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# ASSOCIATIVE EFFECTS OF MIXED DIETS IN SHEEP

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## ABSTRACT

Four suffolk wethers (40 kg) were fed in a 4 x 4 Latin square design to examine the effect of mixed diets of alfalfa hay (ALF) and corn grain (CG) on nutrient digestibility. Lambs were fed diets containing ALF:CG ratios of: (A) 100:00; (B) 67:33; (C) 33:67 or (D) 00:100 in a digestion trial. Digestibility coefficients of dry matter (DM), protein, starch, energy, neutral detergent fiber (NDF) and acid detergent fiber (ADF) were different (P <.05) between the all ALF and all CG diets. However, no differences (P >.05) were found in nutrient digestibilities across the mixed diets containing 33 and 67% CG. Expected nutrient digestibilities for the ALF-CG mixed diets, weighted by the algebraic sum of the nutrient digestibilities when these feedstuffs were fed alone, were compared to the nutrient digestibilities observed for the ALF-CG mixed diets. No differences (P >.05) were found between expected and observed digestibilities for DM, protein, starch, energy, NDF and ADF in the ALF-CG mixed diets. A linear relationship (P <.05) was found between nutrient digestion coefficients and the level of CG in the diet. Level of dietary CG accounted for 78, 41, 71 and 49% of the variation in the digestibility of DM, protein, energy and NDF, respectively. A quadratic relationship was observed (P <.05) between starch digestibility and the level of dietary CG.

(Key words: Associative Effects, Mixed Diets, Digestibility.)

## INTRODUCTION

Associative effects of feedstuffs occur due to changes in digestion and metabolism of nutrients as a result of combining two feedstuffs in ruminant diets. Classical

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research conducted by Armsby (1917), Forbes (1933), Kriss (1943) and Swift and French (1954) reported a reduction in digestibility when grains were added to roughage diets. More recent studies have documented that when mixed grain and roughage diets are fed, the nutritive value of the feedstuffs is dependent on their combination with other ingredients (Byers et al., 1975 a,b; Kromann et al., 1975; Woody et al., 1983). Some researchers have concluded that associative effects in mixed diets occurs from a reduction in fiber digestion (Orskov and Fraser, 1975) while others have reported a depression in starch digestion (Zinn and Owens, 1980; Joanning et al., 1981). In contrast, others have found no associative effects present in mixed grain-roughage diets (Tyrrell and Moe, 1973; Preston et al., 1975). Thus, the presence of associative effects in mixed grain and roughage diets is unclear.

The objectives of our study were to determine the nutrient digestibility of diets with varying proportions of alfalfa hay and corn grain and to determine whether the nutrient digestibility of these mixed diets were equal to the algebraic sum of the nutrient digestibility when these feeds were fed alone.

## MATERIALS AND METHODS

Four Suffolk wether lambs (40 kg) were fed in a 4 x 4 Latin square design to examine the influence of mixed diets of alfalfa hay (ALF) and corn grain (CG) on nutrient digestibility. Lambs were assigned at random to be fed diets containing ALF:CG ratios of: (A) 100:00; (B) 67:33; (C) 33:67 or (D) 00:100 in a digestion trial (table 1). Experimental diets were balanced to provide the same level of total protein. A mineral-vitamin supplement was added to meet NRC (1976) requirements for calcium, phosphorous, trace mineralized salt and vitamins A and D. Diets were ground through a 24/64 mm screen and thoroughly mixed. Lambs received feed and water ad libitum. Lambs were fed twice daily, unconsumed feed was weighed, recorded and discarded.

The lambs were housed in individual pens (130 x 130 cm) for a 10 d adaptation to their respective diets. Following adaptation they were transferred to individual metabolism crates (60 x 122 cm) for 5d collection period during which total fecal and urinary outputs were collected. Following each collection period the lambs were rotated to the next diet and the procedures repeated.

Total fecal collections were made on a daily basis for each lamb. Daily fecal outputs were weighed and mixed, and a 10% (by weight) aliquot was saved for analysis. At the end of the collection period, the daily samples were weighed and dried to a constant weight in a forced-draft drying oven maintained at 95 C. Dry matter values were calculated and averaged for the respective collection periods. These daily samples were then passed through a microhammer mill and composited for each lamb's collection period. Subsamples of this composite were ground through a 2 mm screen in a Wiley Mill and used for subsequent analyses.

Urine production was collected daily into 3-l plastic containers containing 23 ml of 50% (v/v) $H_2SO_4$. Urine volume was recorded and mixed, and a 25% (by volume) subsample was filtered through glass wool and stored at 3 C. At the end of the collection period, urine samples of each wether were mixed and a 10% subsample was frozen (-20 C) for subsequent analyses.

Gross energy determinations were made on the feed and fecal samples using bomb calorimetry as described by procedures outlined by Parr Instrument Company (1960). Acid detergent fiber (ADF), ether extract (EE), lignin and ash were determined by AOAC (1980) procedures. Neutral detergent fiber (NDF) of the feed and feces was determined by the method described by Van Soest and Wine (1967). Total nitrogen content of feed, feces and urine were measured by micro-Kjeldahl technique (AOAC, 1980). Feed and fecal starch determinations were made by a modification of MacRae and Armstrong (1968) procedure. Samples were gelatinized by autoclaving for 1 hr at 130 C. The gelatinized product was incubated at 60 C at a pH of 4.5 for at least 24 hr. The final glucose was determined using a glucose-oxidase reagent according to Sigma Chemical Company (1982).

Statistical analysis of results from this study was accomplished by analysis of variance procedure described by Steel and Torrie (1960). Treatment means were compared using Duncans (1955) Multiple Range Test. The data were further analyzed by least-squares regression analysis (Snedecor and Cochran, 1967).

## RESULTS AND DISCUSSION

Digestibility of DM, protein, starch, energy, NDF and ADF for the CG diet was higher ($P<.05$) than the all ALF diet (table 2). However, nutrient digestibilities for the mixed diets containing 33 and 67% CG were similar. When regression equations were developed by analyzing across all diets, a linear ($P<.05$) relationship was found between the level of CG in the diet and DM ($R^2 = .78$), protein ($R^2 = .41$), energy ($R^2 = .71$), NDF ($R^2 = .49$) and starch ($R^2 = .50$) digestibility (table 3).

Expected nutrient digestibilities for the ALF-CG mixed diets, weighted by the algebraic sum of the nutrient digestibilities of these feedstuffs when fed alone, were compared to the nutrient digestibilities observed for the ALF-CG mixed diets (table 4). No differences ($P>.05$) were found between the expected and observed digestibilities for DM, protein, starch, energy, NDF and ADF for the ALF-CG mixed diets.

Our results are supported by Ledoux et al. (1985) who fed steers corn diets that were supplemented with varying increments of fescue hay and reported that DM and starch digestibility increased linearly ($P<.05$) with increased levels of corn. Additional studies by Brink and Steele (1985) found a linear ($P<.01$) increase in total tract and ruminal starch digestion as CG in the diet increased from 50% to 90%. The fact that Slyter (1976) found a decrease in rumen pH and reduced rumen motility in high grain diets may account for the increase in starch retention time and improved digestibility.

Further studies by Kromann et al. (1975) reported a linear relationship between CG and digestible energy, metabolizable energy and net energy values when lambs were fed corn diets supplemented with increments from 0 to 100% of dehydrated alfalfa. A linear relationship between dietary CG and digestible energy is in agreement with the results of Blaxter and Wainman (1964), Clemens et al. (1968) and Asplund and Harris (1971). Also, Wainman et al. (1976) conducted numerous feeding trials and concluded that associative effects were not present in mixed grain-roughage diets. Preston et al. (1975) summarized three Ohio experiments involving 280 steers and reported that net energy values for grain and silage were constant as the ratio of added grain to silage varied.

A quadratic relationship was observed between starch digestibility and the level of dietary CG (figure 1). This may be due to the high quality of alfalfa hay that was fed. Improvements in digestibility over the predicted values have also been reported by Brandt and Klopfenstein (1986) who fed lambs either low or high quality alfalfa or brome hay at 0, 15, 30, or 100% of the diet. In their study, there were positive associative effects present on digestibility of DM and NDF when the diet contained 30% of each hay fed. Also, Heavens (1978) reported positive associative effects present on the digestibility of cell wall constituents when alfalfa hay was supplemented at 33% of the diet containing low quality timothy hay.

In contrast, others have found negative associative effects present in mixed diets (Byers et al., 1975 a,b; Kromann et al., 1975; Joanning et al., 1981; Woody et al., 1983). Joanning et al. (1981) reported that depressions in starch, NDF and protein digestibility accounted for 59, 26 and 14% of the depression in DM digestibility for mixed immature silage-grain diets and 53, 36 and 10% of the depression in DM digestibility for mixed mature silage-grain diets, respectively. Also, Wheeler (1977) reported that depressions in starch, NDF and protein digestibility accounted for 50, 40 and 7% of the depression in DM digestibility in mixed diets, respectively. Associative effects may also alter the net energy value in growing and finishing steer diets (Lofgreen and Garrett, 1968; Byers et al., 1975 a,b; Woody et al., 1983).

As concluded in our study, there was no depression in nutrient digestibility or negative associative effects found in the mixed diets. This may be due to the physical form of the diets which can influence digestibility. Alfalfa hay and corn grain in our study were finely ground. In support of this theory, Kromann et al. (1975) found no interaction for digestible energy, metabolizable energy and net energy values when sheep were fed pelleted diets of dehydrated alfalfa and corn. However, in an earlier study, Kromann (1967) fed non-pelleted diets of mixed alfalfa hay and sorghum grain and found associative effects present for digestible energy, metabolizable energy and net energy values. Other workers (Moe et al., 1973; Wilson et al., 1973) have also found depressions in DM digestibility in mixed diets when corn was fed either whole or coarse ground.

In summary, the presence of associative effects in mixed grain-roughage diets, whether positive or negative, is variable. From the results of our data and past research, it is concluded that there are several factors that influence nutrient digestibility. These include the physical form of the diet, level of DM intake, proportion of grain-roughage mixture and the type and quality of forage.

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Table 1. Ingredients and Chemical Composition of Alfalfa Hay (ALF) and Corn Grain (CG) Diets

| Item | ALF:CG 100:00 | 67:33 | 33:67 | 00:100 |
|---|---|---|---|---|
| Ingredients: | % dry matter | | | |
| Alfalfa hay | 99.0 | 66.7 | 33.6 | |
| Corn grain | | 29.8 | 54.7 | 79.5 |
| Soybean meal | | .3 | 7.6 | 15.0 |
| Urea | | 1.0 | 1.0 | 1.0 |
| Mineral supplement[a] | .88 | 2.2 | 3.4 | 5.0 |
| Vitamin premix[b] | .02 | .02 | .02 | .02 |
| Chemical composition: | | | | |
| Dry matter | 88.7 | 89.0 | 88.0 | 86.7 |
| Crude protein | 18.5 | 20.9 | 19.1 | 17.8 |
| Starch | 11.6 | 28.2 | 42.2 | 57.7 |
| Neutral detergent fiber | 53.3 | 44.0 | 36.2 | 24.5 |
| Acid detergent fiber | 34.5 | 22.8 | 18.3 | 4.6 |
| Gross energy, kcal/g | 4.4 | 4.1 | 4.2 | 4.2 |

[a]Contains ground limestone, dicalcium phosphate and trace mineralized salt.
[b]10,000 IU vitamin A/g and 3,000 IU vitamin D/g.

Table 2. Nutrient Digestibilities of Mixed Alfalfa Hay (ALF) and Corn Grain (CG) Diets

| Item | ALF:CG 100:00 | 67:33 | 33:67 | 00:100 | SE[a] |
|---|---|---|---|---|---|
| | % | | | | |
| Dry matter | 58.1[b] | 67.5[c] | 71.3[c] | 82.3[c] | 4.5 |
| Crude protein | 67.3[b] | 74.6[bc] | 74.1[bc] | 81.9[d] | 3.2 |
| Starch | 90.1[b] | 97.2[c] | 98.4[c] | 99.0[c] | 1.5 |
| Energy | 58.3[b] | 67.5[bc] | 74.7[bc] | 82.6[d] | 3.2 |
| Neutral detergent fiber | 50.4[b] | 59.7[bc] | 62.5[bc] | 74.4[c] | 4.8 |
| Acid detergent fiber | 48.7[b] | 49.4[c] | 51.5[c] | 56.3[c] | 5.1 |

[a]Standard error of the mean.
[b,c,d]Means in same row with unlike superscripts are different ($P < .05$).

Table 3. Regression of Corn Grain (CG) on Dry Matter, Protein, Starch, Energy and Neutral Detergent Fiber Digestibility

| Nutrient | Regression equation | $r^2$ |
|---|---|---|
| Dry matter | Y = 58.2 + .231 (%CG) | .78 |
| Crude protein | Y = 68.0 + .129 (%CG) | .41 |
| Energy | Y = 58.5 + .240 (%CG) | .71 |
| Neutral detergent fiber | Y = 50.6 + .223 (%CG) | .49 |
| Starch | Y = 92.0 + .083 (%CG) – .002 (%CG²) | .50 |

Table 4. Observed and Expected Nutrient Digestibilities of Mixed Alfalfa Hay (ALF) and Corn Grain (CG) Diets

| | ALF:CG | | | |
|---|---|---|---|---|
| Item | 100:00 | 67:33 | 33:67 | 00:100 |
| | % dry matter | | | |
| Dry matter | | | | |
| Observed | 58.1 | 67.5 | 71.3 | 82.6 |
| Expected | | 66.2 | 74.4 | |
| Change, % | | +1.9 | –4.2 | |
| Crude protein | | | | |
| Observed | 67.3 | 74.7 | 74.1 | 81.9 |
| Expected | | 72.1 | 77.1 | |
| Change, % | | +3.6 | –3.9 | |
| Starch | | | | |
| Observed | 90.1 | 97.2 | 98.4 | 99.0 |
| Expected | | 93.0 | 96.1 | |
| Change, % | | +4.5 | +2.4 | |
| Digestible energy | | | | |
| Observed | 58.3 | 67.5 | 74.7 | 82.6 |
| Expected | | 65.5 | 74.2 | |
| Change, % | | –3.1 | –.7 | |
| Neutral detergent fiber | | | | |
| Observed | 50.4 | 59.7 | 62.5 | 74.4 |
| Expected | | 58.3 | 66.4 | |
| Change, % | | +2.4 | –5.9 | |
| Acid detergent fiber | | | | |
| Observed | 48.7 | 49.4 | 51.5 | 56.3 |
| Expected | | 51.2 | 53.2 | |
| Change, % | | –3.5 | –4.1 | |

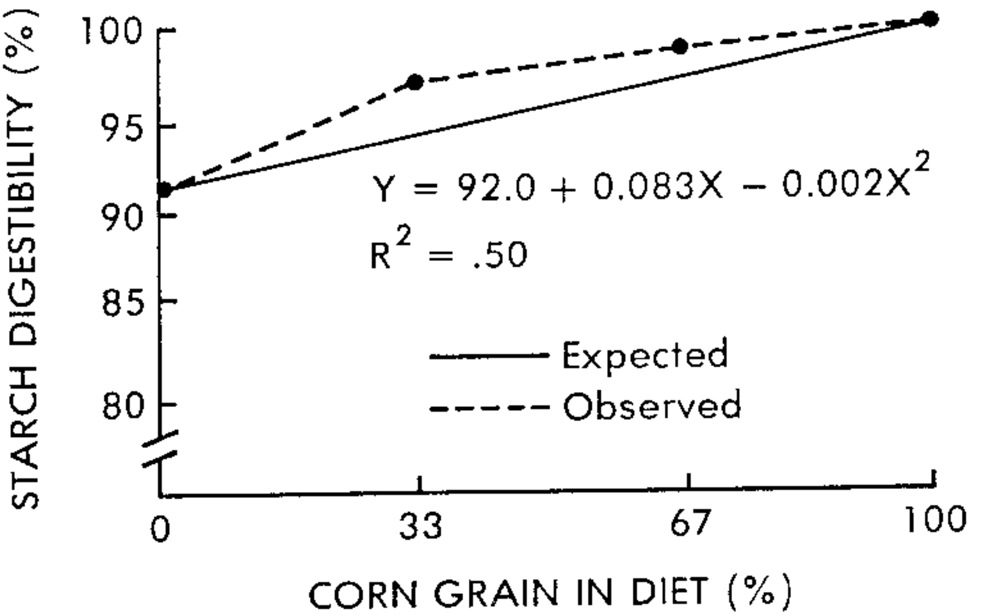


Figure 1. Relationship between diet corn grain level and starch digestibility.