Aspen Sawdust as a Partial Roughage Substitute in a High-Concentrate Dairy Ration 1,2

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Abstract

Twelve lactating cows divided into three groups of four were fed either equal parts of hay and pelleted concentrate (A), limited hay and pelleted concentrate containing 32% aspen sawdust (B), or limited hay and pelleted concentrate (C), to determine if aspen sawdust could serve as a partial roughage substitute in a high-concentrate ration. There were no significant ration effects on milk production or per cent milk protein. Adjusted means of 2.59, 3.13, and 1.67 for per cent milk fat, for Rations A, B, and C were significantly different. Adjusted ruminal acetate: propionate ratios were 3.99, 2.70, and 1.27 for Rations A, B, and C. Time spent ruminating was highest for cows fed Ration B, followed by Rations A and C (5.8, 5.3, and 3.3 hr/day). Dry matter intakes of hay and concentrate on Rations A, B, and C were 7.3 and 7.8, 2.0 and 14.9, and 1.9 and 12.4 kg, respectively. Cows receiving Ration B (with aspen) compensated for the lower digestibility of this ration by eating more of it. Thirty per cent dietary aspen sawdust was effective as a partial roughage substitute for hay.

Introduction

It appears necessary to include some roughage in high-concentrate rations fed to fattening steers to minimize the incidence of rumen lesions and liver abscesses (24). Somewhat more roughage is necessary in dairy cow rations to prevent abnormally low milk fat tests (5, 23). Hay supplies are limited and costly in some areas of the United States. In these areas it would be desirable to have an alternate roughage that would meet the “roughage requirement” for fattening beef or lactating dairy cows and yet be compatible with automated feeding systems.

Several attempts have been made to find alternate or substitute sources of roughage for fattening beef or lambs fed high-concentrate rations. Dinius et al. (10) examined aspen sawdust, fine and coarse oak sawdust, hardwood shavings, oak-flooring waste, fine and coarse clay, 3% clay–7% sawdust, expanded vermiculite, vermiculite flakes, ground corn cobs, cob residue from furfural extraction process, and bagasse as roughage substitutes for constituting 10% of a high-concentrate lamb ration. The digestible energy intake of sheep fed wood by-product, clay, or vermiculite flakes was the same as for sheep fed no roughage or corn cobs. No digestive disorders could be attributed to the treatments other than some scouring by the sheep fed no roughage or corn cobs. No digestive disorders could be attributed to the treatments other than some scouring by the sheep fed no roughage or the cob residue.

El-Sabban et al. (11) concluded that fine or coarse oak sawdust constituting 5 or 15% of high-concentrate beef finishing rations could substitute for 5% ground timothy hay as the sole roughage source without significantly affecting rate of gain. Feed efficiency was highest, however, for the 5% timothy ration. Abscessed livers were present in all treatment groups.

Anthony and Cunningham (2) compared oyster shells and oak sawdust as roughage substitutes in high-concentrate lamb and steer rations. Sawdust at 2.5 or 10% of the ration supported gains equal to or larger than the ration containing no roughage and in all cases supported larger gains than rations containing 2.5% oyster shell. No deleterious effects resulted from feeding oak sawdust. Cody et al. (7) fed several levels of wood fiber to dairy calves receiving high-concentrate rations. A ration containing 15% wood fiber was incapable of maintaining a normal rumen mucosa, but there was evidence that higher wood fiber was effective in controlling rumen parakeratosis and clumping of rumen papillae.

In two other studies the following have been compared as roughage sources in all-concentrate
rations: Hay with cottonseed hulls, ground corn-cobs, oyster shells, sand, ground polyethylene and pelleted polyethylene (14), and hay with rice straw, rice hulls, and sudangrass pellets (25). Aside from rice straw and cottonseed hulls, none of the materials in either of these studies supported higher rates of growth than the all-concentrate ration. Only hay gave any measurable protection against rumen parakeratosis and liver abscesses (14).

Little work has been done with roughage substitutes in dairy cattle rations. Therefore, the purpose of this study was to determine if aspen sawdust when incorporated into a high-concentrate ration known to depress milk fat would maintain fat test and serve as a roughage substitute.

Methods and Procedures

Nine Holstein and three Ayrshire cows from early to mid-lactation were assigned to one of three equal groups on the basis of breed, previous milk production, and per cent of milk fat. All cows were placed on a standardization or pre-experimental ration of one part of long-alfalfa hay and 1.5 parts of 0.55-cm pelleted concentrate containing the ingredients listed under Concentrate A in Table 1. After being on the pre-experimental ration for 26 days, the cows were divided into their respective groups and fed pelleted Concentrates A, B, or C as shown in Table 1. Varying levels of soybean oil meal were included to make the concentrate mix isonitrogenous.

Cows receiving pelleted Concentrate A were fed an equal amount of long alfalfa hay, and the cows receiving pelleted Concentrate B or C were fed 2.3 kg of hay daily. Cows receiving Concentrate A and an equal amount of hay were intended as a control group with normal milk fat. Cows fed Concentrate C plus 2.3 kg of hay were intended as a control group with depressed milk fat. Cows receiving Concentrate B containing 32% aspen, plus 2.3 kg of hay, were meant to measure the effectiveness of aspen in maintaining milk fat in an otherwise high-concentrate ration. The aspen contained in Concentrate B was obtained from a sawmill sawing barkfree logs of Populus grandidentata. After air drying, the sawdust was hammer-milled through a 0.16-cm screen, with 53.6% of the resulting material being in the 10- to 40-mesh range and 35.8% in the 40- to 80-mesh range. This was incorporated directly into pelleted Concentrate B. The experimental rations were fed for 38 days. The amount of feed offered was adjusted so that refusals usually did not exceed 1 kg/day; feed intake was essentially ad libitum for both periods.

Feed intake, milk production, milk composition, and ruminal volatile fatty acid concentration were measured during the last 9 days of the pre-experimental period and the last 18 days of the experimental period. Feed intake and milk production were recorded daily, and milk composition was determined twice weekly on combined morning and evening milk, with a total of three and eight samples obtained for the pre-experimental and experimental periods, respectively. Milk fat was measured by the Babcock test, milk protein by the dye-binding procedure of Ashworth et al. (3), and solids-not-fat by the Golding bead method (13). Ruminal volatile acids were determined in fluid ingesta obtained from the reticulo-rumen by a suction-strainer technique (17). Samples were obtained 5 to 6 hours after feeding, acidified to approximately pH 2 with H₂SO₄, strained through three layers of cheese cloth, and centrifuged at 12,000 g for 15 minutes. Total acidity was determined by steam distillation, and the relative amounts of volatile acids were measured with gas chromatography as described by Baumgardt (6).

Eating and rumination times during 24 hours were observed for all cows during the last part of the experimental period. An observation was made every 5 minutes of whether a cow was ruminating, resting, or eating. It was assumed that 5 minutes of rumination accompanied each momentary observation of rumination. Since rumination periods were usually 20 minutes or longer, this represented a fairly accurate measure. The eating times were probably less accurate.

Differences among treatment means in the experimental period were analyzed after adjustment by covariance for differences between groups in the pre-experimental period. Duncan’s multiple range test was used to identify significant differences between the three treatment rations (22).

| TABLE 1. Composition of pelleted concentrates. | Concentrate |
| Ingredient | A | B | C |
| Ground shelled corn | 63.7 | 42.7 | 63.7 |
| Aspen | 32.4 | .... | .... |
| Oats | 19.6 | 14.7 |
| Soybean oil meal | 9.8 | 19.6 | 14.7 |
| Molasses | 4.9 | 3.3 | 4.9 |
| Dicalcium phosphate | 1.0 | 1.0 | 1.0 |
| Trace-mineral salt | 1.0 | 1.0 | 1.0 |
SAWDUST FOR ROUGHAGE

Table 2. Daily milk production and milk composition.

<table>
<thead>
<tr>
<th>Ration</th>
<th>Milk Fat (kg/day)</th>
<th>Solids-not-fat (%)</th>
<th>Protein (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-experimental</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>20.9</td>
<td>2.62</td>
<td>8.06</td>
</tr>
<tr>
<td>B</td>
<td>22.1</td>
<td>2.55</td>
<td>8.72</td>
</tr>
<tr>
<td>C</td>
<td>22.1</td>
<td>2.35</td>
<td>8.24</td>
</tr>
<tr>
<td>Experimental</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>18.9 (19.6)a</td>
<td>2.66 (2.59)bA</td>
<td>7.98 (8.08)b</td>
</tr>
<tr>
<td>B</td>
<td>18.8 (18.5)a</td>
<td>3.15 (3.13)aA</td>
<td>8.83 (8.68)a</td>
</tr>
<tr>
<td>C</td>
<td>17.6 (17.3)a</td>
<td>1.58 (1.67)bB</td>
<td>8.78 (8.82)a</td>
</tr>
</tbody>
</table>

1 Means in parentheses are adjusted by covariance.
2 Means in column with similar upper- or lower-case letters are not significantly different. Dissimilar lower-case letters indicate significance at (P < 0.05) and dissimilar upper-case letters indicate significance at (P < 0.01).

Results and Discussion

The daily milk production and milk composition for the pre-experimental and experimental periods are in Table 2. Covariance removed group differences that appeared in the pre-experimental period; the adjusted means (in parentheses) as well as the unadjusted means are shown. All discussion will refer to the adjusted means.

There were no significant effects of rations on the quantity of milk produced. The cows fed Ration A (Concentrate A) produced slightly more milk, followed by those fed Rations B and C. Rations similar to Ration C have been used in several lactation trials to depress milk fat and, despite their high-digestible energy content, frequently do not seem to sustain milk production as well as rations containing more roughage (21). Ration B supported an intermediate production. It appears that 30% dietary aspen was not detrimental to milk yield in cows producing approximately 20 kg of milk daily.

Dietary aspen nearly doubled (P > 0.01) the per cent milk fat when it was added to the low-roughage ration. The aspen ration supported an even higher (P < 0.05) milk fat content than did Ration A, which contained equal amounts of hay and concentrate. The cows in this experiment were probably below herd average in fat test before the experiment began.

There was an unexpected drop in milk fat content during the pre-experimental period when all cows were fed 1.5 parts concentrate to 1 part alfalfa hay. The pre-experimental ration was intended to maintain normal milk fat content. Since it was desired to have one group of control cows maintaining a normal milk fat content during the experimental period, the amount of roughage fed to cows receiving Concentrate A was increased at the start of the experimental period so that equal amounts of hay and concentrate were fed. In spite of this, milk fat content remained low for cows fed Ration A. Even though the fiber of the dietary aspen sawdust was very short, it appeared even more effective than long alfalfa hay in maintaining fat test in relatively high-concentrate rations.

The milk of cows fed Ration A had less solids-not-fat than did that of cows from the two other groups (P < 0.05). The three rations had no significant effect (P > 0.05) on milk protein. The protein and solids-not-fat content of milk of aspen-fed cows was intermediate between the other groups.

The molar per cent of ruminal volatile fatty acids is in Table 3. The cows fed equal parts of hay and concentrate had the highest molar percentage of acetate and differed (P < 0.01) from those fed aspen. Likewise, the aspen-fed cows had much higher proportions (P < 0.01) of acetate than did those fed Ration C. The inverse of this was noted for ruminal propionate, with Rations C, B, and A having propionate molar percentages of 36.3, 22.3, and 16.9%. The molar proportions of butyrate were not significantly affected by treatment. There were highly significant differences in the proportions of valerate and iso-valerate, with Ration C supporting the highest valerate and lowest iso-valerate levels. There was a modest difference in total volatile acid concentration, with Ration A having less (P < 0.05) total acidity per volume of rumen fluid than Ration C. Ration B was intermediate and not significantly different from the other rations.

The differences in proportions of ruminal acetate, propionate, and butyrate are characteristic of those associated with either high- or
low-roughage rations (1). Ration B was fer-
mented like a high-roughage ration even though
the cows were fed only 2.3 kg of hay and the
aspen fiber was very short. It is probable that
the relatively high ruminal acetate and low
propionate with Rations A and B were respon-
sible for the maintenance of near-normal milk
fat. In contrast, feeding Ration C resulted in
relatively low ruminal acetate and high propio-
ate, and cows on Ration C had a low milk fat
content. Numerous studies have shown a high
correlation between the ruminal acetate:propio-
ate ratios and percentage milk fat (23).

The reason for the marked effect of aspen
on ruminal fatty acid proportions is not clear.
The large contribution of cellulose and hemi-
cellulose by aspen could lead to higher ruminal
acetate, provided cellulose and hemicellulose
were degraded by rumen microorganisms, chiefly
to acetate. This is unlikely, however, because
Satter et al. (19, 20) showed that cellulose-14C
and hemicellulose-14C incubated with ingesta
from a cow fed a high-concentrate ration yielded
acetate-14C and propionate-14C in ratios of 2.1
to 2.4. Therefore, the higher substrates per se
of cellulose and hemicellulose are not responsible
for the elevated ruminal acetate associated with
Ration B. It is more likely that dietary aspen
was affecting rumen pH by stimulating saliva
secretion which, in turn, was related to increased
ruminating (4, 8). Rumen pH of 6 to 7 is
associated with considerably higher acetate:
propionate ratios than is a pH of 5 to 6 (12,
18). Because rumen-fluid samples were taken by
stomach tube, it was thought that the small
amount of saliva contamination that occasion-
ally occurs would make pH observations inac-
curate.

The time spent ruminating was about equal
for cows fed Rations A and B (5.3 and 5.8 hr/
day), and differed (P < 0.05) from those fed
Ration C, which spent 3.3 hr/day ruminating.
The amount of time spent eating ranged be-
tween 2.0 and 2.4 hr/day. The differences in
eating time were not significant. Even though
the aspen sawdust was pelleted and had short
fibers, Ration B containing 30% aspen was as
effective in stimulating rumination as was Ra-
tion A, which contained 50% long-alfalfa hay.
It would appear plausible that the increased
time spent ruminating Rations A and B could
have enhanced salivation to the point where
rumen pH and, consequently, rumen fermenta-
tions were quite different when Ration C was
fed. It is unfortunate that measurements of
rumen pH were not obtained.

The daily feed intake for each of the three
rations is in Table 4. At the start of the experi-

<table>
<thead>
<tr>
<th>Ration</th>
<th>Acetate</th>
<th>Propionate</th>
<th>Butyrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>65.5</td>
<td>19.2</td>
<td>13.0</td>
</tr>
<tr>
<td>B</td>
<td>60.8</td>
<td>23.3</td>
<td>13.4</td>
</tr>
<tr>
<td>C</td>
<td>61.8</td>
<td>22.2</td>
<td>13.4</td>
</tr>
</tbody>
</table>

Table 3. Molar per cent and total concentration of ruminal volatile fatty acids.

1 Means in parentheses are adjusted for covariance.
2 Means in column with similar upper-case letters are not significantly different. Dissimilar lower-case letters indicate significance at (P < 0.01).
TABLE 4. Daily dry matter intake of hay and pellets.

<table>
<thead>
<tr>
<th>Ration</th>
<th>Pre-experimental</th>
<th>Experimental</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hay</td>
<td>Pellets</td>
<td>Hay</td>
</tr>
<tr>
<td>A</td>
<td>5.5 9.2</td>
<td>7.3 7.8</td>
</tr>
<tr>
<td>B</td>
<td>5.5 9.2</td>
<td>2.0 14.9</td>
</tr>
<tr>
<td>C</td>
<td>4.8 9.0</td>
<td>1.9 12.4</td>
</tr>
</tbody>
</table>

* All cows received the same pre-experimental ration. They were separated into groups for the experimental period.

ment, three or four days of partial hunger were required before the cows would consume the pellets containing aspen. There appeared to be a repulsive volatile component in the aspen because the cows would readily detect a difference between Rations B and C from a distance of 10 to 12 cm. Once consumption started, however, there was no problem with feed intake. As shown in Table 4, the cows fed aspen had the highest feed intake. They compensated in part for the lower digestibility of the dry matter of the aspen by eating a greater quantity of dry matter, thus tending to maintain a constant digestible energy intake.

Aspen compared to other woods has a fairly high digestibility (16). Mellenberger (15) observed that aspen had a dry-matter digestibility of 28% when incorporated into high-grain rations for goats. With a dry-matter digestibility of 28 for aspen and 75% for the concentrate portion of the pellet, the cows consuming 14.9 kg of dry matter from aspen-concentrate pellets would obtain 8.9 kg of digestible dry matter, compared to 9.3 kg for the cows consuming 12.4 kg of dry matter from the pellets of Ration C. The tendency to compensate by eating more feed is in agreement with the work of Dinius and Baumgardt (9). They fed sheep rations containing oak sawdust ranging from 0 to 50% of the ration. Oak, being almost totally indigestible, served as an energy diluent in the ration. The sheep maintained a rather constant digestible energy intake by eating more of the oak rations. They were able to compensate fully for all rations containing up to 35% of oak. Beyond that, total feed intake could not increase enough to maintain constant digestible energy intake.

Inability to compensate for lower digestibility of dietary wood would probably decrease production or gain in weight. Cows producing 20 kg of milk daily can consume at least 30% of their ration as aspen sawdust without reducing the intake of digestible dry matter or the production of milk.

From the start of the pre-experimental period to the end of the experimental period, cows fed Rations A, B, and C gained 14, 11, and 29 kg. Weight changes during the experimental period only were not recorded. No ill effects were observed in the cows fed aspen.

In summary, aspen sawdust was effective as a partial roughage substitute in a high-grain dairy ration. Cows receiving 2.3 kg of hay and about 17 kg of pelleted grain, one-third of which was aspen sawdust, maintained a normal milk fat level. Cows receiving a similar ration without sawdust had a milk fat content half as great. The ratio of ruminal acetate to propionate was much higher in the cows fed aspen and was closer to the ratio in the group of cows fed equal amounts of hay and concentrate. Inclusion of aspen in a high-concentrate ration nearly doubled ruminating time. If less dietary aspen would be equally as effective in complete pelleted dairy rations, aspen sawdust could become an attractive roughage substitute in areas where hay is expensive and difficult to obtain.

Acknowledgment

The authors thank Ralph Lance and Howard Wilson for assistance in this experiment, and Dr. George E. Shook and Arden R. Hardie for advice in the statistical analysis.

References


