

COTTONSEED HULLS: WORKING WITH A NOVEL FIBER SOURCE

Mary Beth Hall and Adenike Akinyode
Department of Dairy and Poultry Sciences
University of Florida, Gainesville

"Such material as this (cottonseed hulls) belongs with the very lowest grade of coarse fodder, as both composition and experience demonstrate."

– W. H. Jordan, 1903.

"When properly fed, cottonseed hulls are generally about equal in value to fair-quality grass hay and are worth more per ton than corn or sorghum stover, straw, or poor hay. The hulls are well liked by cattle, even when fed as the only roughage."

– F. B. Morrison, 1950.

Cottonseed hulls are a curious by-product feed. Alternately praised and disparaged, they possess feeding characteristics different from most other high fiber feedstuffs. Cottonseed hulls are comprised of the seed coat with some attached lint that is separated from the cottonseed kernel during oil production. A ton of cottonseed will yield approximately 900 lb meal, 320 lb oil, 540 lb hulls, 160 lb linters, and 80 lb waste. Each year, ~3.5 million tons of cottonseed are crushed for oil. Historically, their availability, low cost, and excellent mixing characteristics have made them an important source of roughage for ruminants in the Southeast. However, their feed analysis suggests a low feeding value (Table 1). Cottonseed hulls are low in crude protein (4 to 12% of dry matter), varying with the amount of cottonseed meal or kernels present. The main component of cottonseed hulls is neutral detergent fiber (NDF) which includes a relatively large proportion of acid detergent lignin. These two fractions tend to be negatively correlated with digestibility, which is reflected in the low digestibilities reported for NDF (31.9%, Torrent et al., 1994; 38.7%, Moore et al., 1990) and dry matter (32.7%, Torrent et al., 1994; 34.3%, Garleb et al., 1988). At odds with these analyses, is the fact that cottonseed hulls are very palatable, and that cattle tend to increase their intakes when hulls are fed. This paper will review research information regarding the feeding of cottonseed hulls and their impact on animal performance.

Table 1. Cottonseed hull composition (% of sample dry matter).

Nutrient	Hsu et al., 1987	Garleb et al., 1988	Mertens, 1994
Ash	3.4	2.8	2.8
Crude protein (CP)	12.4	6.7	4.4
NDF	73.5	84.4	89.0
ADF	60.9	61.9	70.0
AD lignin	19.4	21.3	---
Ether extract (EE)	9.2	---	1.7
NSC (calculated) ^a	1.5	---	2.1

^a Nonstructural carbohydrates (NSC) = 100 – (CP + NDF + EE + Ash)

EFFECTS ON INTAKE

Poorly digested, high fiber feedstuffs typically depress dry matter intake. This has been suggested to be a consequence of indigestible material taking up space in the limited capacity of the rumen. Ingested feed must be removed from the rumen via fermentation or passage in order to allow for additional intake (Mertens, 1992). However, cottonseed hulls do not affect intake in the same fashion as other high fiber, relatively indigestible feeds. Intake tends to increase with addition of cottonseed hulls to rations for dairy cattle (Harris, et al., 1983, Van Horn et al., 1984, Morales et al., 1989, Adams et al., 1995, Gu et al., 1996, Gu and Moss, 1996) and steers (Moore et al., 1990, Bartle et al., 1994). Intake increased with cottonseed hull level of the diet in research trials (Fig. 1), however the increases among studies were not uniform. The relative changes in dry matter intake were likely affected by animal body weight, interactions among feeds in the diets, feeding management, etc. On relatively low (40% of dry matter) roughage diets, intake increased curvilinearly when cottonseed hulls were substituted for sorghum silage in diets of 10 lactating Holstein cows (treatment effect $P = 0.0001$, Akinyode and Hall, unpublished; Fig. 2). Intake as a percentage of bodyweight also increased curvilinearly from 3.12% to 3.87% in that study, as hulls were increased from 0% to 24% of diet dry matter. It is interesting that although intake of the non-cottonseed hull portion of the diet seemed to decline after the 8% level of hulls, concentrate intake increased with increasing cottonseed hull inclusion (Fig. 2).

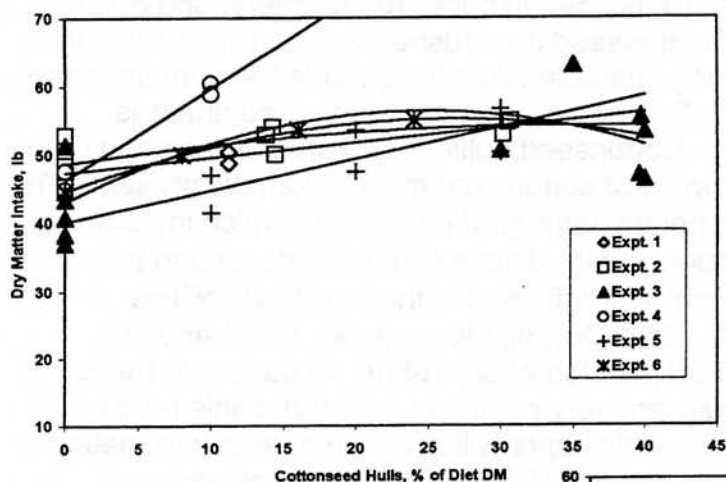
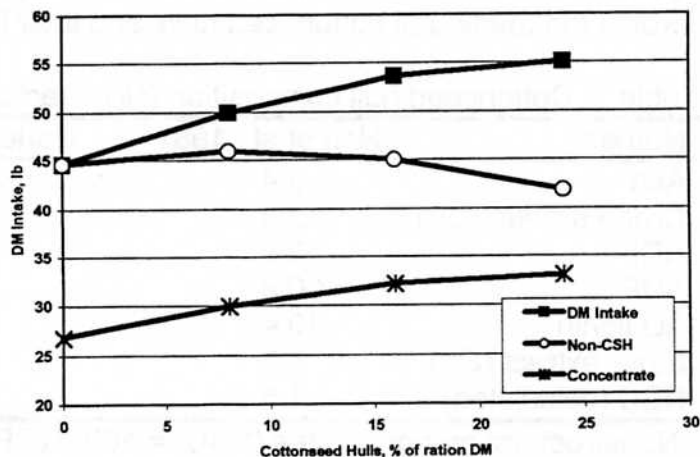


Figure 1. Changes in intake with cottonseed hull inclusion. Regression lines are drawn through treatment means Expts: 1 = Adams et al., 1995, 2 = Morales et al., 1989, 3 = Harris et al., 1983, 4 = Gu et al., 1996, 5 = Gu and Moss, 1996, 6 = Akinyode and Hall, 1999, unpublished.

Figure 2. Effects on intake of cottonseed hull substitution for sorghum silage in 40% roughage diets (% of DM). P -values of trt effects on intakes are dry matter ($P = 0.0001$), non-cottonseed hull components ($P = 0.0752$), and concentrates ($P = 0.0001$). Least squares means plotted. (Akinyode and Hall, 1999, unpublished).



The changes in intake related to cottonseed hull feeding can increase NDF intake above usual predictions of what is feasible. Morales et al. (1989) found that dry matter intake as a percentage of body weight decreased as ration NDF was increased with addition of alfalfa haylage. In contrast, dry matter intakes increased when dietary NDF was raised to the same level by feeding cottonseed hulls alone or with alfalfa haylage (Fig. 3). Mertens (1994) suggested that the maximum recommendation for NDF intake without reducing milk yield below a cow's potential is approximately 1.2% of bodyweight per day. This was estimated to allow adequate supplementation of concentrate, and prevent ruminal fill from limiting intake. When the majority of dietary NDF comes from forage, these numbers are reasonable. However, feeding cottonseed hulls increased voluntary NDF intake as a percentage of bodyweight to 1.4 – 1.5% (Morales et al., 1989) (Fig 4). The effects of cottonseed hulls on performance will be discussed in a later section.

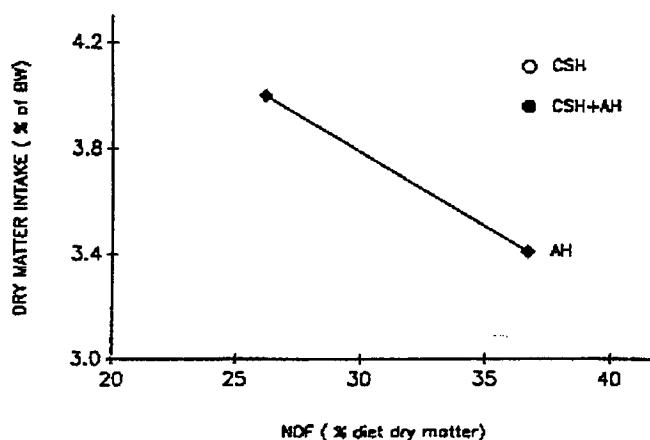


Figure 3. Effect of NDF percentage of diet dry matter on intake by roughage source (Morales et al., 1989). Data points are for diets: CSH = 30% cottonseed hulls, AH = 35% or 65% alfalfa haylage, CSH+AH = 14% cottonseed hulls + 35% alfalfa haylage (% of diet DM).

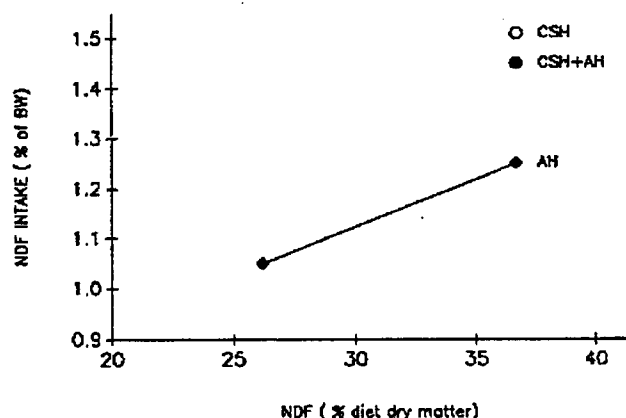


Figure 4. Effect of NDF percentage of diet dry matter on NDF intake by roughage source (Morales et al., 1989). Data points are for diets: CSH = 30% cottonseed hulls, AH = 35% or 65% alfalfa haylage, CSH+AH = 14% cottonseed hulls + 35% alfalfa haylage (% of diet DM).

Cottonseed hulls have been recommended for use in calf starters and feeds as a palatable source of fiber that cannot be readily sorted out by the animal (B. Harris, personal communication, Feb. 1996). Dr. Harris has recommended inclusion levels of 10% cottonseed hulls for calf starters.

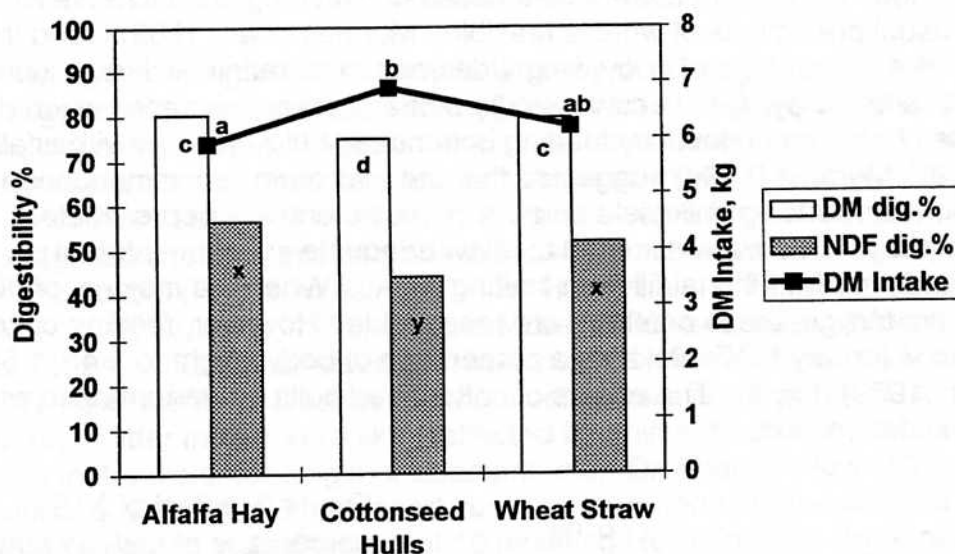


Figure 5. Effects roughage source on dry matter and NDF digestibility and dry matter intake in diets fed to steers (Moore et al., 1990). Diets: alfalfa = 34.4% alfalfa hay, cottonseed hulls = 17.2% alfalfa hay + 17.2% cottonseed hulls, wheat straw = 17.2% alfalfa hay + 17.2% wheat straw. (^{a,b} points with different superscripts differ, $P < 0.10$; ^{c,d x,y} bars with different superscripts differ, $P < 0.05$).

EFFECTS ON DIGESTIBILITY

The digestion of cottonseed hulls and their effect on the digestibility of other ration components is likely affected by their physical form as well as composition. Cottonseed hulls are composed of a lignified seed coat and attached cellulosic lint. Little of the lignin disappears after in situ or in vivo fermentation, and the remaining cellulose is rather crystalline (Garleb et al., 1991). It was suggested that lignin encrustation and cellulose crystallinity are factors that inhibit cottonseed hull fermentation (Garleb et al., 1991). Observation of hull particles in feces tends to show little to no residual lint, suggesting that the cellulose lint attached to the hulls is largely fermented, whilst the heavily lignified seed coat is less extensively fermented. Consequently, that suggests that cottonseed hulls with greater or lesser amounts of lint will differ in the amount of fermentable fiber they contain.

Cottonseed hulls have been reported to decrease the digestibility of other dietary components. With steers on a milo diet, digestion of NDF and apparent digestion of dry matter were lower when cottonseed hulls replaced half of the alfalfa hay (Moore et al., 1990) (Fig. 5). Digestibility of cell solubles was not affected by treatment. In preliminary data from lactating dairy cows, total tract digestibility of NDF was decreased from 63.5% to 58.7% when 16% cottonseed hulls replaced sorghum silage in a 40% roughage diet (Akinyode et al., 1999).

The simplest explanation for the depression in digestibility is that an increased rate of passage accompanies the increased intake, and reduces digestion of feed in the rumen (Van Soest, 1994). Rate of passage can increase with increasing dry matter

intake. As rate of passage increases, less of the more slowly degrading fractions, such as NDF or slowly fermenting concentrates, are fermented ruminally. Although starch and protein digestion occurs in the small intestine, and some fermentation takes place in the hindgut, overall digestibility of the diet may decrease. Moore et al. (1990) found that rates of passage for liquid and solid fractions were consistently but not significantly highest for a cottonseed hull+alfalfa hay diet as compared to alfalfa hay or alfalfa hay+wheat straw diets fed to steers. Preliminary data indicate that fecal flow of NDF and organic matter were increased by approximately 30% on 40% roughage diets where 16% cottonseed hulls were substituted for sorghum silage (Akinyode et al., 1999). The reduction in digestibility with increased intake is not unique to cottonseed hulls; it is an element to be considered with any ruminants with high intakes.

EFFECTS ON THE RUMEN ENVIRONMENT

Ruminal effects of cottonseed hulls may be mediated by their relative indigestibility, particle size, and their associative effects on rate of passage. Rumen pH varies with the rate and amount of organic acids produced from fermentation, the rate of passage or absorption of those acids, amount of rumination with its salivary buffering, buffering capacity of the diet, feeding management, number of meals, etc. The rate of fermentation for cottonseed hulls is quite low (for the potentially digestible fraction: 1.9%/hour, Moore et al., 1990; 3.5%/hour, Torrent et al., 1994), as is the extent of digestion. Accordingly, hulls will not tend to add much to the mass of fermentation acids in the rumen. At the same time, cottonseed hulls do not appear enhance rumination, despite their high NDF content. Although a cottonseed hull+alfalfa hay diet had the highest NDF content (30.3% DM basis) of the diets fed to steers, it produced as many minutes of rumination/day as an alfalfa hay diet with much less NDF (22.9%), but less than an alfalfa hay+wheat straw diet (24.2% NDF) (Moore et al., 1990). The alfalfa hay and wheat straw were chopped to a maximum particle length of 5 cm in that study. The relatively small particle size of hulls (3-5 mm diameter) is likely related to the lower level of rumination. However, in terms of rumen buffering, the high level of lignin in hulls may offer innate buffering capacity (Van Soest, 1994).

A higher ruminal pH was reported for a cottonseed hull diet (6.46) as compared to soy hull (5.36), oat hull (6.25), or corn fiber (5.85) diets fed to sheep ($P < 0.05$; Hsu et al., 1987). With the diets comprised of 80% of the by-product feed tested, low production of volatile fatty acids seemed related to the high pH on the cottonseed hull diet. Ruminal pH did not differ ($P = 0.92$) among 40% roughage diets fed to 10 Holstein cows where cottonseed hulls were substituted for sorghum silage (5/8" theoretical cut) at rates of 0, 8, 16, and 24% of ration dry matter (Akinyode and Hall, unpublished; Fig. 6). It is possible that cottonseed hulls affect ruminal pH by increasing the passage of feeds, thus reducing their extent of ruminal fermentation and contribution of organic acids. P. J. Van Soest (personal communication) has suggested that ruminants have a "lignin requirement" – the flow of indigestible material enhances passage of microbes and feedstuffs from the rumen. Cottonseed hulls may provide a tool to manipulate the indigestible dry matter content of the diet without depressing intake.

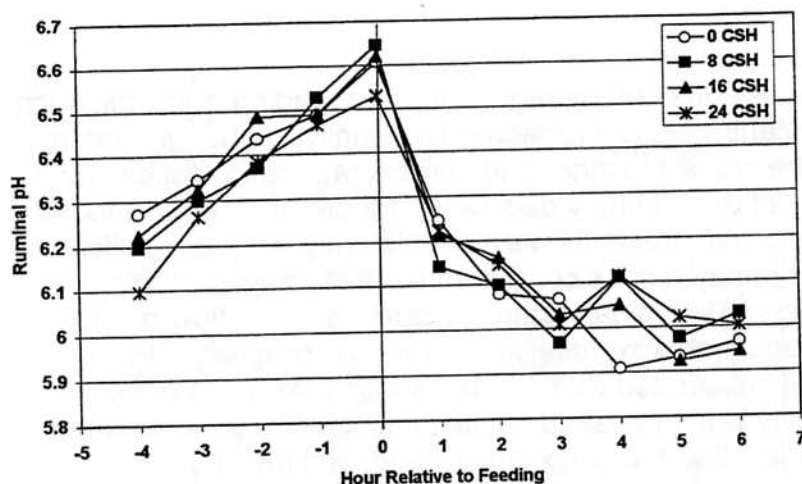


Figure 6. Effect on ruminal pH of substitution of cottonseed hulls for sorghum silage in 40% roughage diets (Akinyode and Hall, 1999, unpublished). Number in legend designates the amount of cottonseed hulls as a % of diet dry matter. Least squares means plotted.

EFFECTS ON PERFORMANCE

The effects of cottonseed hulls on feed efficiency and overall performance have varied. Gain efficiency of steers was 11.8% greater ($P < 0.001$) for chopped alfalfa hay diets than for cottonseed hull diets where diet roughage equivalent ranged from 10% through 30% of ration dry matter (Bartle et al., 1994). The steers fed cottonseed hulls consumed more feed ($P < 0.001$), but tended to have lower gains ($P = 0.11$).

Milk production of dairy cattle fed diets containing cottonseed hulls has been equivalent to, or greater than control diets containing corn silage (Harris et al., 1983, Adams et al., 1995, Gu et al., 1996) or alfalfa haylage (Morales et al., 1989). Fat percentages were decreased on a 30% cottonseed hull diet (2.77% fat) as compared to a 35% alfalfa haylage diet (3.38% fat) ($P = 0.001$) (Morales et al., 1989). No difference in fat percentage was evident in a comparison of 40% corn silage (3.15% fat) and 30% cottonseed hull (3.19% fat) diets (Harris et al., 1983). Results of studies in which corn silage- or alfalfa haylage-based diets containing 10% to 14% cottonseed hulls were fed showed no difference in fat percentage as compared to control diets (Morales et al., 1989, Adams et al., 1995, Gu et al., 1996). Generally, there was no effect of cottonseed hulls on milk protein percentage. The exception was a study in which the reported milk protein percentage on a cottonseed hull diet (3.23%) was higher than the corn silage control diet (3.02%) ($P < 0.05$) when rumen undegradable protein was held at 33% of ration crude protein (Gu et al., 1996).

Feed efficiency (solids- or fat-corrected milk / DM intake) of the cottonseed hull diets was less than (Morales et al., 1989, Gu et al., 1996) or equivalent to (Morales et al., 1989) the control diets. Feed efficiency did not decrease with increasing cottonseed hull inclusion (Gu and Moss, 1996). Feed efficiency on cottonseed hull diets was improved by increasing the undegradable protein content of the diet from 33% to 43% of crude protein (diet crude protein content = 16% of dry matter) (Gu and Moss, 1996). Anecdotal reports from the field suggest that high levels of cottonseed hulls ($\geq 30\%$ of ration DM) can result in high intakes without commensurate increases in production. Proper formulation of cottonseed hull rations to meet nutrient requirements is essential,

even with the uncertainties of the impact of a potentially changing passage rate on digestibilities.

SUMMARY

Cottonseed hulls can provide a useful source of fiber for ruminant diets. It has the advantage of being a fiber supplement that can be readily handled for incorporation into concentrate mixes or total mixed rations. Its effects of increasing intake and maintaining ruminal pH while not necessarily impairing production suggest that it may complement forage in dietary manipulations. The possible effects on feed efficiency as related to nutrient management bear watching. A better understanding of the effects of cottonseed hulls on digestion, feed efficiency, and feed passage will allow us to improve our use of this feed in ration formulation.

The work by A. Akinyode was supported by a grant from the Florida Milk Check-Off. Special thanks to C. Casey, J. Jennings, and E. Oelfke for their assistance on this paper.

LITERATURE CITED

- Adams, A. L., B. Harris, Jr., H. H. Van Horn, and C. J. Wilcox. 1995. Effects of varying forage types on milk production responses to whole cottonseed, tallow, and yeast. *J. Dairy Sci.* 78:573-581.
- Akinyode, A., M. B. Hall, C. R. Staples, and W. E. Kunkle. 1999. Effect of cottonseed hulls on feed intake and fecal flow in dairy cows. *J. Dairy Sci.* 82 (Suppl. 1):41.
- Bartle, S. J., R. L. Preston, and M. F. Miller. 1994. Dietary energy source and density: effects of roughage source, roughage equivalent, tallow level and steer type on feedlot performance and carcass characteristics. *J. Anim. Sci.* 72:1943-1953.
- Garleb, K. A., G. C. Fahey, Jr., S. M. Lewis, M. S. Kerley, and L. Montgomery. 1988. Chemical composition and digestibility of fiber fractions of certain by-product feedstuffs fed to ruminants. *J. Anim. Sci.* 66:2650-2662.
- Garleb, K. A., L. D. Bourquin, J. T. Hsu, G. W. Wagner, S. J. Schmidt, and G. C. Fahey, Jr. 1991. Isolation and chemical analyses of nonfermented fiber fractions of oat hulls and cottonseed hulls. *J. Anim. Sci.* 69:1255-1271.
- Gu, S. C., B. R. Moss, W. McElhenney, and J. C. Lin. 1996. Effects of forage sources in high and low rumen undegradable protein diets on lactating cow performance. *J. Dairy Sci.* 79 (Suppl. 1): 151 (Abstr.).

Gu, S. C. and B. R. Moss. 1996. Lactation performance of cows fed low and high rumen undegradable protein diets with varying levels of cottonseed hulls and protein. J. Dairy Sci. 79 (Suppl. 1): 152 (Abstr.).

Harris, B. Jr., H. H. Van Horn, K. E. Manookian, S. P. Marshall, M. J. Taylor, and C. J. Wilcox. 1983. Sugarcane silage, sodium hydroxide- and steam pressure-treated sugarcane bagasse, corn silage, cottonseed hulls, sodium bicarbonate, and *Aspergillus oryzae* product in complete rations for lactating dairy cows. J. Dairy Sci. 66:1474-1485.

Hsu, J. T., D. B. Faulkner, K. A. Garleb, R. A. Barclay, G. C. Fahey, and L. L. Berger. 1987. Evaluation of corn fiber, cottonseed hulls, oat hulls and soybean hulls as roughage sources for ruminants. J. Anim. Sci. 65:244-255.

Jordan, W. H. 1903. The Feeding of Animals, 2nd Ed., The Rural Science Series, L. H. Bailey, editor. The Macmillan Company, New York.

Mertens, D. R. 1992. "Chapter 25: Nonstructural and structural carbohydrates" In Large Dairy Herd Management. H. H. Van Horn and C. J. Wilcox, ed. American Dairy Science Association, Champaign, IL.

Moore, J. A., M. H. Poore, and R. S. Swingle. 1990. Influence of roughage source on kinetics of digestion and passage, and on calculated extents of ruminal digestion in beef steers fed 65% concentrate diets. J. Anim. Sci. 68:3412-3420.

Morales, J. L., H. H. Van Horn, and J. E. Moore. 1989. Dietary interaction of cane molasses with source of roughage: intake and lactation effects. J. Dairy Sci. 72:2331-2338.

Morrison, F. B. 1950. Feeds and Feeding, A handbook for the student and stockman, 21st Ed. The Morrison Publishing Company, Ithaca, NY.

Torrent, J., D. E. Johnson, and M. A. Kujawa. 1994. Co-product fiber digestibility: kinetic and in vivo assessment. J. Anim. Sci. 72:790-795.

Van Horn, H. H., B. Harris, Jr., M. J. Taylor, K. C. Bachman, and C. J. Wilcox. 1984. By-product feeds for lactating dairy cows: effects of cottonseed hulls, sunflower hulls, corrugated paper, peanut hulls, sugarcane bagasse, and whole cottonseed with additives of fat, sodium bicarbonate and *Aspergillus oryzae* product on milk production. J. Dairy Sci. 67:2922-2938.

Van Soest, P. J. 1994. Nutritional Ecology of the Ruminant. Cornell University Press, Ithaca, NY.