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UTILIZATION OF COFFEE FRUIT WITHOUT SEEDS IN RUMINANT FEEDING[1]

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Summary

Three digestibility and nitrogen balance trials were performed with steers fed four rations containing 0, 20, 40 or 60% coffee fruit without seeds (CFWS). Intakes of ration dry matter and CFWS dry matter for each treatment were: 3.5, 3.2, 2.6, 2.1 and 0, 6, 1.0, 1.3 kg/100 kg/day, respectively. Apparent digestibilities of organic matter (OM), cell walls (CW), acid detergent fiber (ADF), gross energy (GE) and crude protein (CP) were: 51.2, 50.6, 54.0 and 53.9%; 38.9, 39.1, 42.5 and 44.8%; 33.0, 32.7, 36.6 and 41.5%; 48.0, 48.4, 49.6 and 51.4%; 47.0, 45.7, 37.8 and 36.2%, respectively. Differences between the first two and the last two rations were significant ($P < .05$) for OM, CW, ADF and CP digestibilities. The amounts of nitrogen consumed, absorbed, and retained, decreased ($P < .05$) as CFWS increased in the ration. Percent of nitrogen retained from intake and absorption, decreased ($P < .05$) when CFWS constituted 40 to 60% of the ration. Urinary excretion increased ($P < .05$) in steers fed CFWS. Digestibilities of OM, GE and CP of CFWS were calculated to be 54.8, 51.1 and 27.0%. Three additional experiments were conducted to determine the effects of the following treatments on calf performance: Experiment 1: control, 30% CFWS, .12% caffeine (C) and .24% C; Experiment 2: control, 30% CFWS, .75% tannic acid (TA) and 1.50% TA; Experiment 3: .75% TA, .75% TA + .12% C, .75% TA + .18% C, and .75% TA + .24% C. The CFWS treatments contained .12% C and .76% tannins provided by the pulp. When given alone, the .12% C level and the two TA levels did not produce adverse effects on calf performance. Reductions in feed intake, weight gains ($P < .05$) and feed conversion were observed in animals consuming CFWS, .24% C and the three combinations of C and TA. These effects were more pronounced as the quantity of C increased.
Key Words: coffee fruit without seeds, coffee pulp, caffeine, tannins, ruminant feeding.

Introduction

Coffee fruit without seeds (coffee pulp) is an abundant agricultural byproduct that causes serious environmental pollution problems. Chemical analyses have shown that this material could be an appropriate feedstuff for ruminants (Bressani et al., 1972). Dry coffee pulp (DCP) however, reduces animal performance when fed at levels higher than 20% of the ration (Jarquín et al., 1973; Braham et al., 1973; Cabezas et al. 1974b). The research reported herein, was therefore, carried out to determine the effects of high levels of DCP on the nutritive value of rations used for beef production. The possible relationship of caffeine and tannic acid to an impaired performance of animals fed DCP on the nutritive value of rations used for beef production.

Materials and Methods

The coffee pulp used in these studies was obtained at a commercial plant where coffee is processed according to the methods described by Bressani et al. (1972). The material was air dried immediately after removal of the coffee beans to reduce its water content from 83% to about 15%, and then stored with no additional treatment.

Digestibility and nitrogen balance

The effect of different levels of DCP in the ration on nutrient digestibility and nitrogen utilization by steers was studied. The rations used in this experiment contained either 0, 20, 40 or 60% DCP and were calculated to be

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isoproteic at a 15% level on a dry basis (Table 1). These rations were fed ad libitum for 11 weeks to groups of three Holstein steers averaging 190 kg of weight. During this period, the animals had free access to water. On weeks 4, 7 and 10, the animals were placed in metabolism stalls for a week of adaptation followed by 7-day total collection periods. Feed, feces and urine were collected and sampled according to the techniques described by Harris (1970). Steers were weighed at the beginning and the end of the collection periods to obtain their average weight for each period.

TABLE 1 Ingredient and Chemical Composition of Experimental Rations Used for the Determination of Digestibility and Nitrogen Balance in Steers

Item	International feed number	Ration No. 1	2	3	4
Ingredient composition, %					
Coffee, fruit without seeds, dehy	1-09-734	0.0	20.0	40.0	60.0
Cotton, hulls	1-01-599	54.0	37.5	21.5	5.0
Cotton, seeds without oil, prepressed solv extd, ground, 41% protein	5-07-872	25.0	21.5	17.5	14.0
Sugarcane, molasses, more than 46% invert sugars more than 79.5° brix	4-04-696	20.0	20.0	20.0	20.0
Mineral mix[a]		1.0	1.0	1.0	1.0
Chemical composition					
Dry matter, %		83.2	83.3	82.6	81.9
Composition of dry matter, %					
Crude protein		14.4	14.4	15.0	15.0
Ash		5.1	5.8	6.8	7.8
Cell walls		62.7	58.5	55.6	51.8
Acid detergent fiber		48.0	46.8	46.9	47.2
Cellulose		35.5	31.8	28.6	25.9
Lignin		12.6	15.0	18.1	21.1
Gross energy (Mcal/kg dry matter)		4.4	4.3	4.5	4.4

[a]Commercial mix containing: Ca, 23%; P, 12%; NaCl, 18%, and trace minerals.

Proximate analyses of feed and fecal samples, and nitrogen determinations in urine samples were performed according to the AOAC (1970). Gross energy was determined in an adiabatic bomb colorimeter. Detergent fiber analyses were conducted as outlined by Goering and Van Soest (1970). In addition, DCP was analyzed for caffeine (Ishler et al., 1948) and tannins (Schanderl, 1970). Digestibility of DCP was calculated by difference (Crampton and Harris, 1969).

Performance of calves and steers fed rations containing dry coffee pulp, caffeine and tannic acid

Three consecutive experiments were performed with Holstein calves and steers that had been reared artificially and weaned at 8 weeks of age. Prior to the experiments their diet consisted of a dry forage plus concentrate. The first two experiments lasted 14 weeks and the third, 12 weeks. The animals were housed in corrals containing open sheds with concrete slatted floors. Feeding was ad libitum and mineralized salt and water were also available at all times. The animals were weighed after a 16-hour fast, every four weeks, and weight gains calculated.

Experiment 1. To study the effects of DCP and caffeine (USP) on performance, 24 calves averaging 95 kg and 14 weeks of age were divided into three equal groups, each receiving one of the three rations characterized in Table 2. The two levels of caffeine, .12 and .24%, added to the control ration in treatments 3 and 4, were considered representative of the quantities of caffeine furnished when DCP constituted more than 20% of a ration. Treatment 2 was included in order to compare the effects of the two pure caffeine levels, with those produced by a ration containing 30% DCP. This amount of DCP added approximately .12% caffeine and .76% tannins to the ration.

Experiment 2. The effects of DCP and tannic acid (USP) on steer performance were studied using 32 calves, similar in age and weight to those in Experiment 1. Four comparable groups of eight calves each were assigned to different ration treatments. The first two were the same as treatments 1 and 2 in Experiment 1. For treatments 3 and 4, tannic acid was added to the control ration instead of cottonseed hulls, in the amounts of .75 and 1.50%, respectively. The chemical compositions of all rations were very similar to those in Experiment 1 (Table 2).

TABLE 2 Ingredient and Chemical Composition of Experimental Rations (Experiment 1)

Item	International feed number	Treatments 1 Control	2 30% DCP[a]	3 .12% C[b]	4 24% C
Ingredient composition, %					
Cotton, hulls	1-01-599	48.00	18.00	47.88	47.76
Coffee, fruit without seeds, dehy	1-09-734	—	30.00	—	—
Caffeine, USP		—	—	0.12	0.24
Cotton, seeds without oil, prepressed solv extd ground, 41% protein	5-07-872	15.00	15.00	15.00	15.00
Wheat, bran, dry milled	4-05-190	15.00	15.00	15.00	15.00
Sugarcane, molasses, more than 46% invert sugars more than 79.5° brix	4-04-696	20.00	20.00	20.00	20.00
Urea, 45% nitrogen 281.25% protein equivalent	5-05-070	1.00	1.00	1.00	1.00
Animal, bones, steamed dehy ground	6-00-400	0.28	0.28	0.28	0.28
Calcium, carbonate, $CaCo_3$	6-01-069	0.29	0.29	0.29	0.29
Salt-trace mineralized		0.30	0.30	0.30	0.30
Sulfur		0.13	0.13	0.13	0.13
Chemical composition, %					
Dry matter		85.5	84.2	84.6	85.7
Composition of dry matter, %					
Crude protein		13.4	15.3	14.9	15.3
Ether extract		2.8	2.8	2.7	2.8
Crude fiber		30.0	21.1	30.5	29.7
Ash		5.6	7.0	5.6	5.7
Nitrogen free extract	48.	48.2	53.7	46.3	46.5

[a]Dry coffee pulp
[b]Caffeine

Experiment 3. The design of this experiment was based on the results obtained in the two previous experiments. The goal was to study the effect of different combinations of caffeine and tannic acid on

steer performance. Twenty-four steers averaging 205 kg and seven months of age were distributed into four equal groups. Each group was assigned to one of the following treatments: 1) .75% tannic acid; 2) .75% tannic acid + .12% caffeine; 3) .75% tannic acid + .18% caffeine; 4) .75% tannic acid + .24% caffeine. In all cases, caffeine and tannic acid substituted for the cottonseed hulls of the control ration used in Experiments 1 and 2; therefore, the rations' chemical compositions were similar to that of the control ration (Table 2).

Proximate composition evaluations of rations as well as of DCP, and determinations of caffeine and tannins in DCP were carried out in the last three experiments according to the methods used for determining digestibility and nitrogen balance.

When applicable, data from all experiments were treated to analysis of variance and significant means separated by Duncan's Multiple Range Test (Steel and Torrie, 1960).

Results and Discussion

Chemical composition of coffee pulp

The chemical composition of DCP used in these studies (Table 3), shows the great potential of this material as a feedstuff for ruminants. Caffeine concentration was lower than reported by Bressani et al. (1972), who found levels of up to 1.5% of this compound. The same authors observed that the caffeine content of DCP varies according to the variety and altitude of the coffee plantations.

TABLE 3 Average Chemical Composition of Coffee Pulp

Item	
Dry matter, %	83.6
Composition of dry matter, %	
Crude protein	12.3
Ash	6.8
Crude fiber	28.2
Cell walls	62.6
Acid detergent fiber	59.8
Hemicellulose	2.8
Cellulose	31.5
Lignin	27.9
Cell contents	37.8
Caffeine	0.4
Tannins	2.6
Gross energy (Mcal/kg, dry matter)	4.4

Digestibility and nitrogen balance

Results of this experiment are presented in Table 4. Total dry matter intake during the collection periods decreased linearly (r - .89; $P < .05$) as DCP increased in the ration. Intake of dry matter from DCP in the same periods increased ($P < .05$) from .6 to 1.0 and 1.3 % body weight when the animals consumed rations with 20, 40 and 60% DCP, respectively. The negative effect of DCP on voluntary intake has been consistently observed by different authors (Jarquin et al., 1973; Braham et al., 1973; Cabezas et al., 1974b).

TABLE 4 Dry Matter Intake, Nutrient Digestibility, Nitrogen Utilization and Urinary Excretion by Steers Fed Rations Containing Different Levels of Dry Coffee Pulp

Ration No.	1	2	3	4
Level of coffee pulp, %	0	20	40	60
Number of observations	9	9	9	9
Daily intake				
Total dry matter, kg	8.6^a	7.7^b	6.1^c	4.7^d
Total dry matter, % body weight	3.5^a	3.2^b	2.6^c	2.1^d
Dry matter from coffee pulp, % body weight	0.0	0.6^a	1.0^b	1.3^c
Apparent digestibility, % dry matter				
Organic matter	51.2^a	50.6^a	54.0^b	53.9^b
Cell walls	38.9^a	39.1^a	42.5^b	44.8^b
Acid detergent fiber	33.0^a	32.7^a	36.6^b	41.5^b
Gross energy	48.0	48.4	49.6	51.4
Nitrogen utilization				
Intake, g/day	214.1^a	192.6^b	151.8^c	119.2^d
Absorption, g/day	100.6^a	88.1^b	57.4^c	43.2^d
% of intake	47.0^a	45.7^a	37.8^b	36.2^b
Retention, g/day	40.4^a	36.3^b	20.2^c	4.7^d
% of intake	18.9^a	18.8^a	13.3^b	3.9^c
% of absorption	40.2^a	41.2^a	35.2^b	10.8^c
Urinary excretion				
Lt/day	8.2^a	10.7^b	11.4^b	18.6^c
Lt/kg dry matter intake	1.0^a	1.4^b	1.8^c	3.8^d
g nitrogen/lt urine	7.3^a	4.9^b	3.3^c	2.1^d

^{a,b,c,d}Means on the same line with different superscripts are significantly different ($P < .05$).

Apparent digestibility values of organic matter, cell walls and acid detergent fiber were higher ($P < .05$) for rations 3 and 4 than for rations 1 and 2. The same trend was observed with gross energy digestibility, but no significant differences were detected. These digestibility increments may well be a consequence of the reducted feed intake. In any case, they indicate that this intake reduction is not due to an effect of DCP on

digestibility, but to other factors associated with palatability or nutrient metabolism.

The amounts of nitrogen consumed and absorbed decreased ($P < .05$) when the percentage of DCP in the ration and the intake of this material increased Nitrogen utilization did not improve concurrently. Percent nitrogen absorption decreased ($P < 05$) from 47 0 and 45.7 with rations 1 and 2, to 37.8 and 36 2 with rations 3 and 4. Nitrogen retention as a percentage of both intake and absorption, was the same with 0 and 20% DCP, but decreased ($P < 05$) with higher levels of DCP in the ration. The lower efficiency of nitrogen utilization produced by these rations was accompanied by increased increments of ($P < 05$) in urinary excretion, expressed as liters per day and as liters per kg dry matter intake. The nitrogen concentration in urine decreased ($P < .05$) with each increment of DCP in the ration, but the percentage of nitrogen intake excreted through urine increased ($P < 05$) only with rations 3 and 4 Similar effects on nitrogen utilization by calves fed rations containing 24% DCP were reported by Cabezas et al (1974a). Thus, it seems that nitrogen metabolism is affected by DCP and that this may partially account for the lower performance of ruminants fed rations containing high levels of this material

Calculating the apparent digestibility of organic matter, gross energy and crude protein of DCP by difference, produced the values presented in Table 5 The level of DCP in the ration did not significantly affect these values. According to the digestibility values determined in this experiment, the digestible energy and digestible protein content of DCP are, on a dry basis, 2.2 Mcal/kg and 3 8%, respectively This makes DCP a feedstuff with a nutritive value equivalent to a good quality forage

TABLE 5 Apparent Nutrient Digestibility of Dry Coffee Pulp Calculated by Difference

Item	Level of coffee pulp in the ration, % 20	40	60	Average
Apparent digestibility, % dry matter				
Organic matter	51 8	57 7	55.0	54 8
Gross energy	49 3	52 9	51 1	51 1
Crude protein	31 4	23 2	26 5	27 0
Digestible energy content, Mcal/kg dry matter	2 2	2 3	2 2	2 2
Digestible protein content, % dry matter	4 4	3 3	3 7	3 8

Performance of calves and steers fed rations containing dry coffee pulp, caffeine and tannic acid

Experiment 1 (Table 6) Adding 30% DCP to the ration (Treatment 2), reduced average daily gain ($P < 05$) and feed intake of calves when compared to the control ration Similar results were reported by Jarquín et al (1973), Braham et al (1973) and Cabezas et al. (1974b). Calves that consumed the ration with .12% caffeine performed similarly to the control group Calves that received the ration with 24% caffeine gained the same weight but consumed less feed than those fed the ration containing 30% DCP. Feed conversion was higher for the DCP ration than for the other three treatments. These results suggest that caffeine may be one of the factors responsible for the adverse effects of DCP on animal performance, considering that a level of .24% caffeine can be present in rations with more than 20% DCP (Bressani et al , 1972) On the other hand, since 12% caffeine did not produce the negative effects induced by DCP, the reduced calf performance cannot be attributed exclusively to caffeine Other factors acting individually or with caffeine may, therefore, also be involved in producing such effects

TABLE 6 Performance of Calves Fed Dry Coffee Pulp and Caffeine (Experiment 1)

Item	Treatments 1 Control	2 30% DCP	3 12% C	4 24% C
Average initial weight, kg	95 3	95 5	95 6	96 0
Average final weight, kg	215 0	195 1	215 1	191 2
Average daily gain, kg	1 2[a]	1 0[b]	1 2[a]	1 0[b]
Average daily feed intake, kg	8 2	7 4	8 1	6 8
kg feed/kg gain	6 8	7 4	6 8	6 8

[a,b] Means on the same line with different superscripts are significantly different ($P < 05$)

Experiment 2 (Table 7) The performance of the control group in this experiment was inferior to that of the control in Experiment 1, but the difference between this group and the one fed 30% DCP was still evident ($P < 05$) Neither of the two tannic acid levels significantly reduced average daily gain Feed intake was not greatly affected by neither of the two tannic acid treatments Feed conversion of calves fed 1 5% tannic acid was lower than that of those receiving 30% DCP, but higher than the groups consuming the control ration and 75% tannic acid

Experiment 3. The tannic acid level used in the four treatments of this experiment (75% of the ration) was selected on the basis of the quantities of tannins contributed by DCP in previous experiments and because such a level did not produce adverse effects on calf performance in Experiment 2 This evidence was confirmed by the

TABLE 7 Performance of Calves Fed Dry Coffee Pulp and Tannic Acid (Experiment 2)

Item	Treatments 1 Control	2 30% DCP	3 .75% TA[a]	4 1.50% TA
Average initial weight, kg	93.8	93.6	93.4	93.6
Average final weight, kg	200.6	183.1	202.8	192.3
Average daily gain, kg	1.1[b]	0.9[c]	1.1[b]	1.0[b,c]
Average daily feed intake, kg	7.6	6.8	7.9	7.4
kg feed/kg gain	6.9	7.6	7.2	7.4

[a]Tannic acid.

[b,c]Means on the same line with different superscripts are significantly different ($P < .05$).

results of the third experiment (Table 8). Average daily gains of the group that received only .75% tannic acid (Treatment 1) were of the same order as those obtained with the control ration in Experiments 1 and 2. In Experiment 3, feed conversion was higher because the experimental animals were older and heavier. When .75% tannic acid was administered with .12% caffeine, average daily gain decreased ($P < .05$) as a result of a lower feed intake. These effects were more marked when caffeine was increased to .18 and .24%, producing significant differences ($P < .05$) in average daily gains between all treatments. The results of this experiment clearly demonstrate an interaction between caffeine and tannic acid that may be an important contributor to the negative effects of DCP on both feed intake and nutrient utilization by ruminants. The reduction in percent nitrogen retention as well as the additional increment in urinary excretion described previously in the digestibility and nitrogen balance study, and by Cabezas et al. (1974a) in calves fed high levels of DCP, may be attributed to caffeine consumption, considering the well known diuretic properties of this compound (Sollman, 1957).

TABLE 8 Performance of Steers Fed Caffeine and Tannic Acid (Experiment 3)

Item	Treatments 1 .75% TA	2 .75% TA +.12% C	3 .75% TA +.18% C	4 .75% TA +.24% C
Average initial weight, kg	205.8	204.7	206.0	205.0
Average final wieght, kg	305.0	296.3	290.0	279.8
Average daily gain, kg	1.2[a]	1.1[b]	1.0[c]	0.9[d]
Average daily feed intake, kg	11.3	10.5	10.3	10.0
kg feed/kg gain	9.4	9.5	10.3	11.1

[a,b,c,d]Means on the same line with different superscripts are significantly different ($P < .05$).

Conclusions

From these results it can be concluded that the adverse effects on animal performance produced by DCP are mostly due to reductions in feed intake and nitrogen utilization. These effects appear to be related to the presence of caffeine and tannins in DCP. Even though high levels of DCP have induced some deleterious effects on animal performance, practical feeding trials have shown that DCP can be used economically for beef and dairy cattle feeding when caffeine concentration does not exceed .12% of the ration. Most of the DCP analyzed in this laboratory has contained as an average, between .4 and .5% caffeine; this concentration permits the incorporation of 20-30% DCP in the ration without adverse effects on animal performance. Higher levels might be used if processing techniques being developed at present prove capable of economically reducing the caffeine and tannins contents. These techniques may also increase protein utilization. Another possibility under study is supplementing rations containing high levels of coffee pulp with protein concentrates.

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