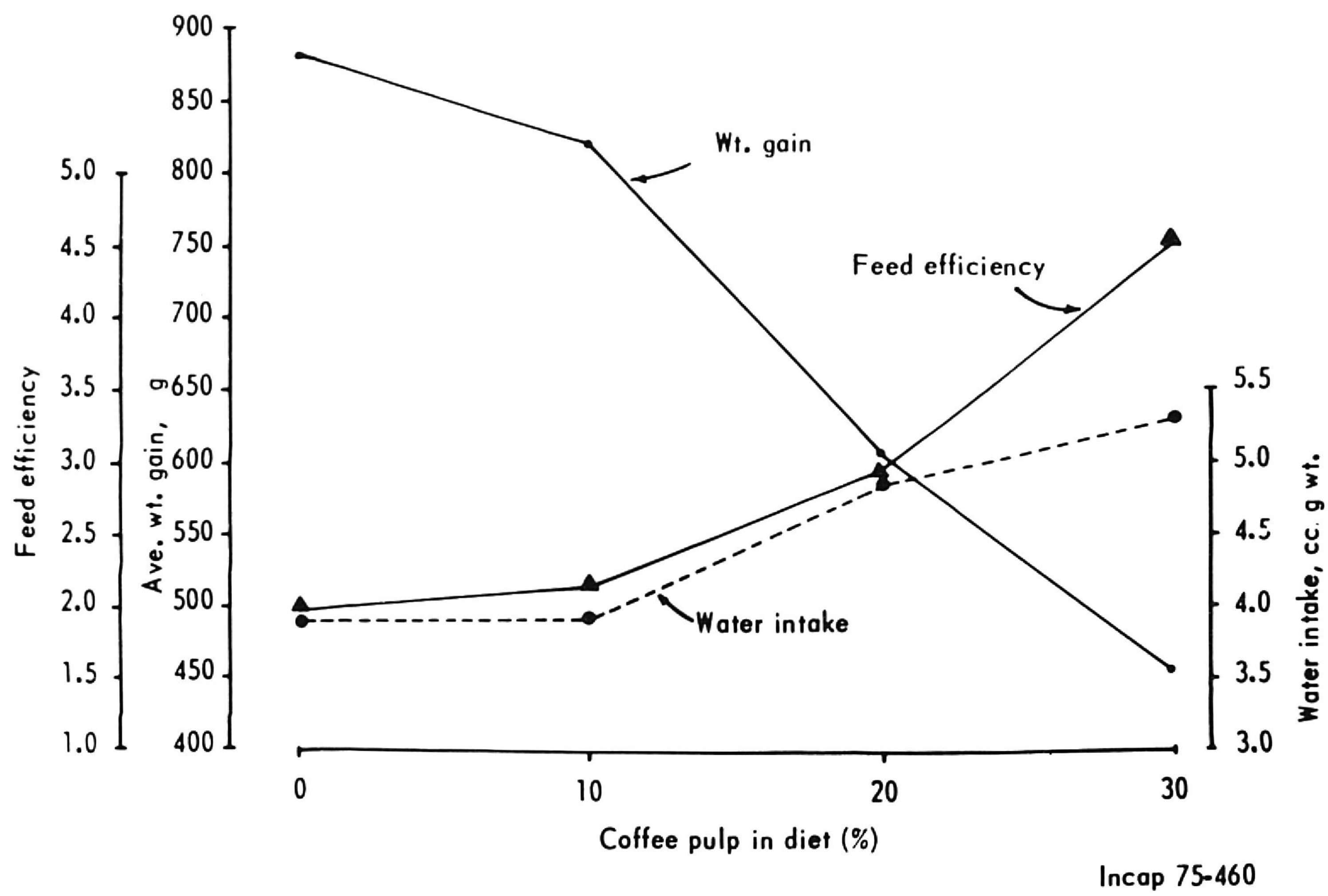

Fig. 5 EFFECT OF COFFEE PULP INCREASING LEVELS IN BROILER RATIONS

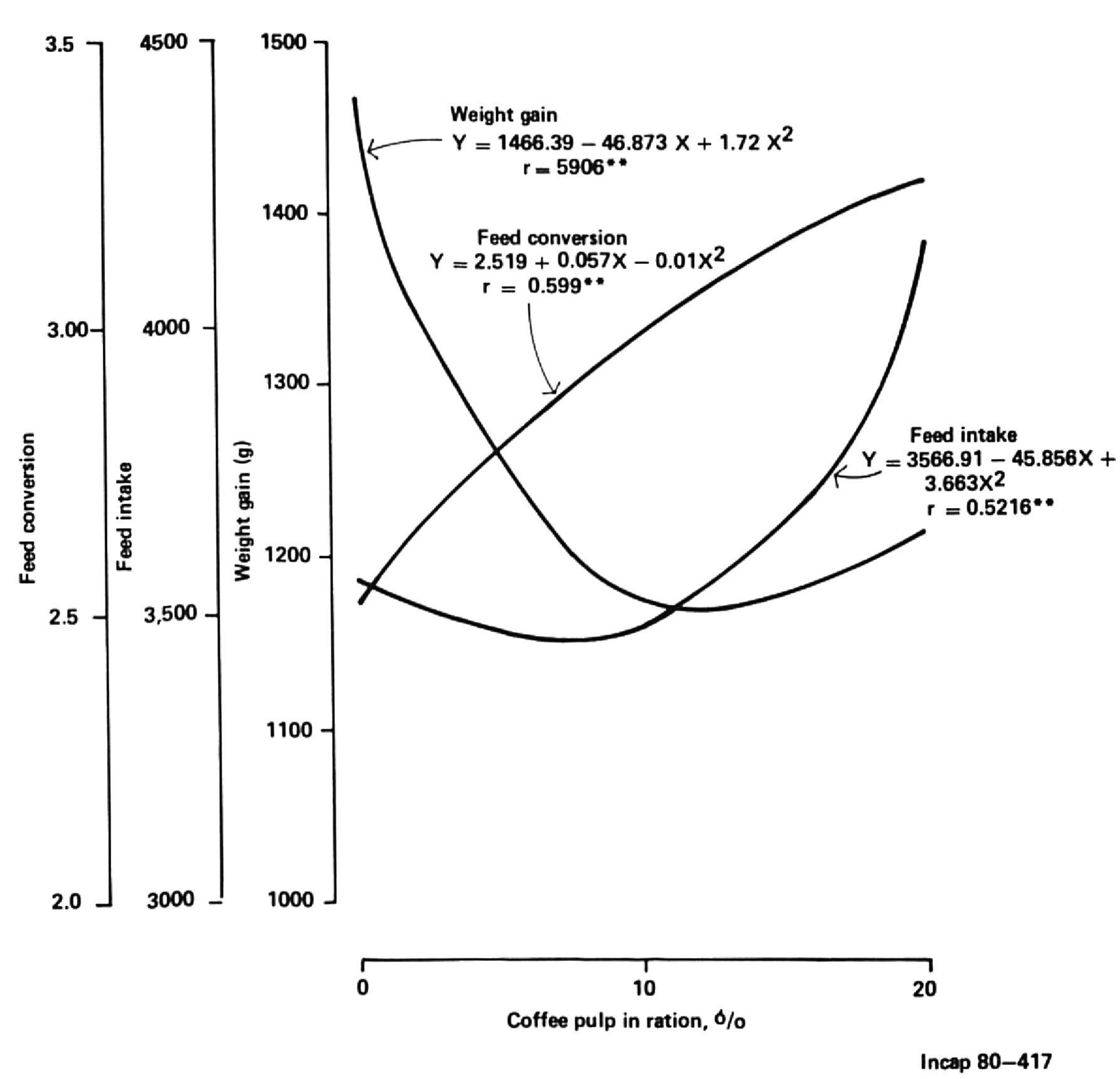

Fig. 6 EFFECT OF CAFFEINE AND TANNIC ACID ON CALF PERFORMANCE

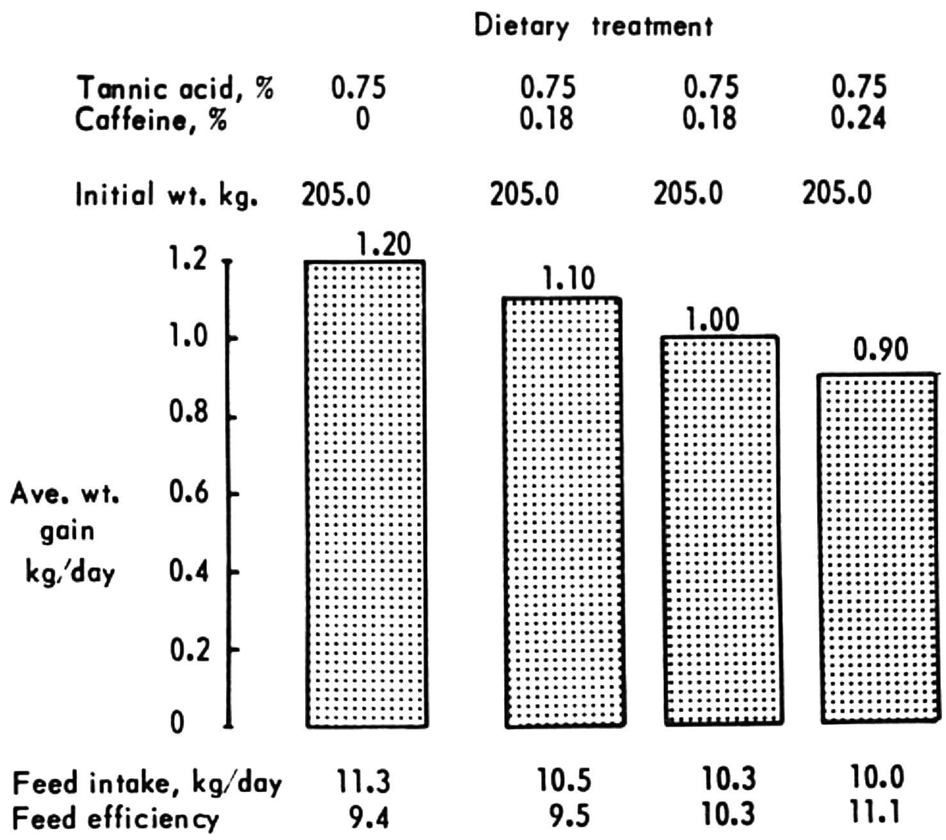

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Fig. 7 HANDLING OF COFFEE PULP

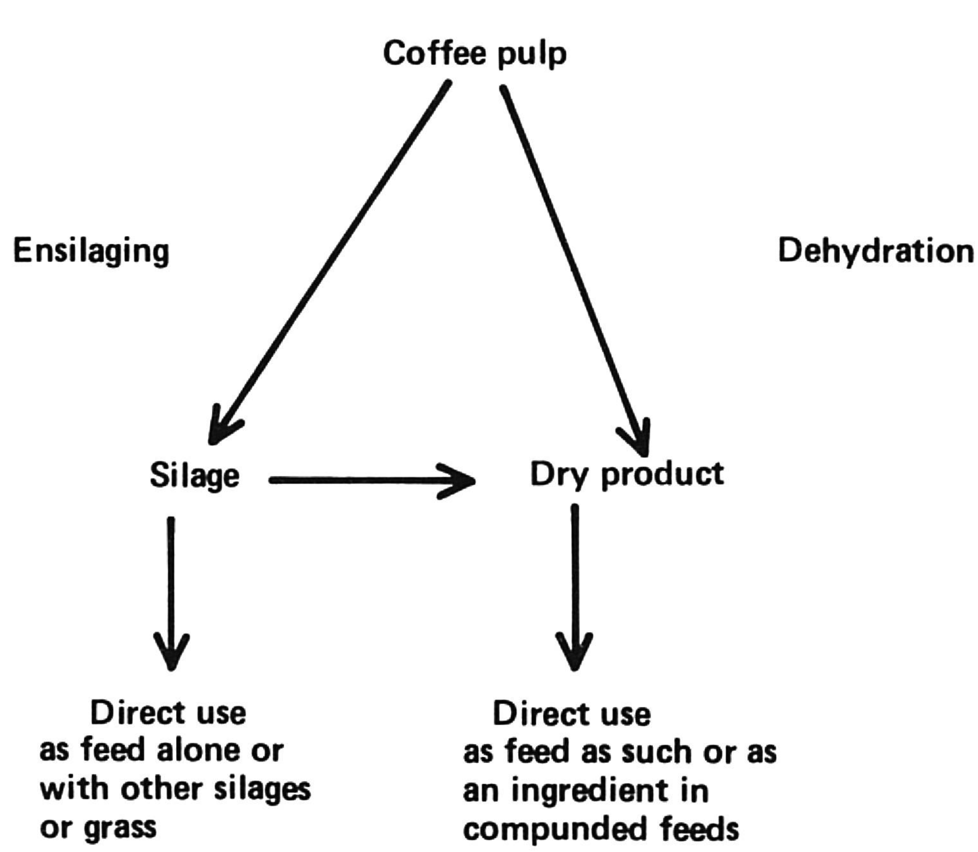

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Fig. 8 **ENSILAGING OF COFFEE PULP**

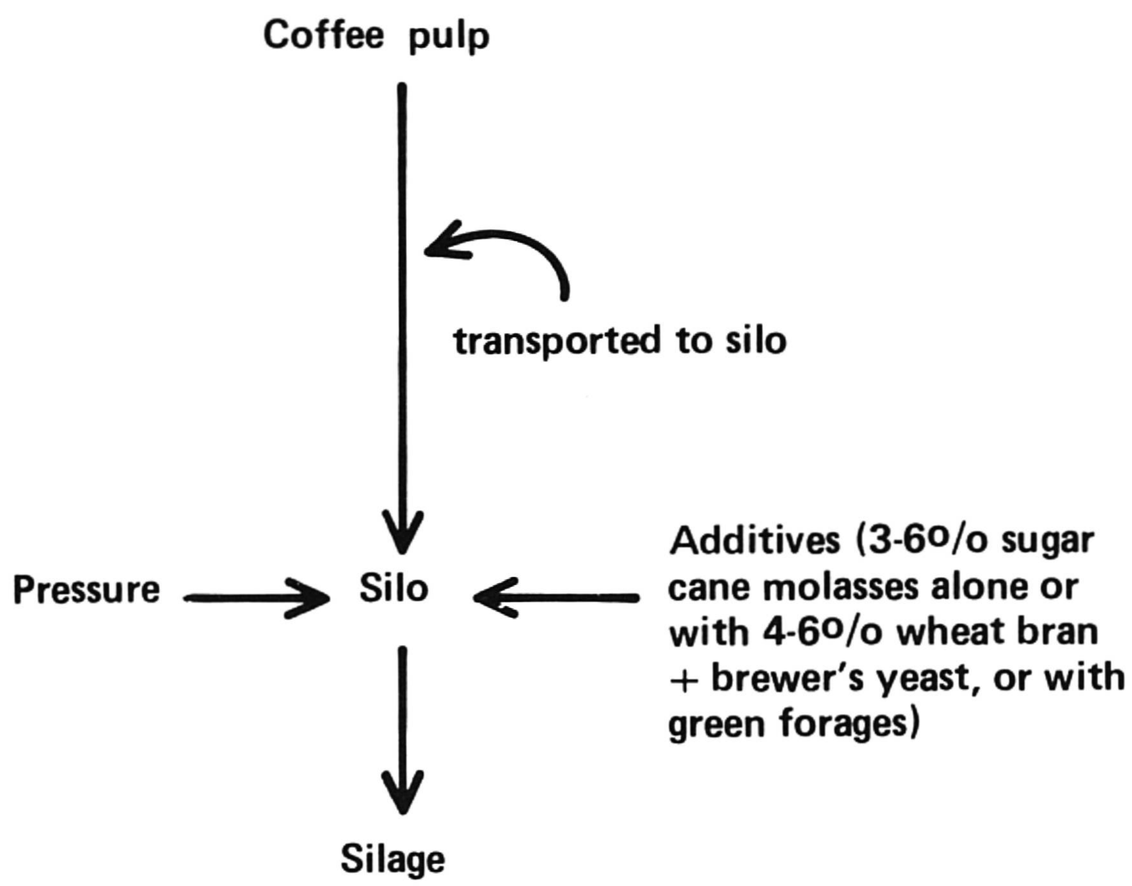

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Table 1 MATERIAL BALANCE FROM COFFEE CHERRY PROCESSING

	Fresh wt. g.	o/o wt.	Moisture o/o	Dry wt. g.	o/o
Coffee cherry	1000	100.0	65.5	345	–
↓ pulper					
Coffee pulp	432	43.2	77.0	99	28.7
+					
Coffee beans + mucilage + coffee hulls	568	56.8	56.0	250	72.2
↓ Fermentation and washing					
Mucilage	–	–	–	17	4.9
+					
Coffee beans + coffee hulls	450	–	50.0	225	–
↓ Dehulled					
Coffee hulls	61	6.1	32.0	41	11.9
+					
Coffee beans	389	38.9	51.0	191	55.4

Bressani et al., Turrialba, 22:299, 1972.

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Table 2 **CHEMICAL COMPOSITION OF COFFEE PULP (o/o)**

	Fresh	Dehydrated	Naturally fermented and dehydrated
Moisture	76.7	12.6	7.9
Dry matter	23.3	87.4	92.1
Ether extract	0.48	2.5	2.6
Crude fiber	3.4	21.0	20.8
Crude protein N x 6.25	2.1	11.2	10.7
Ash	1.5	8.3	8.8
Nitrogen free extract	15.8	44.4	49.2

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Table 3 **CONTENT OF OTHER COMPONENTS IN COFFEE PULP**

Component	o/o dry weight
Tannins	1.80 – 8.56
Total pectic substances	6.5
Reducing sugars	12.4
Non-reducing sugars	2.0
Caffeine	1.3
Chlorogenic acid	2.6
Total caffeic acid	1.6

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Table 4

CELLULAR WALL CONSTITUENTS AND STRUCTURAL POLYSACCHARIDES IN COFFEE PULP
(g o/o)

Cellular content	63.2
Neutral detergent fiber	36.8
Acid detergent fiber	34.5
Hemicellulose	2.3
Cellulose	17.7
Lignin	17.5
Lignified protein	3.0
Crude protein	10.1
Insoluble ash	0.4

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Table 5

ASH AND MINERAL CONTENT OF COFFEE PULP

Component	Content
Ash, g o/o	8.3
Ca, mg o/o	554
P, mg o/o	116
Fe, mg o/o	15
Na, mg o/o	100
K, mg o/o	1765
Mg	Traces
Zn, ppm	4
Cu, ppm	5
Mn, ppm	6.25
B, ppm	26

Bressani et al. Turrialba 22:299, 1972.

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Table 6 AMINO ACID CONTENT OF COFFEE PULP PROTEIN (g/16 gN)

Amino Acid	Coffee pulp	Maize	Soybean meal	Cottonseed meal
Lysine	6.8	1.7	6.3	4.3
Histidine	3.9	2.8	2.4	2.6
Arginine	4.9	3.1	7.2	11.2
Threonine	4.6	3.3	3.9	3.5
Cystine	1.0	1.0	1.8	1.6
Methionine	1 3	1.6	1.3	1.4
Valine	7.4	5.0	5.2	4.9
Isoleucine	4.2	4.3	5.4	3.8
Leucine	7.7	16.7	7.7	5.9
Tyrosine	3.6	5.0	3.2	2.7
Phenylalanine	4.9	5.7	4.9	5.2
Hydroxiproline	0.5	–	–	–
Aspartic Acid	8.7	–	–	–
Serine	6.3	–	–	–
Glutamic Acid	10.8	–	–	–
Proline	6.1	–	–	–
Glycine	6.7	–	–	–
Alanine	5.4	–	–	–

Bressani et al. Turrialba 22:299, 1972.

Incap 80–405

Table 7 AVERAGE WEIGHT GAIN AND FEED INTAKE OF 78 DAY OLD CALVES FED INCREASING LEVELS OF SUN–DRIED COFFEE PULP IN THE DIET*

	Coffee pulp, o/o in diet			
	0	10	20	30
Initial wt., kg	90.5	89.6	89.2	90.5
Final wt., kg	170.6	167.3	155.6	146.9
Ave. wt. gain, kg/day	0.95[a]	0.92[a]	0.79[b]	0.67[b]
Feed intake, kg/day	5.9	5.9	5.3	4.5
Feed efficiency	6.2	6.4	6.7	6.7

* Duration of study: 84 days

a,b Values with different letters are statistically significant ($P < 0.05$).

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Table 8

WEIGHT GAIN AND FEED CONSUMPTION AND UTILIZATION BY STEERS FED RATIONS CONTAINING DIFFERENT CONCENTRATIONS OF DRY COFFEE PULP

	Coffee pulp in ration, o/o			
	0.0	20.0	40.0	60.0
Initial weight (kg)	232.1	232.1	234.8	232.8
Final weight (kg)	354.5	335.1	301.3	238.9
Weight gain (kg/day)	1.5[a]	1.3[b]	0.8[c]	0.1[d]
Dry matter total intake (kg/100 kg wt./day)	4.1[a]	3.7[b]	3.2[c]	2.6[d]
Coffee pulp dry matter intake (kg/100 kg wt./day)	0.0	0.74	1.27	1.57
Crude protein intake (kg/100 kg wt./day)	0.58	0.58[b]	0.48[b]	0.38[c]
Feed conversion*	8.0[a]	8.2[a]	11.0[a]	34.9[b]
Caffeine intake (g/100 kg wt./day)	--	3.6[a]	6.2[b]	7.6[c]
Tannin intake (g/100 kg wt./day)	--	22.1[a]	38.1[b]	46.0[c]

a, b c, d : Average on the same line with different letters are significantly ($P < 0.05$) different.

* : Kg of dry matter intake per kg of weight gain.

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Table 9

PERFORMANCE OF 100 DAY OLD CALVES FED SUN–DRIED COFFEE PULP OR EQUIVALENT AMOUNTS OF CAFFEINE*

	Control diet	30o/o Dehydr. coffee pulp	0.12o/o Caffeine	0.24o/o Caffeine
Initial wt., kg	95.3	95.5	95.6	96.0
Final wt., kg	215.0	195.1	215.1	191.2
Ave. wt. gain, kg/day	1.21[a]	1.00[a]	1.21[a]	0.96[b]
Feed intake, kg/day	8.2	7.3	8.1	6.8
Feed efficiency	6.8	7.3	6.6	7.0

* Duration of study 99 days.
Amounts of caffeine equivalent to that in 30 and 60o/o coffee pulp (caffeine in coffee pulp, 0.40o/o).

a,b Values with different letters are statistically significant ($P < 0.05$).

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Table 10 **IN VIVO DIGESTIBILITY COEFFICIENTS OF COMPONENTS IN COFFEE PULP (RUMINANTS)**

Component	Coefficient of digestibility, o/o
Dry matter	54.8
Organic matter	54.4
Crude fiber	46.9
Energy	51.1
Protein	27.0

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Table 11 **GENERAL OBSERVATIONS ON THE EFFECTS OF COFFEE PULP ON ANIMAL PERFORMANCE**

1. Reduced dry matter intake
2. Reduced daily weight gains
3. Reduced feed efficiency
4. Increased urinary output
5. Decreased nitrogen retention
6. Adaptation with respect to time
7. Undesirable effects decrease when fed with green forages
8. High protein rations decrease effects of coffee pulp

Incap 80–410

Table 12 **CHEMICAL COMPOSITION OF DRY AND ENSILAGED COFFEE PULP**

Component	Coffee pulp silage	Dry coffee pulp
Moisture, o/o	86.0	12.6
Protein, o/o*	13.6	11.2
Soluble sugars, o/o*	4.0	––
Caffeine, o/o*	0.66	1.3
Tannins , o/o*	1.89	1 80
Lactic acid, o/o*	0.038	––
Ash, o/o*	1.5	8.3
Cellular walls**	53.1	36.8
Lignin	21.2	17.5
Cellulose	27.2	17.7
Hemicellulose**	3.0	2.3
pH	4.2	––
Digestibility, o/o	55.0	54.8

* Dry weight basis.
** Percentage of dry matter.

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Table 13 CHANGES IN SOME COMPONENTS IN COFFEE PULP DURING ENSILAGING

Days of ensilaging	pH	Soluble sugars g/100 g	Protein g/100 g
		CONTROL	
0	4.35	10.8	12.1
60	4.28	3.1	13.9
120	5.20	2.9	12.6
		+ MOLASSES	
0	4.38	20.1	11.4
60	4.32	3.3	14.3
120	4.30	3.4	11.1
		+ MOLASSES + WHEAT BRAN	
0	4.45	18.4	13.4
60	4.30	3.7	14.5
120	4.30	3.9	13.1

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Table 14 SOME VOLATILE FATTY ACIDS IN COFFEE PULP SILAGE
(mg/100 g)

Days of ensilaging	Lactic acid			Acetic acid			Propionic acid		
	C.P.	C.P.+M	C.P.+M+W.B.	C.P.	C.P.+M	C.P.+M+W.B.	C.P.	C.P.+M	C.P.+M+W.B.
0	0.27	0.33	0.35	0.11	0.12	0.14	0	0	0
7	0.63	0.88	1.12	0.36	0.40	0.40	0	0	0
30	0	0.28	0.38	1.41	1.76	1.78	0.22	0.14	0.16
60	0	0	0.18	1.86	2.39	2.16	0.28	0.20	0.16
90	0	0	0	1.11	4.54	3.95	0.29	0.30	0.76
120	0	0	0	0.70	3.53	4.29	0.47	0.29	0.33

C.P. Coffee pulp.
M. Molasses.
W.B Wheat Bran.

Incap 80–412

Table 15 PERFORMANCE OF CALVES FED ON COFFEE PULP SILAGE

Age of coffee pulp silage	Aver. wt. gain kg/day	Feed intake kg/day	Aver. wt. gain kg/day	Feed intake kg/day
	4 months		14 months	
Control	1.21*	8.2	1.19**	9.1
30o/o sun-dried coffee pulp	1.00*	7.3	0.98**	7.7
30o/o dehydrated coffee pulp silage	1.06*	7.1	1.08**	7.5

* Average initial weight, 95.4 kg.
** Average initial weight, 130.9 kg.

Incap 80–413

Table 16 EFFECT OF ADDING $Ca(OH)_2$ TO FRESH COFFEE PULP

$Ca(OH)_2$ added*	Liquor extracted o/o of total	pH of residue**
0	34.5	4.5
0.2	35.5	5.8
0.6	45.0	8.9
1.0	46.5	9.6

* Holding time: 20 minutes.
** After pressing.

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