ORIGINAL ARTICLE

Feasibility of Including Coffee Waste into Livestock Feeding System of Southwestern Ethiopia

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ABSTRACT

A series of laboratory and animal experiments were conducted with yearling rams to evaluate the nutritive value of coffee pulp alone and in combination with sugarcane stem, sugarcane top, banana foliage, elephant grass and natural pasture. Quality and nutrient composition of the silages and feed intake, weight gain, and protein digestibility by yearling rams were used as evaluation parameters. Based on appearance, odor and pH value, good quality silage was produced from coffee pulp alone and in combination with 30% of the forages. The color of both coffee pulp and banana foliage turned black when taken out of the silo due to the occurrence of enzymatic browning reactions. The composition of crude protein, lignin, lignified protein, tannins, caffeine, potassium and cutin were highest in pure coffee pulp silage and decreased in the fortified silages. All treatment silages were completely rejected by the animals. Severe diarrhea, swelling around the face and neck, bloating and emaciation were observed in yearling rams fed with the silages, all of which lost weight. The treatment groups placed on >70% coffee pulp recuperated and regained its average initial body weight following 15 days of grazing subsequent to completion of the experimental period. Supplementation with Alfalfa, oil seed cakes and leguminous tree foliage failed to improve the adverse effect of coffee pulp on the animals, suggesting that, investigating into the possibility of using coffee pulp in the production of fuel briquette seems to be the future direction of research on coffee pulp.

Keywords: Anti-nutritional factors, coffee pulp, ensiling, feed value and green forages

INTRODUCTION

The story of coffee has its beginnings in Ethiopia, the original home of the coffee plant, which still grows wild in the forests of the country. At present coffee is critical to the Ethiopian economy with about 25% of the population depending directly or indirectly on coffee for its livelihood. The total area used for coffee cultivation in Ethiopia is estimated to be about 4,000 km^2. Ethiopia is the world's 7^{th} largest and Africa's top producer of coffee, with 260,000 metric tons in year 2006. The United States Department of Agriculture put Ethiopia as the world's 6th largest coffee producer for the 2010/2011 crop year.

Ethiopia had earned 841.6 million dollars from the export of coffee in 2010/2011 fiscal year and coffee accounts for about 65% of all export earnings of the country (Meron Tekleberhane, 2012).

In Ethiopia, small household farms and/or backyard garden coffee trees are responsible for about 95% of all the national coffee production. The large scale commercial coffee plantation, initiated starting from the early 1980s, necessitated the establishment of industrial type wet coffee processing mills. It is calculated that wet method of coffee processing consumes 6-7 cubic meters (6000-7000 liters) of water per ton of coffee cherries. About 59% of the coffee bean is made up of contaminants which, when discarded destroy fauna in streams and rivers and harm people. Coffee waste mainly consists of coffee pulp, processing effluent, parchment and coffee husks, all of which result in bad odors of the surrounding, breeding of disease vectors, and pollution of ground and surface water bodies. The decomposition of coffee waste organic matters in rivers makes the water unsuitable for various uses and damages the aquatic ecosystem. Serious ecological impacts were reported from the discharge of organic pollutants from the wet coffee processing plants in Southwestern Ethiopia.

Coffee pulp could be used as fertilizer, biogas compost, livestock feed and production of products such as enzymes, organic acids, flavor and aroma compounds. In Ethiopia, small amount of coffee pulp are used as fertilizer and mulching materials whereas; large quantities of the by-product accumulate at the processing installations warranting serious disposal problems. Therefore the utilization of coffee pulp as livestock feed has significant economic and environmental implication under the present Ethiopian conditions. These research undertakings conducted at Jimma University College of Agriculture and Veterinary Medicine (JUCAVM) were aimed at investigating into the feasibility of including wet processed coffee pulp into livestock feeding system of Southwestern Ethiopia.

MATERIALS AND METHODS

Experimental treatments

In all the six consecutive experiments conducted, wet processed coffee pulp (80% water) was sun-dried for about 8 hr to reduce its moisture content to about 60%. Earthen pit silo of 1.5m wide, 1m deep and 10 m long with about 10% slope were dug into the ground to be used as an ensiling containers. The walls and floors of the silos were covered with plastic sheets. In all the experiments, adequate quantities of locally available forages (sugarcane stem, sugarcane top, elephant grasses, natural pasture and banana foliage) were chopped. Finally the treatment silages were prepared by ensiling sundried coffee pulp in combination with different levels of the chopped forages (Table 1).

Experimental animals

In each experiment, 32 yearling rams were purchased and treated against internal parasites. The sheep were ear tagged, weighed and divided into 8 groups of 4 sheep each with approximately equal average body weight. Each group was housed in separate individual pen. The treatment silages were fed to the animals in a completely randomized design with 2 replicates. In all the experiments, water was made available permanently and the treatment silages were offered at about 10% above intake. Ort and feaces were collected and weighed twice a day. Feed intake was measured daily and body weight was recorded weekly throughout the experimental feeding periods of 3months in each case.

Silage quality and chemical analysis

The silage quality was evaluated on the basis of visual appraisal, color, odor, and pH values. Silages and faeces were oven dried at 65°C for 72 hr. After grinding to pass through 1 mm screen, dry matter, crude protein, ether extract, ash, crude fiber and nitrogen-free-extract were determined according to AOAC (1990). Neutral-detergent fiber (NDF), Acid-detergent fiber (ADF), cellulose, hemicelluloses, lignin, cutin, silica and ADF-nitrogen were determined by the method of Goering and Van Soest (1970). Soluble sugars, caffeine, tannic acids, Ca, P, Mg, K, Zn and Cu were determined according to the AOAC (1990).

In-Vitro Digestibility

Six, 2g samples of each treatment silages were taken to determine in- vitro dry matter and organic matter digestibility by the two-stage Moore modification of the Tilley and Terry procedures as described by Summer and Sherrod (1974). The rumen fluid for the in- vitro digestibility was obtained from fistulated steer fed on alfalfa hay based diet. Dry matter residue was determined after 96 hours of digestion followed by ashing of the residue to determine in-vitro organic matter digestibility.

In- Situ Nylon Bag Evaluation

Approximately 2g samples were placed in a 6 x 15 cm oven dried and tarred nylon bag with 150 micro-meter diameters pores (Mehrez and Orskkov, 1977). The bags were suspended in the rumen of fistulated steer and four replicated runs were made with the same steer with eight bags per treatment per run. After 48 hours of incubation the bags were removed, washed, dried and the loss of weight was used for calculating the amount digested.

Statistical analysis

Analysis of variance was carried out by Fisher's method (Snedecor and Cochran, 1972), with Duncan's multiple range tests being used to group treatment means, where F values were significant.

RESULTS AND DISCUSSION

Silage quality and fermentation characteristics

Coffee pulp is the first product obtained during processing and represents about 29% of the weight of the whole berry on dry-weight basis. Coffee pulp has been studied from an animal nutrition point of view and reported to have a promising role in livestock feeding, if it could be efficiently and economically dehydrated. The pulp from wet processing is high in moisture content and does not store well. In fact the high moisture content represents the main drawback in the utilization of this product from the point of view of transportation, handling, processing, and its direct use as an animal feed. Wet processed coffee pulp is also seasonal in availability indicating that ensiling by its own and in combination with other locally available feed resource is the best method of preservation and improvement of its feeding value.

The fermentation characteristic of coffee pulp ensiled by its own and in combination with locally available forage crops (sugarcane stem, sugarcane top, banana foliage, elephant grass and natural pasture) is shown in Table 1. Appearance and color of the treatment silages were characteristic of silage having undergone adequate anaerobic fermentation. On the basis of pH and visual appraisal, comparatively good quality silages were produced by ensiling coffee pulp by its own and in combination with 30% of locally available forages. As shown in Table 1, pH values of 3.8 to 4.8 were recorded from those treatment silages containing coffee pulp and coffee pulp in combination with either sugarcane stem, sugarcane top and banana foliage whereas; pH values of 4.8 – 5.0 were recorded from the treatment silages containing coffee pulp in combination with 30, 50 and 70% of either elephant grass or natural pasture.

The percentage respiratory losses that occurred on the wall and upper surface of the earth pit silos were higher for the treatment silages containing different levels of either elephant grass or natural pasture. This result agrees with that of McDowell *et al.* (1975) who reported that generally tropical forages are low in soluble carbohydrates resulting in silage with relatively high pH. At the usual recommended age of cutting, they are difficult to pack in the silo, causing the trapping of air which results in large aerobic losses. In contrast reasonably low aerobic losses and pH values were recorded from coffee pulp and coffee pulp in combination with banana foliage, probably due to the better soluble carbohydrate contents and compressibility of coffee pulp and the blends of coffee pulp and banana foliage. The pH values of the silages containing pure coffee pulp and equal parts of coffee pulp and sugarcane stem (3.8) exceeded the limit of 4.2 considered to be appropriate for good silage. The soluble sugar contents of these two silages were also lower than those of the other treatment silages. The better characteristics of the pulp and pulp plus sugarcane stem silages as compared to the others was probably due to the higher concentrations and better utilization of sugars by fermenting micro-organisms.

Table 1. Fermentation characteristics of coffee pulp treatment silages

Item	Treatment									
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
Coffee pulp	100	50	50	50	70	50	30	70	50	30
Sugarcane tops	-	50	-	-	-	-	-	-	-	-
Sugarcane stem	-	-	50	-	-	-	-	-	-	-
Banana foliage	-	-	-	50	-	-	-	-	-	-
Elephant grass	-	-	-	-	30	50	70	-	--	-
Natural pasture	--	-	-	-	-	-	-	30	50	70
pH	4.1	4,8	3.8	4.7	4.6	4.8	5.0	4.6	4.8	5.0
Original color	brown	brown	brown	brown	brown	Brown	Brow n	brown	brown	brown
Color after Exposure to air	Black	dark	dark	dark	black	Dark	Dark	black	dark	dark
Odor	Pun.	-	-	-	Pun.	-	-	Pun	-	-
Aerobic Loss (%)	5.0	10.0	5.0	10.0	5.0	10.0	12.0	5.0	10.0	12.0
Dry matter (%)	92.0	91.0	90.0	89.0	92.9	91.8	90.6	89.3	92.0	90.5

Pure coffee pulp silage had pH of 4.1 and a strong pungent odor followed by treatment silages containing coffee pulp and banana foliage. The color of both coffee pulp and banana foliage turned black when taken out of the silo. There was change in color of all the silages containing coffee pulp from brown to black when the silages were exposed to air. It has been indicated that fresh or properly ensiled coffee pulp, on contact with air, changes from the deep blood red color it is when fresh to a dark brownish or blackish hue. This change in color has been attributed to enzymatic browning reactions caused by oxidation of the polyphenols to quinones which in turn combine with free amino-acids and proteins to give dark-colored complexes. The free polyphenols bind proteins and digestive enzymes and may interfere with the metabolic activity of microorganisms (Murillo *et al*., 1977; Bressani *et al*., 1979).

Chemical composition

The nutrient content of the treatment silages are shown in Table 2. All the treatment silages showed decreases in dry matter content compared to the original materials ensiled. The crude protein content of coffee pulp (13%) was found to be higher compared to most of the tropical roughage low in crude protein and/or fermentable nitrogen. However, about 40% of the total nitrogen in coffee pulp was found to be non protein nitrogen. Moreover, about 1.2 and 5.2% of coffee pulp protein exists as caffeine and ADF-nitrogen respectively. The remaining is assumed to be true protein since published evidences indicate a high quality essential amino acid profile on chemical analysis of coffee pulp protein. Coffee pulp protein has similar or higher levels of amino acids than cottonseed, soybean flours and corn. Coffee pulp protein is relatively high in lysine whereas; it is deficient in sulfur-containing amino acids (Jarquin and Bressani, 1976).

Table 2. Chemical composition of coffee pulp treatment silages

Item (%)	Treatment									
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
Dry matter	92.0	89.0	91.0	89.0	89.0	92.9	91.8	89.3	92.0	90.5
Crude protein	13.7	9.4	11.9	9.9	12.2	11.0	7.3	7.2	7.1	6.4
Cellular content	54.0	38.0	28.0	32.0	26.0	21.2	33.3	31.5	16.0	21.2
NDF	46.0	62.0	72.0	68.0	74.0	79.8	76.7	68.5	84.0	79.8
ADF	41.0	49.0	56.0	54.0	58.0	55,2	56.1	60.5	52.9	55.2
Hemicelluloses	5.0	13.0	16.0	14.0	16.0	24.6	20.6	8.0	31,1	24.6
Cellulose	30.0	33.0	39.0	38.0	35.0	34.2	33.4	29	34.6	34.2
Lignin	18.0	11.0	9.0	12.0	10.0	8.6	9.8	16.0	5.5	8.6
ADF-Nitrogen	2.04	1.37	1.13	1.34	1.12	0.66	0.75	0.83	0.57	0.66
Caffeine	0.5	0.16	0.11	0.16	0.11	0.19	0.22	0.66	0.13	0.19
Caffeine N	29.0	29.0	29.0	29.0	29.0	29	29	29	29	29
Ash	11.0	9.0	11.6	11.5	12.6	12.3	109	10	12.5	12.3

See Table 1 for composition of silages: the ensiling period was 120 days in each case

The total cell wall content of coffee pulp is lower than that of the forages used to ensile it, indicating the potential feed value of coffee pulp compared to fibrous tropical roughages. However lignifications of the cell wall as measured by percentage composition of ADF and ADF- nitrogen are higher for coffee pulp. The cell wall of coffee pulp mainly consisted of cellulose, lignin, and cutin, whereas; the cell wall of the forage crop used to ensile coffee pulp consisted of hemicelluloses, cellulose and plant metabolic silica. Hemicelluloses and cellulose are potentially degradable by ruminant animals depending on the degree of lignifications. Lignin and silica are component of the cell wall which are completely indigestible and used as markers in the indirect method of estimating the digestibility of feeds by ruminants. The relation of cutin to the nutritive value of the other cell wall constituents is not well understood. Nevertheless cutin is resistant to microbial degradation (Goering and Van Soest, 1970).

The percentage composition of tannin and caffeine of pure coffee pulp silage was 5.4 and 0.7% respectively and showed no considerable reduction as a result of the ensiling process. These results agree with that of Walter *et al.* (1985), who reported similar lignin, tannin and caffeine content of the original and fermented coffee pulp, but suggested partial modification in their structure. The results of the current studies showed that, there was decrease in tannin, caffeine and ADF-nitrogen as a result of dilution of coffee pulp with locally available forages. The content of caffeine and tannin is of interest in terms of the potential use of coffee pulp as feed, since all the available data suggests that tannin and caffeine interfere with proper utilization of nutrients in this by-product (Bressani 1979; Walter *et al.* 1985).

The relative amount of Ca, P, Mg, and Cu in pure coffee pulp silage was slightly higher than that of the locally available forages used to ensile coffee pulp (Table 3). On the contrary Zn, which is considered to be one of the limiting minerals in Ethiopia, seems to be suboptimal in coffee pulp. The percentage composition of K in coffee pulp was found to be 5.3%, about 12 times higher than the requirement of domestic animals. Some of the results reported elsewhere indicate that 5% of K in the growing lambs significantly depressed feed consumption and had detrimental effect on the absorption and utilization of Mg (Newton *et al.*, 1972).

Table 3. Mineral composition of coffee pulp treatment silage

Item (%)	Treatment									
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
Total ash	11.0	9.0	11.6	11.5	12.6	12.3	109	10	12.5	12.3
Cutin	13.8	--	-	-	-	-	-	8.0	3.7	6.5
Silica	0.31	-	-	-	-	-	-	3.7	4.3	8.3
Tannic acid	5.4	-	-	-	-	-	-	3.8	3.2	3.5
Ca	0.5	-	-	-	-	-	-	0.49	0.46	0.47
P	0.33	-	-	-	-	-	-	0.25	0.19	0.17
Mg	0.13	-	-	-	-	-	-	0.11	0.10	0.12
K	5.3	-	-	-	-	-	-	2.2	1.2	1.6
Zn	0.003	-	-	-	-	-	-	0.01	0.15	0.14
Cu	0.2	-	-	-	-	-	-	0.08	0.73	0.061

See Table 1 for composition of silages: the ensiling period was 120.days in each case

In-Vitro and *In-Situ* Digestibility

The results of the *In-Vitro* and *In-Situ* digestibility of the treatment silages are shown in Table 4. The *in-vitro* dry matter digestibility of all the treatment silages were found to be lower than the values recorded from the *in-situ* ruminal digestion which might partially be attributed to the effect of the nylon bag washing procedures. Nevertheless, both the in-vitro and in-situ dry matter digestibility was higher for pure coffee pulp silages and significantly depressed as a result of dilution of coffee pulp with locally available forages. Difference in percentage composition of the cell wall and types of fiber may explain this difference in digestibility.

The locally available forage (sugarcane tops, elephant grass and natural pasture) used to ensile coffee pulp contained more cell wall than coffee pulp as measured by percentage composition of ADF. This difference is mainly due to the higher percentage composition of hemicelluloses in the forages (>31%) as compared to pure coffee pulp (5% hemicelluloses). Hemicelluloses appear to have special relation to lignin and lignin and hemicelluloses (degree of lignifications) are the best pair of digestibility predictor in all tropical grasses (Barton *et al.*, 1976). According to the results of these studies hemicelluloses, which is abundant in locally available forages, was found to be the least digested cell wall polysaccharides (Table 4). The compositional analysis of coffee pulp shows low silica but high lignin (16%) which could have negatively affected digestibility compared to the forages. Such a high lignin content of coffee pulp is attributed to the occurrence of enzymatic browning reaction caused by drying of coffee pulp before ensiling and oxidation of the polyphenols when the silages were exposed to air which elevated ADF, ADF- nitrogen and lignin value of the pulp.

Table 4. *In-vitro* and *In-situ* digestibility of coffee pulp treatment silages

Item	Treatment									
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
Susbania susban (kg/d/h)	1	-	-	-	-	-	-	1	1	1
In-Vitro Digestibility (%)										
Dry matter	48.0	-	-	-	-	-	-	43.4	40.8	42.2
Organic matter	50.1	-	-	-	-	-	-	44.0	41.5	43.0
In-Situ Digestibility (%)										
Dry matter	61.0	-	-	-	-	-	-	56.3	43.9	48.7
Organic matter	62.0	-	-	-	-	-		58.1	44.6	49.6
Neutral detergent fiber	52.8	-	-	-	-	-	-	47.4	40.8	43.6
Acid detergent fiber	51.1	-	-	-	-	-	-	51.2	42.1	49.8
Hemicelluloses	29.0	-	-	-	-	-	-	26.2	23.8	26.0
Cellulose	68.8	-	-	-	-	-	-	65.7	45.2	51.9
Animal performance										
Dry matter intake	0.49a	0.65b	0.79b	1.21c	-	-	-	1.7a	2.4c	2.1b
Initial body weight(Kg)	22.1	21.8	20.7	20.8	-	-	-	17.6	18.5	18.2
Final body weight (, Kg)	19.9	19.8	19.0	20.6	-	-	-	20.9	28.7	27.8
Daily weight gain (g)	-2.0	-2.04	-1.72	-0.2	-	-	-	55.0a	170c	160b

See Table 1 for composition of silages: the ensiling period was 120 d and the feeding period was 90 d in each case. Along rows, values without a suffix letter in common differ ($P < 0.05$).

Animal Performance

One of the principal factors used to determine the nutritive value of feed is the quantity that animals consume when they have free access. The treatment silage containing > 70% coffee pulp and coffee pulp in combination with banana foliage were completely rejected by the animals. There was fluctuation in intake by the treatment groups on > 70% coffee pulp and treatment groups on different combinations of coffee pulp and banana foliage. These treatment silages induced regular and low feed intake for about 3-5 days followed by relatively higher intake for 1-2 days, which were commonly accompanied by ill health and/or death of the experimental animals. Recovered animals repeated the same pattern of intake. The use of 30-50% of sugarcane top, elephant grass or natural pasture to ensile coffee pulp failed to improve the negative effect of coffee pulp.

The addition of 1kg/day/head of supplementary *Susbania susban*, Alfalfa (*M. sativa*) and Niger seed cake (*Guzeta abbysinica*) also failed to improve the negative effects of coffee pulp and coffee pulp plus banana foliage. On the other hand there was significant improvement in the negative effect of pure coffee pulp, as a result of ensiling the pulp in combination with 30-50% of locally available forages (other than banana foliage) and with addition of supplementary feeding. There were no significant differences between the treatment groups fed on the silages prepared by ensiling coffee pulp in combination with 30 – 50% of sugarcane top, elephant grass or natural pasture in mean daily feed consumption (Table 4). The groups assigned to coffee pulp plus 70% of either elephant grass or natural pasture with 1kg/head/day of *Susbania susban* supplementation had significantly higher ($P<0.05$) feed intake than the others.

Similar results have been reported by other authors. One of the limitations to the use of coffee pulp as an animal feed is the reluctance of animals to eat it when it is supplied as the main feed ingredient. The low intake of pulp is due to its low palatability and, probably, to adverse effects on digestion and metabolism of the animals. The low protein digestibility of coffee pulp has a negative effect on nitrogen retention and affects nitrogen status and voluntary intake. Other factors that apparently affect consumption and utilization of pulp are the time during which it is consumed and the method employed to introduce it into the ration (Bressani *et al.*, 1979).

All the available evidences tend to indicate that low feed intake, protein digestibility and nitrogen retention are the major factors limiting the use of coffee pulp as animal feed. These effects appear to be due to the presence of anti nutritional factors such as caffeine, tannins, potassium and other polyphenols in coffee pulp. Three factors appear to be important in relation to caffeine and the effects observed in various animals: the relatively high concentration of nitrogen in caffeine; its known effect of stimulating increased activity; and its diuretic effect (Bressani, 1979). Caffeine levels of 0.12% in ruminant calves did not cause adverse effects but higher levels produced a significant decrease in growth as a result of lower feed consumption (Cabezas *et al.*, 1977). In the current studies, the caffeine concentrations of the treatment silages ranged between 0.11 and 0.23%. The nitrogen content of the caffeine was about 29% indicating that caffeine nitrogen was present in amounts of about 0.07 to 0.15% which is equivalent to 4 to 9% of the total crude protein content of the treatment silages.

All the treatment groups lost weight whichever silage was fed at the beginning. Severe diarrhea, swelling around the face and neck, bloating and emaciation were observed in animals forced to consume equal parts of coffee pulp and banana foliage indicating that banana foliage is not suitable feed material to ensile coffee pulp. Significant mortalities were recorded from the groups fed on the treatment silages containing > 70% of coffee pulp. Almost all the mortalities occurred following the days of relatively high feed intake. Postmortem examination results indicated a severe bloat. Emaciation and abnormal hair structure were pronounced and black colored diarrhea resembling poultry droppings was noted in the treatment groups fed on the treatment silages containing > 70% coffee pulp. The groups fed on these treatment silages recuperated (the survivals) and regained its average initial body weight of 20.7 kg following 15 days of grazing after the end of the experimental period. The group fed on 30 to 50% coffee pulp recuperated and regained its average initial body weight during the sixth week of the experimental period. However, positive animal performance ranging from 0.037 to 0.051 kg/head/day was obtained when the treatment silages containing 30% coffee pulp were supplemented with 1kg/day/head of *Susbania susban*.

CONCLUSION

The crude protein content of coffee pulp used in these experiments was about 13% and crude protein of this magnitude seems to be sufficient to supply the crude protein requirement of yearling rams of 20 kg producing 120g/day. The crude protein content of the supplementary *Susbania susban* was about 26%. This means about 78g/day/head was assumed to be contributed through supplementation in addition to intake from the treatment silages and when efficiently utilized, the supplementary protein seems to be sufficient enough to stimulate positive animal performance. Nevertheless, the low digestibility of coffee pulp protein might have negatively affected the nitrogen retention and status of the experimental animals and induced low voluntary feed intake and animal performance. Additionally 8 hrs sun dried coffee pulp was ensiled in combination with chopped forage on weight basis indicating that ensiling 30% coffee pulp in combination with 70% of either elephant grass or natural pasture could not adequately and economically address the current national concern related to coffee pulp in Ethiopia. On the contrary coffee pulp could easily and economically be tapped as a useful energy source. Therefore investigating into the possibility of using coffee pulp in the production of fuel briquette is appealing future direction of research in Ethiopia.

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