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CHEMICAL CHARACTERISTICS OF COFFEE FRUIT WITHOUT SEEDS (COFFEE PULP) AND ITS USE IN SWINE FEEDING[1]

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Summary

The proximate chemical analysis of dehydrated coffee fruit without seeds (CFWS) showed a protein concentration comparable to that of most cereal grains, but a higher crude fiber and a lower fat content.

The amino acid pattern as percentage of the protein of CFWS was found to be superior to that of cereal grain proteins, particularly in those amino acids in which cereal protein is deficient. While lysine content was as high as that of soybean protein, the sulfur-containing amino acids were quite low. The K content was excessively high. The average content of caffeine, tannins, chlorogenic, and caffeic acids were 2.4, 1.3, 2.6 and 1.6%, respectively.

Rations containing 0, 8.2, 16.4 and 24.6% levels of dry finely ground CFWS were evaluated in growing pigs. The protein content of the rations was 18, 15 and 12%, respectively according to the growth stage of the animals, but levels of CFWS were maintained constant throughout the growing period. When levels of 18 and 15% protein were fed to swine, no statistical difference was observed between the control group and those animals fed the diets containing 8.2 and 16.4% of CFWS. Additional trials with swine rations containing 16% of CFWS exposed to different treatments, and the results of nitrogen balance and digestibility studies, support the conclusion that 16% of CFWS can be safely fed to pigs during the growing period.
Key Words: coffee fruit without seeds, coffee pulp, caffeine, tannins, swine feeding.

Introduction

As early as 1944, research reports were published on the use of coffee fruit without seeds (CFWS) as a feed ingredient for milking cows, apparently with good results (Choussy, 1944). Since then, other papers on the use of CFWS as animal feed have been published, among others by Osegueda et al. (1970), Squibb (1950), and Bolaños (1953) Many of these articles are contradictory in nature; however, they suggest the potential of CFWS as animal feed, even though problems in its utilization were encountered.

Around 1970, INCAP, as well as other institutions, renewed their interest in the utilization of this byproduct. At present there is enough experimental evidence to ensure that CFWS can safely be used in ruminant feeding in amounts of up to 30% of the total ration (Braham et al., 1973; Bressani et al. 1975; Cabezas et al., 1974; Jarquín et al., 1973). Nevertheless, its use is not widespread, mainly due to lack of knowledge on the nutritive value of the material and on its handling, preservation, and drying procedures.

It was considered of special interest, therefore, to stress the importance of determining the chemical composition of the CFWS and, at the same time, of analyzing the biological response when more sensitive animals, like swine, are fed an ingredient of this nature.

Materials and Methods

Material Balance and Chemical Analysis of Coffee Fruit Without Seeds

Samples of coffee berries were brought to our laboratories for material balance studies of the different components of the whole fruit. One-kilogram samples were then passed through a laboratory pulper to separate the CFWS from the seed itself, still covered by mucilage and the hull. The amount of mucilage was estimated by

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weighing the washed fresh seeds before and after 48-72 hours of natural fermentation. The beans were then dried and threshed to remove the hull. All samples were analyzed for water content by dehydration in a vacuum oven for 16 hours.

Proximate chemical analysis was carried out on fresh, dehydrated, naturally fermented and dehydrated CFWS following official methods of the AOAC (1970). The dry CFWS were also analyzed for tannins (AOAC, 1970), caffeine (Ishler et al. 1948), and chlorogenic and caffeic acids (Pomenta and Burns, 1971). Calcium, phosphorus and iron content were determined according to the AOAC (1970) and sodium and potassium, by flame photometry (AOAC, 1970). Other trace minerals were determined by atomic absorption spectrophotometry, and the amino acids, by ion exchange column chromatography of acid hydrolysates.

Changes in the deep red coloration of CFWS, when recently separated from the coffee bean, to a dark brown color during drying suggest that enzymatic reactions are involved. These reactions can be blocked among various other possible compounds by the use of sulfite (Hodge, 1953). Therefore, 1.0 kg samples of fresh CFWS were treated with 0, 1 and 2% of sodium metabisulfite ($Na_2S_2O_5$) prior to solar dehydration. This process was performed by spreading the CFWS in layers 5 cm thick on a clean surface and exposing it to solar energy where temperatures rose as high as 40°C. Moisture content dropped to about 12% after 16 hours of continuous exposure. The dry CFWS obtained from the various treatments was then subjected to proximate chemical analysis by AOAC methods (1970), and fractionation of cellular walls according to Van Soest (1963) and Van Soest and Wine (1967, 1968). Caffeine (Ishler et al., 1948) and tannins (AOAC, 1970) were also determined.

Coffee Fruit Without Seeds as a Silage Material

Experience with this byproduct suggests that ensiling is one of the best processes to handle and preserve this material. A better palatability and a more desirable fermentation are obtained with the addition of 6% molasses. Trials have been carried out also with the addition of sodium metabisulfite at the time of ensiling. A well-packed trench silo holds an average of 30 kg of CFWS per cubic foot (González, 1973).

Biological Trials With Swine

In a first trial, 16 male and 16 female Yorkshire pigs, 2 months old were distributed according to sex and weight among four experimental groups. Each group was subdivided into two groups of four animals each, which were kept in pens with concrete floors and optimum sanitary conditions. Feed and water were supplied ad libitum and records of feed consumption and weight gain were registered weekly. Changes in protein concentration of the different diets were made according to the weight reached by the experimental animals. For 12-30, 34-60 and 65-90 kg of body weight, 18, 15 and 12% of protein in the diet were used, respectively. At each level of protein, the diets contained 0, 8.2, 16.4 and 24.6% of ground sun-dehydrated CFWS, which replaced equal amounts of protein from a basic soya-maize blend. Crude fiber was equalized for all diets using finely ground corn plant tops. The same animals were used throughout the study. At the end of each growth period, the animals were fed a commercial diet for 7 days, and then randomized by sex and weight into new groups for the following growth period. Table 1 shows the formulations used in the first stage of growth when 18% of protein was required. Changes to lower protein concentration in the diets according to the stage of growth reached were achieved by reducing the corn-soya mixture and increasing the level of molasses. Cornstarch was used to adjust to 100 g of ration.

TABLE 1 Composition of Diets Used in the First Trial (12-30 kg Body Weight)[a]

Item	International feed number	Treatments 1 (%)	2 (%)	3 (%)	4 (%)
Corn-soybean blend		74 3	70 6	66 9	63.2
Coffee, fruit without seeds, dehy	1-09 734	....	8 2	16 4	24.6
Maize, aerial part, fresh	2-02 789	15 1	10 3	5 5	.7
Maize, starch	4 02 889	....	3	6	.9
Vitamins and minerals[b]		2	2	.2	.2
Aurofac		.2	.2	.2	.2
Minerals[c]		3 0	3 0	3.0	3.0
Sugarcane, molasses, more than 46% invert sugars more than 79 5° brix	4 04 696	7 2	7 2	7 2	7 2
Totals		100 0	100.0	100 0	100.0

[a]When pigs reached 34-60 kg and 65-90 kg body weight, corn-soybean meal blend was reduced and molasses increased to 14.4 and 21 6%, respectively. CFWS was kept constant and cornstarch used to complete 100 g of ration.

[b]From Dohyfral Duphar, Amsterdam, Holland Composition per kg vit. A 2,000,000 IU, vit. D_3 400,000 IU vit E, 1,000 IU, vit B_{12}, 3 mg Fe, 20,000 mg; Mn, 10,000 mg, Cu, 1,500 mg, 1,150 mg and Zn, 40,000 mg.

[c]Bone meal, 33%, iodized salt, 32% calcium carbonate, 33%, and minor elements, 2%. Taken from Jarquín et al. (1974).

In a second trial 40 Landrace pigs, 20 males and 20 females, weighing an average of 61 kg were distributed according to sex and weight into five groups. The animals were housed, fed and handled as described for the first trial, and fed the rations detailed in Table 2, which contained 16% of sun-dried CFWS as well as of this byproduct, ensiled with molasses and with sodium metabisulfite, respectively.

A metabolic study was also performed with eight male pigs weighing an average of 13.6 kg. Two animals were assigned to each of the rations shown in Table 1, and five consecutive nitrogen balances were performed. Each balance required 7 days, three for adaptation, and four for quantitative collection of feces and urine.

All animals were weighed at the beginning and at the end of each balance. Although the amount of feed offered changed between balances, it was restricted to the consumption of the group fed the ration with the highest level of

TABLE 2 Formulations for Swine Using CFWS Exposed to Different Treatments

Item	International feed number	Treatments 1 (%)	2 (%)	3 (%)	4 (%)	5 (%)
Corn-soybean blend		50.00	50.00	50.00	50.00	50.00
Coffee, fruit without seeds, sun-cured	1 13-456	—	16.00	—	—	—
CFWS, molasses added ensiled		—	—	16 00	—	—
CFWS, 1.5% $Na_2S_2O_5$ added, ensiled		—	—	—	16 00	16.00
Maize, aerial part, fresh	2-02 799	8.00	—	—	—	—
Sugarcane, molasses, more than 46% invert sugars more than 79 5° brix	4-04-696	15.00	15 00	15 00	15 00	15 00
Minerals[a]		3 00	3 00	3.00	3.00	3.00
Maize, dent yellow, grain	4 02 935	23 75	15 75	15 75	15.75	15.50
Vitamins + minor elements[b]		.25	25	25	.25	.25
DL Methionine	5-03 086	—	—	—	—	.25
Totals		100 0	100 0	100.0	100 0	100 0

[a]Same as in Table 1.
[b]Same as in Table 1.

CFWS. Urine and feces samples were kept in a room at 4°C and 5 ml of concentrated acetic acid were added daily to the urine flasks. Daily collections of urine and feces were pooled, homogenized and kept at an adequate temperature until analyzed for nitrogen (AOAC, 1970) and calories with an adiabatic bomb calorimeter.

Results and Discussion

Material Balance in the Processing of the Coffee Fruit

The material balance and its process are presented in Table 3. From 1000 g of fruit 432 g of CFWS are obtained, which on a dry weight basis represent about 29% of the weight of the whole fruit. Further processing yields 61 g of wet coffee hulls or 41 g on a dry weight basis, equivalent to about 12% of the fruit. The mucilage amounts to around 5% of the dry weight of coffee berries (Bressani et al., 1972). From these results it can be estimated that there are approximately over 1.5 million metric tons of dry CFWS, and about .5 million metric tons of hulls available in Latin America.

Chemical Composition of Coffee Pulp

Representative values (Bressani et al., 1972; Molina et al., 1974) are given in Table 4. Attention is called to the high water content of fresh CFWS. For purposes of handling, transportation, processing and direct use as an animal feed, this moisture level constitutes a problem. The dried CFWS contains about 10% crude protein, 21% crude fiber, 8% ash and 44% nitrogen-free extract.

The average content of tannins, caffeine, chlorogenic acid and total caffeic acid in dry CFWS, is presented in the same table. This information is of interest in terms of the potential use of CFWS, since available data suggest that these compounds interfere with the proper utilization of the nutrients in this byproduct.

TABLE 3 Material Balance From Coffee Fruit Processing[a]

Part	Process	(%) of Fresh Weight	Dry Matter	(%) of Dry Fruit
Coffee fruit		100.0	34.5	100.0
	Removing pulp			
Coffee fruit wo seeds (coffee pulp) (IFN 2-11-471)		43.2	23.0	28.7
+				
Coffee seeds + mucilage + coffee hulls		56.8	44.0	72.7
	Fermentation and washing			
Mucilage		—	—	4.9
+				
Coffee seeds + coffee hulls		—	50.0	—
	Removing hulls			
Coffee hulls (IFN 1-10-448)		6.1	68.0	11.9
+				
Coffee seeds		38.9	49.0	55.4

[a]Data taken from: Bressani et al. 1972.

The mineral breakdown of the ash fraction is also shown in Table 4. Emphasis should be made on the high potassium concentration, as this could have important implications in the use of CFWS. Minor elements are quite low (Bressani et al., 1972).

Table 5 summarizes the average amino acid content of two samples (Bressani et al., 1972). It is of interest to note the relatively high level of lysine in CFWS, which is as high as that found in soybean meal on a per gram nitrogen basis; the protein is, however, deficient in sulfur-containing amino acids, the biological availability of which is unknown. This is an aspect that requires some investigation since it is a well-known fact that tannins react with protein making its amino acids biologically unavailable to the animal.

The results of some chemical and structural analyses of CFWS treated with two levels of $Na_2S_2O_5$ prior to dehydration (Murillo et al., unpublished data) are shown in Table 6. The addition of bisulfite reduced the lignified protein; caffeine content remained relatively constant, while tannins increased. As the data reveal, there is a marked increase in cellular content and a decrease in cellulose and lignin.

Coffee Fruit Without Seeds in Swine Feeding

The chemical composition and amino acid content

TABLE 4 Chemical Composition of Coffee Fruit Without Seeds[a]

Component	Fresh (%)	Dehydrated (%)	Naturally fermented and dehydrated (%)
Moisture	76.7	12.6	7.9
Dry matter	23.3	87.4	92.1
Ether extract	.48	2.5	2.6
Crude fiber	3.4	21.0	20.8
Crude protein	2.1	11.2	10.7
Ash	1.5	8.3	8.8
N-free extract	15.8	44.4	49.2
Tannins		2.4	
Caffeine		1.3	
Chlorogenic acid		2.6	
Caffeic acid		1.6	
Ca, mg		554	
P, mg		116	
Fe, mg		15	
Na, mg		100	
K, mg		1765	
Mg		Traces	
Zn, ppm		4	
Cu, ppm		5	
Mn, ppm		6.25	
B, ppm		26	

[a]Data taken from: Bressani et al., 1972, and from Molina et al. (1974).

of CFWS suggest that it has good possibilities as a source of nutrients for swine, despite its high crude fiber content. Table 7 shows the results of the first growth study (Jarquín et al., 1974).

At each growth stage, weight gain and feed efficiency were inversely related to the level of CFWS in the diet. The highest level of this material resulted in a significantly lower performance of the animals. Daily gains obtained during the first stage of growth, when 8.2 and 16.4% of CFWS were used in the diet, are comparable to those given by the NRC (1968), for pigs of that age. At the lower level of this byproduct in the diet, a greater feed consumption was recorded.

From 34 to 64 kg live weight on 15% protein rations, average daily weight gains were 770, 6[illegible]0, 640 and 570 g for the control group and for the animals fed the diets containing the different levels of CFWS, respectively. According to the NRC (1968), the daily gain expected for animals of this age and weight is 750 grams.

The average daily gains obtained in the last period of growth were 760, 710, 610 and 510 g for the control group and for those fed the respective levels of CFWS. In this case even the control animals did not reach the daily weight gain stipulated by the NRC (1968). It has been reported that a higher level of protein increases the tolerance to high levels of CFWS in the diet (Bressani et al., 1973). This finding may explain the lower daily weight gain reached on the third stage of growth. Although protein concentration of the diets was adequate (NRC, 1968), it may have been quite low according to the level of CFWS used, as this has a high percentage of lignified protein that may be unavailable to the animal.

TABLE 5 Amino Acid Content of Coffee Fruit Without Seeds (Coffee Pulp) Protein As Compared to Other Feeds[a]

Amino acid	Coffee pulp (g/16 gN)	Maize (g/16 gN)	Soybean meal (g/16 gN)	Cotton-seed meal (g/16 gN)
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	----	----	----

[a]Data taken from: Bressani et al. (1972).

TABLE 6 Chemical and Structural Changes in Coffee Fruit Without Seeds (Coffee Pulp) Sun-Cured and Treated with Different Levels of $Na_2S_2O_5$[a]

Component	Level of $Na_2S_2O_5$ (%) 0	(%) 1	2
Protein, %	10.0	9.7	9.3
Lignified protein	6.3[b]	3.3[c]	3.3[c]
Caffeine	.72[b]	.66[b]	.65[b]
Tannins	1.85	3.75	3.50
Cellular content	43.7[b]	55.3[c]	58.7[c]
Cellular walls	53.3	41.9	38.4
Cellulose	29.9[b]	22.2[c]	20.0[c]
Lignin	19.5[b]	15.6[c]	14.1[c]

[a]Data taken from: Murillo et al. (unpublished data).
[b,c]Numbers with different letters are significantly different.

TABLE 7 Performance of Swine Fed Different Levels of CFWS[a]

Experimental stage	Weight pigs (kg)	Protein in diet (%)	CFWS in diet (%)	Protein from CFWS % of ration	Protein from CFWS % of total protein	Daily gain (kg)	Feed conversion (kg/kg gain)
1	12 30	18	0	0	0	.54[b]	2 8
			8 2	.9	5	.56[b]	2.9
			16.4	1.8	10	.51[b]	3.0
			24.6	2.7	15	.42[c]	3 3
2	34-64	15	0	0	0	77[b]	3 9
			8 2	.9	6	.68[b]	4.3
			16 4	1.8	12	.64[b]	4.5
			24 6	2 7	18	.57[c]	4.6
3	66 92	12	0	0	0	.76[b]	5 8
			8 2	.9	7 5	.71[b]	5.6
			16.4	1.8	15 0	61[c]	6.6
			24.6	2 7	22 5	.51[c]	7.1

[a]Data taken from: Jarquín et al. (1974).
[b,c]Numbers with different letters are significantly different.

TABLE 8 Growth Response of Swine Fed CFWS Exposed to Different Treatments

Treatments	Initial weight (kg)	Final weight (kg)	Feed conversion (kg/kg gain)	Daily gain (g)
Control	61.4	104.9	4.9	691
CFWS, sun-dried	60.9	105.1	5.1	701
CFWS, ensiled with molasses	61.3	100.6	5.6	623
CFWS, ensiled with 1.5% $Na_2S_2O_5$	60.9	98.4	5.2	595
CFWS; ensiled with 1.5% $Na_2S_2O_5$ + methionine	61.6	94.1	5.3	517

The tendency of swine to attain less growth and an inferior feed conversion as the level of CFWS increased in the diet, has been already reported in rats and chicks by Bressani et al., 1973; and for ruminants by other investigators (Braham et al., 1973; Cabezas et al., 1974; Jarquín et al., 1973). The responsible factors for this effect still have not been identified, although according to Jaffé and Ortiz (1952), these factors are present in the alcoholic extract of CFWS. If it is true that caffeine has some growth depressive action (Estrada, 1973), this does not explain the total effect observed.

Based on the improvements in chemical composition (Table 7) when bisulfite was added to CFWS, it was deemed convenient to investigate whether said improvements would exert some beneficial effect on swine rations containing 16% of dry CFWS, previously ensiled with molasses, or ensiled with 1.5% of $Na_2S_2O_5$ plus the addition of methionine at the time of mixing the ration. The response of the pigs in the second trial is presented in Table 8. No significant differences were detected among treatments. The addition of metabisulfite did not improve the final results as expected according to the chemical analyses shown previously. Furthermore, these results indicate that methionine or total sulphur in the diet was not a limiting factor. Nevertheless, the findings related to CFWS sun-dried or ensiled with molasses, and later sun-dried, are encouraging since both processes are the cheapest. Furthermore, ensiling keeps the material in good condition, especially where sun-drying has to be delayed due to rain.

Regression statistical analyses of the results of the metabolic trial are summarized in Table 9. Using all the nitrogen balance values, regressions of nitrogen intake (NI) on nitrogen absorption (NA) and retention (NR) and NA on NR were calculated. As observed, NI was highly significantly correlated to NA at all levels of CFWS used in the diet. However, the regression coefficients decreased as the byproduct in the diet increased. The regression coefficients were not significantly different for the different levels of CFWS. When the same relationships were calculated, this time expressing NA as percentage of NI, the regression coefficients proved to be similar. The intercepts of the equations, representing apparent protein digestibilities, decreased as coffee pulp increased in the diet. This decrease may have been the result of a lower total food intake, particularly when the diet contained 24.6% CFWS. Another possibility is that although the diet contained 18.0% crude protein, 2.7 g came from CFWS. However, approximately 60% of CFWS protein is in a lignified form and may not be available to the animal.

The regression coefficients of NA on NR increased with respect to the levels of CFWS, particularly when 16.4

TABLE 9 Relationship Between Nitrogen Intake, Nitrogen Absorption, and Nitrogen Absorption to Nitrogen Retention

CFWS in diet (%)	NA = a + b NI: a		b	r
0	−1.60	+	.84	.96
8.2	.49	+	.76	.96
16.4	-.29	+	.71	.94
24.6	2.75	+	.68	.95
	NR = a + b NA			
0	.04	+	.56	.92
8.2	− .56	+	.57	.95
16.4	−7.11	+	.69	.84
24.6	−5.00	+	.62	.95
	Digestion coefficients: Protein (%)		Energy (%)	Dry matter (%)
0	86		79	80
8.2	80		79	79
16.4	74		75	73
24.6	72		70	68

and 24.6% were used. This relationship is an index of biological value (Allison, 1955). It appears that even though the regression coefficients are not significantly different, there is a tendency for high indices of biological value with higher levels of CFWS.

It is of interest to indicate that Cunningham (1968) reported increases in NR in swine fed 1.5 g caffeine/kg of diet, a finding that supports the conclusion reached from the nitrogen balance study; however, levels of feed intake may have also affected final results. Therefore, these suggest that the effect of CFWS is due to decreases in protein digestibility rather than to effects at the metabolic level, at least up to the highest concentration of CFWS tested in the present studies.

Table 9 summarizes additional information on dry matter and energy digestibility, which decreased as coffee pulp increased in the diet. These findings are highly correlated with protein digestibility.

The results presented herein, indicate that CFWS may have a place in swine feeding, and from these studies as well as from others using native pigs, the use of levels as high as 16% can be recommended.

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