Effect of Bisulfite Addition on the Chemical Composition and Cellular Content Fractions of Dehydrated Coffee Pulp

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The effects of drying sulfite-treated coffee pulp by solar energy and drum drying were compared. Fresh coffee pulp was treated with 0.5, 1.0, 1.5, and 2.0% sodium metabisulfite and dried by either method. Proximate chemical composition did not reveal significant differences between dehydrating procedures. Sodium metabisulfite treatment resulted in a decrease in crude fiber, nitrogen, cellular walls and cellulose, and an increase in ash and nitrogen-free extract. Likewise, tannins and cellular content were higher and lignin and lignified protein lower in metabisulfite-treated samples. Lignified protein was higher in sun-dehydrated pulp than in those samples dried by drum drying. The significance of these findings in terms of the digestibility of coffee pulp is discussed.

Results of previous investigations have indicated the relatively large availability of coffee pulp in coffee-producing countries. Its chemical composition (Bressani et al., 1972) and nutritional value as a feedstuff in diets for ruminants (Jarquín et al., 1973; Braham et al., 1973; Cabezas et al., 1974a, 1974b), swine (Jarquín et al., 1974), and poultry (Bressani et al., 1973) have also been described. Because of the presence in coffee pulp of antiphysiological factors such as caffeine, tannins, and free phenolic compounds (Cabezas et al., 1975), recommended levels in animal feeds do not exceed 20% of the diet replacing cereal grains or their by-products.

The main problem in coffee pulp utilization is the large amount of water it contains (Bressani et al., 1972; Molina et al., 1974), which must be removed for its efficient preservation and handling. Present systems include dehydration by solar energy or by hot air (Molina et al., 1974). In both methods the color of the pulp changes from a deep red when recently separated from coffee beans to a dark-brown color, suggesting that an enzymatic browning reaction is involved. This reaction is probably responsible to a very large extent for the relatively low digestible protein reported for coffee pulp (Vargas, 1974; Daqui, 1975) and for increasing the negative effects caused by caffeine and possibly other substances present in it.

High-temperature forage dehydration has been reported to induce an increase in the fraction known as crude fiber (Tomlin et al., 1965), which has been associated with an increase in the amount of nitrogen bound to lignin (Donoso, 1962). Furthermore, high-temperature dehydration also decreases cellular wall content (Van Soest, 1965) as determined by the chemical fractionation scheme proposed by Van Soest (1963; Van Soest and Wine, 1967, 1968) for forages. This analysis shows that the acid-detergent fiber fraction is affected. Detailed chemical analysis of this fraction can indicate the amount of protein which has been lignified and that alters the results on lignin content (Van Soest, 1965). On the other hand, when forages are dried at low temperatures and for a long period of time, an enzymatic reaction takes place when carbohydrate degradation products react with proteins and free amino acids, giving a dark insoluble polymer and increasing the lignin content of the material (Van Soest, 1965).

It is well known that these enzymatic reactions and dark color development can be blocked through the use of sulfite among various possible compounds (Hodge, 1953).

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The present study, therefore, deals with the effect of treating coffee pulp prior to dehydration with various concentrations of sulfite on its content of lignin-bound protein, acid-detergent fiber, and other compounds of particular interest.

MATERIALS AND METHODS

Fresh coffee pulp, in amounts of 1.0 kg, was treated with 0.5, 1.0, 1.5, and 2% sodium metabisulfite ($Na_2S_2O_5$) prior to its dehydration by solar energy and drum drying.

Sun dehydration was performed by spreading the coffee pulp 5 cm deep on a clean surface and exposing it to solar energy at a temperature as high as 40 °C. Moisture content dropped to about 12% after 16 h of continuous solar exposure. For dehydration with the drum dryer (drum dryer, General Food Model), the fresh pulp was first ground. It was then dropped on the drums of a laboratory drum dryer rotating at 2.5 rpm, with steam at 60 lb/in.^{2} and a surface temperature of 143 °C. After dehydration, the coffee pulp from the various treatments was subjected to proximate chemical analysis by the AOAC methods (1970); fractionation of cellular walls, cellular contents, and lignified protein was performed by the methods of Van Soest (1963; Van Soest and Wine, 1967, 1968). For these analyses samples of coffee pulp were treated with neutral detergent to determine cellular wall content which when subtracted from 100 gives the cellular content. Acid-detergent treatment of the original sample gives lignocellulose. Lignified protein was obtained from nitrogen analyses on the lignocellulose fraction. Caffeine was determined according to Ishler et al. (1948) and tannins as per Schandreld's procedure (1970).

RESULTS

The results of the proximate chemical analysis shown in Table I did not reveal significant statistical differences between the samples treated with the same amount of metabisulfite for the two dehydration methods applied, expressed on an as-is moisture basis. In both, metabisulfite treatment of coffee pulp decreased crude fiber as well as nitrogen content and increased ash and nitrogen-free extract content. The concentration of all gross components analyzed on samples from both processes showed a linear relationship with the level of metabisulfite added.

For crude fiber and nitrogen content, the correlation coefficient was highly significant ($r = -0.89$). Ash content also presented a highly significant correlation coefficient with respect to metabisulfite level ($r = -0.98$).

Significant statistical differences between drying systems with respect to cellular wall fractionation are shown in Table II. Lower values for lignin content were found in samples of sun-dehydrated coffee pulp. On the other hand,

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Table I. Effect of the Type of Dehydration and Addition of Sodium Metabisulfite on the Proximate Analysis of Coffee Pulp

Treatment	Water, %	Ether extract, %	Crude fiber, %	Nitrogen, %	Ash, %	Nitrogen-free extract, %
Mechanical drying						
0.0% metabisulfite	12.0	2.6	23.9	2.0	5.7	40.5
0.5% metabisulfite	9.0	2.6	18.6	1.6	9.5	49.2
1.0% metabisulfite	10.0	2.8	17.1	1.5	10.2	50.3
1.5% metabisulfite	9.6	2.5	16.3	1.5	12.6	49.7
Sun drying						
0.0% metabisulfite	10.2	3.1	23.4	1.6	5.8	46.5
0.5% metabisulfite	8.9	2.6	19.2	1.7	9.6	49.3
1.0% metabisulfite	8.6	2.7	18.0	1.5	10.0	51.0
1.5% metabisulfite	8.8	2.6	17.1	1.5	13.2	49.8
2.0% metabisulfite	9.1	2.3	16.5	1.5	13.7	49.1

Table II. Fractionation of Cellular Walls in Coffee Pulp Treated with Sodium Metabisulfite[a]

Treatment	Cellular content, %	Cellular walls, %	Hemi-cellulose, %	Cellulose, %	Lignin, %	Insoluble ash, %
Mechanical drying						
0.0% metabisulfite	39.1[a]	57.1	3.8	28.4[a]	24.2[a]	0.7
0.5% metabisulfite	52.1[b]	44.9	3.0	20.6[b]	20.2[b]	1.1
1.0% metabisulfite	53.5[b]	43.3	3.2	20.2[b]	18.5[b]	1.4
1.5% metabisulfite	55.9[b]	41.1	3.0	18.4[b]	18.1[b]	1.6
2.0% metabisulfite	56.3[b]	40.9	2.8	18.3[b]	18.1[b]	1.7
Sun drying						
0.0% metabisulfite	43.7[a]	53.3	3.0	29.9[a]	19.5[b]	0.9
0.5% metabisulfite	52.3[b]	44.6	3.1	22.3[b]	17.7[b]	1.5
1.0% metabisulfite	55.3[b]	41.9	2.8	22.2[b]	15.6[bc]	1.3
1.5% metabisulfite	57.6[b]	39.5	2.9	21.2[b]	14.1[c]	1.3
2.0% metabisulfite	58.7[b]	38.4	2.9	20.0[b]	14.1[c]	1.4

[a] Numbers with different letters are statistically different.

drying systems did not affect cellular nor cellulose content, although metabisulfite treatment in either method of drying caused an increase in cellular content and a decrease in cellular wall, cellulose, and lignin content. The greatest decrease in lignin content was observed in the coffee pulp sample which was sun-dehydrated and treated with 1.5–2.0% of metabisulfite.

With respect to hemicellulose and insoluble ash content, no significant differences were found with respect to dehydration methods or to concentration of added metabisulfite. The increase in total ash was probably due to the addition of sodium metabisulfite. Since the sodium salts produced are soluble, they do not appear in the insoluble ash obtained from the determination of cellular wall fractionation.

Table III presents results on lignified protein, caffeine, and tannin content of the various samples. The addition of metabisulfite from as low a level as 0.5% reduced the amount of lignified protein independent of the drying system employed. On the other hand, caffeine content remained relatively constant, while tannin content was retained to about 83% of values as found in fresh coffee pulp to which metabisulfite was added.

Table III. Lignin Content, Lignified Protein, Caffeine, and Tannins in Coffee Pulp Treated with Sodium Metabisulfite[a]

Treatment	Protein: Crude, %	Protein: Lignified, %	Caffeine, %	Tannins, %
Mechanical dehydration				
0.0% metabisulfite	12.3	7.2[a]	0.74[a]	1.80
0.5% metabisulfite	10.2	4.0[b]	0.68[b]	3.15
1.0% metabisulfite	9.6	2.8[b]	0.62[b]	3.60
1.5% metabisulfite	9.3	2.9[b]	0.65[b]	3.15
2.0% metabisulfite	9.2	2.9[b]	0.65[b]	3.40
Sun drying				
0.0% metabisulfite	10.0	6.3[a]	0.72[b]	1.85
0.5% metabisulfite	10.4	4.0[b]	0.67[b]	3.20
1.0% metabisulfite	9.7	3.3[b]	0.66[b]	3.75
1.5% metabisulfite	9.5	3.4[b]	0.63[c]	3.40
2.0% metabisulfite	9.3	3.3[b]	0.65[b]	3.50

[a] Numbers with different letters are statistically different.

DISCUSSION

Studies carried out on the dehydration of herbage show that from the time of mowing to that at which it is considered dried, there occurs active enzymatic activity that causes changes in the concentration of nutrients in the herbage. Factors of importance regarding the extent of change are initial moisture content, rate of removal, and drying temperature (Van Soest, 1965). It has been found that the faster the drying, the more rapidly enzymatic activity ceases, and in general, losses in nutritive value are smaller (Hatfield and Wilson, 1973). Various organic compounds are affected, however; of particular interest is lignin and insoluble protein content. Coffee pulp is a product with a high water content, and for this reason, the time employed to dehydrate it may very well induce increases in crude fiber (cellulose + lignin).

Coffee pulp is relatively high in low molecular weight and phenolic compounds which, after oxidation by the enzyme polyphenol oxidase, form brown products containing quinone groups that can combine with proteins, modifying their biological properties. Likewise, higher molecular weight phenolic compounds commonly called "tannins" can form insoluble complexes with proteins (Driedger and Hatfield, 1972; Glick and Joslyn, 1970; Van Buren and Robinson, 1969). In order to prevent these two reactions from occurring, it is necessary to stop oxidation of the free phenolic compounds on the one hand, and, on the other, to block the complexing of tannins with protein. This may be accomplished by the addition of a reducing agent such as metabisulfate with other compounds.

The results presented herein indicate that metabisulfite was active in this respect, since its addition resulted in higher cellular content, lower lignin concentration, and less lignified protein. At the same time, tannin concentration in the treated pulp was higher than that not receiving metabisulfite. It must be recognized, however, that levels as high as those added in the present report may induce undesirable effects on the palatability of the final product. Independent of the drying system applied, there is a positive relationship between lignin and lignified protein content, with an overall correlation coefficient of 0.65. These results indicate that the presence of high levels of lignin found in dehydrated coffee pulp may be attributed to the sum of lignin and lignified protein that develops during drying and is not found in the fresh pulp. It has been indicated that lignified protein is not digestible (Donoso et al., 1962), a fact which may explain the low protein digestibility coefficients that have been found for coffee pulp protein (Vargas, 1974; Daqui, 1975).

The consistent increase in ash content on samples from the two dehydration processes cannot be explained on the basis of the added metabisulfite alone. It is of interest to point out that crude fiber as determined by the AOAC method decreased as consistently as ash increased. It can be speculated that the sulfite treatment destroyed some of the carbohydrate fractions accounting thus for the increase in ash as a concentration effect.

The drying methods used represent extremes in conditions of drying. Sun dehydration is a low-temperature extended process while drum drying uses high temperatures with a considerable shorter exposure time. Results of various investigators have shown that rapid heat drying has advantages over slow ambient drying in preserving nutritive value (Hatfield and Wilson, 1973); however, apparently it does not apply to protein digestibility. The drying temperature has a definite effect, since it has been determined that higher temperatures result in lower digestibility (Van Soest, 1965). This is due to the nonenzymatic browning reaction, and Van Soest (1965) demonstrated that the dark-colored nitrogenous products accumulate in the acid-detergent fiber fraction. From the results of the present study, it appears that pulp dehydration by drum drying, even though temperatures were as high as 143 °C, does not cause an increase in lignified protein, as it occurs when coffee pulp is dehydrated by sun drying at lower temperatures and for longer periods of time. It is possible, therefore, that the former process, taking significantly less time, may not be as harmful a process as the latter one in affecting protein digestibility. Finally, drying systems should also consider the cost of the operation. Future reports will deal with this problem.

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