# Effects of Different Levels of Concentrate in Complete Rations on Nutrient Digestibilities and Ruminal Metabolites in Sheep and Growth Performance in Korean Native Bulls

M. G. Baik[1], J. K. Ha[2], W. Y. Kim and In K. Han

Department of Animal Science and Technology, College of Agriculture and Life Sciences, Seoul National University, Suweon 441-744, Korea

**ABSTRACT**: Objectives of the present study were to investigate effects of different levels of concentrate in complete rations on nutrient digestibilities and ruminal fermentation in sheep and growth performance in Korean native bulls. Increasing levels of concentrate (35, 50, 65, and 80% of complete rations) improved digestibilities of dry matter (DM), crude protein (CP) and ether extract (EE) without affecting digestibility of neutral detergent (NDF) and acid detergent fiber (ADF). Increasing levels of concentrate decreased ruminal fluid pH but increased concentrations of $NH_3$-N, propionic acid, and total volatile fatty acids (VFA). Both the disappearance rates of DM and nitrogen (N) in an *in sacco* study were linearly increased as the levels of concentrate in complete rations increased. Meanwhile, increasing levels of concentrate in complete rations improved growth rate and feed conversion ratio in Korean native bulls. In conclusion, the complete rations containing 80% concentrate showed better digestibility and energy supply than those of the lower levels (35, 50 and 65%) of concentrate of the rations, resulting in improved growth performance of Korean native bulls.

**(Key Words:** Complete Ration, Concentrate Level, Ruminal Fermentation, Korean Native Bull)

## INTRODUCTION

Modern beef cattle farmers often feed rations containing a large proportion of concentrate to obtain maximum growth performances. Recent studies suggested that restricted feeding of high-concentrate (more than 80%) rations was favorable for the growth performances of steers (Sip and Prichard, 1991) and growing lambs (Murphy et al., 1994). Furthermore, the cost per unit of energy is frequently greater for roughages than for cereal grains. The physical handling of large quantities of roughages is also a problem. Consequently, most growing ruminants in Korea are fed high-concentrate rations.

Rice straw has been frequently incorporated into complete rations as a source of roughage especially in Asian countries, where high quality roughages are generally in shortage. However, without supplementation of deficient nutrients required by microorganisms in the rumen and by the animals, low quality roughage such as rice straw only supports low productivity (Preston and Leng, 1984.) Therefore, replacing some of rice straw portions in complete rations with concentrates may increase nutrient contents of complete rations, resulting in an improved growth performance of growing ruminants. However, when rations for ruminant animals are changed abruptly from high roughage rations to high concentrate rations, carbohydrate engorgement may occur (Tremere et al., 1968). Acute acidosis, off-feed, and laminitis are some problems associated with this condition (Walker and Elliot, 1969). Thus, supplying complete rations with optimal levels of concentrates is important for maximum animal performance with minimum digestive disturbances.

Little information is available on optimum concentrate levels in complete rations containing rice straw for growing cattle, particularly for Korean native bulls. Therefore, this study was conducted to examine effects of different levels concentrates in complete rations containing rice straw as a major roughage source on nutrient digestibilities and ruminal fermentation in growing sheep and on growth performance in Korean native bulls.

[1] Department of Genetic Engineering, College of Natural Science, Jheon-Nam National University, Kwangju, Korea.

[2] Address reprint requests to J. K. Ha.

Received January 25, 1997; Accepted May 21, 1997

## MATERIALS AND METHODS

### Digestion trial

Twelve growing sheep weighing an average of 60 kg fitted with ruminal cannula were used in a complete randomized design with 4 treatments and 3 replications to investigate the effects of four levels (35, 50, 65, and 80%) of concentrates in pelleted complete rations on nutrient digestion and rumen fermentation. Nutrient digestibility of the experimental rations (tables 1 and 2) was measured by total fecal collection method. Four pelleted complete rations were fed at 2.5% of body weight daily which were divided into two equal amount during digestion trials with free access to water. Sheep were allowed a preliminary period of 7 days prior to 5 day fecal collection period. Fecal samples were collected once a day, weighed and an aliquot of total feces was dried at 65℃ for 48 hours. The dried samples were ground in a Wiley mill with an 1mm screen and stored for later analyses. Rumen fluid was taken at 6 hours after feeding through the cannula to measure ruminal pH, concentrations of $NH_3$-N and volatile fatty acids (VFA).

**Table 1.** Ingredient and chemical composition of the experimental grower rations diets for growing sheep and bulls

| Item | Levels of concentrate (%) | | | |
|---|---|---|---|---|
| | 35 | 50 | 65 | 80 |
| Ingredient (%) | | | | |
| Rice straw | 45.5 | 35 | 24.5 | 14 |
| Orchardgrass hay | 19.5 | 15 | 10.5 | 6 |
| Corn | 5 | 5 | 10 | 10 |
| Wheat | 6 | 10 | 19 | 25 |
| Molasses | 4 | 3 | 3 | 3 |
| Soybean meal | 18 | 12.6 | 8.8 | 5 |
| Perilla meal | – | – | 2 | 2 |
| Wheat bran | – | 12.4 | 13 | 25.6 |
| Corn gluten | – | 5 | 7 | 7 |
| Rice bran | 0.37 | 0.37 | 0.37 | 0.37 |
| $CaCO_3$ | 0.5 | 1.1 | 1.3 | 1.5 |
| Tricalcium phosphate | 0.6 | – | – | – |
| Salt | 0.4 | 0.4 | 0.4 | 0.4 |
| Vit. Min. mixture[1] | 0.16 | 0.16 | 0.16 | 0.16 |
| $K_2SO_4$ | 0.1 | 0.1 | 0.1 | 0.1 |
| Chemical composition (%) | | | | |
| Crude protein | 13.68 | 13.56 | 13.88 | 13.18 |
| Ether extract | 1.58 | 2.26 | 2.42 | 2.59 |
| Neutral detergent fiber | 44.86 | 41.94 | 36.48 | 35.10 |
| Acid detergent fiber | 28.38 | 24.17 | 21.04 | 16.05 |
| Calcium | 2.53 | 0.98 | 1.20 | 0.89 |
| Phosphorus | 0.40 | 0.36 | 0.37 | 0.43 |

[1] Composition (per kg): Vit. A, 4,000,000 IU; Vit. D, 3,800,000 IU; Vit. E, 4,000,000 IU; Mn, 8,000mg; Cu, 4,000mg; Fe, 4,000mg, I, 200mg; Se, 80mg; Zn, 8,000mg; Co, 160mg; Antioxidant, 2,000mg.

**Table 2.** Ingredient and chemical composition of the experimental finisher rations for growing sheep and bulls

| Items | Levels of concentrate (%) | | | |
|---|---|---|---|---|
| | 35 | 50 | 65 | 80 |
| Ingredients (%) | | | | |
| Rice straw | 45.5 | 35 | 24.5 | 14 |
| Orchardgrass hay | 19.5 | 15 | 10.5 | 6 |
| Corn | 5 | 7 | 17 | 25 |
| Wheat | 12 | 26 | 26 | 30 |
| Molasses | 3 | 3 | 3 | 3 |
| Soybean meal | 3 | – | – | – |
| Rapeseed meal | 1.6 | 2 | – | 1 |
| Sunflower meal | – | 2 | 2 | 1.8 |
| Wheat bran | – | 2.6 | 8.6 | 10.6 |
| Corn gluten | – | 5 | 6 | 6 |
| Rice bran | 0.37 | 0.17 | 0.17 | 0.47 |
| $CaCO_3$ | – | 0.4 | 0.9 | 1.2 |
| Tricalcium phosphate | 0.7 | 0.5 | 0.1 | – |
| Salt | 0.6 | 0.6 | 0.6 | 0.6 |
| Urea | 0.6 | 0.6 | 0.5 | 0.2 |
| Vit. Min. mixture[1] | 0.16 | 0.16 | 0.16 | 0.16 |
| $K_2SO_4$ | 0.1 | 0.1 | 0.1 | 0.1 |
| Chemical composition (%) | | | | |
| Crude protein | 11.67 | 11.42 | 11.76 | 11.81 |
| Ether extract | 2.09 | 2.59 | 2.65 | 2.59 |
| Neutral detergent fiber | 51.93 | 44.93 | 38.15 | 34.86 |
| Acid detergent fiber | 30.94 | 28.55 | 19.16 | 15.54 |
| Calcium | 1.28 | 1.15 | 1.59 | 1.66 |
| Phosphorous | 0.52 | 0.35 | 0.41 | 0.45 |

[1] Composition (per kg): Vit. A, 4,000,000 IU; Vit. D, 3,800,000 IU; Vit. E, 4,000,000 IU; Mn, 8,000mg; Cu, 4,000mg;Fe, 4,000mg, I, 200mg; Se, 80mg; Zn, 8,000mg; Co, 160mg; Antioxidant, 2,000mg.

### *In sacco* disappearance rate

Nylon bag technique was used to determine the DM and N disapperance from the rumen of 12 rumen-cannulated sheep weighting an average of 60 kg. Each complete ration was ground using a 2mm screen and samples of approximately 5g were weighed into the nylon bags. Nylon bags (6 × 10cm) were prepared according to Crawford et al. (1978) with nylon cloth of an average

pore size of 49 $\mu$m. Bags were suspended in the ventral sac of rumen and attached to the cannula with about 30cm nylon string. They were removed after 6 and 12 hr incubation and rinsed with running tap water until the water became clear, then dried at 65℃ for 48 hours and DM and N contents were determined. Disappearance of DM and N from nylon bags was expressed as aproportion of dietary DM or N introduced initially in the bags.

### Feeding trial

Rice straw and orchardgrass hay were ground through a 7mm screen. Four different complete rations containing concentrate to roughage ratio of 35:65, 50:50, 65:35 and 80:20 were pelleted with a commercial pellet machine. The roughages used were rice straw (70%) and orchardgrass hay (30%). The diameter of pellets was 7mm and the hardness of pellet decreased with increasing concentrate levels in complete rations. All the rations were formulated to contain isolevels of CP, Ca and P (tables 1 and 2). The average levels of CP in grower (first 10 weeks) and finisher (last 6 weeks) rations were 13.5% and 11.5%, respectively.

Twenty Korean native bulls weighing about 155 kg were used in complete randomized design with 4 treatments and 5 replications to determine effects of concentrate to roughage ratio of pelleted complete rations on growth performance. All animals were housed in a barn, fed *ad libitum*, with free access to water and with a minimum of 2hr of daily exercise throughout the experimental period of 16 weeks. Intakes were recorded daily and representative feed samples were taken weekly for later analyses. Initial and final body weights were measured after fasting for 12 hours. Body weights were measured at weekly-intervals during the entire experimental period.

### Sample analyses

Proximate chemical composition of feed and feces was determined by procedure of AOAC (1984). Cell wall constituents, NDF, ADF, cellulose and lignin, were analyzed according to Goering and Van Soest (1970).

Rumen samples were immediately strained through four layers of cheese cloth and pH was measured. VFA in rumen fluid were analyzed by gas chromatography according to Erwin et al. (1963). In brief, a 5ml aliquot of the filtrate was acidified with 1ml of 25% metaphosphoric acid and centrifuged at 3,000 rpm for 10 min. The supernatant was decanted and analyzed for VFA by gas liquid chromatography (Packard 439-GLC) using 10% SP−1, 200/1% phosphoric acid on 80/100 mesh chromosorb (Supelco, Inc., Bellefonte, PA).

Ruminal ammonia was analyzed according to Chaney and Marbach (1962). In brief, a 12ml aliquot of the filtrate was centrfuged at 475 xg for 15 min. The supernatant was decanted and mixed with phenol color reagent and alkali-hypochlorite reagent. The optical density was measured by using spectrophotometer at 530nm.

### Statistical analyses

Date were examined by analysis of variances with treatment sums of squares partitioned to test for linear, quadratic and cubic effects due to levels of concentrate supplementation (Steel and Torrie, 1980).

## RESULTS AND DISCUSSION

### Digestion trial

Nutrient digestibilities of the experimental rations for lambs are given in table 3. Digestibilities of dry matter (DM), crude protein (CP) and ether extract (EE) increased with enhancing levels of concentrates in the rations ($p < .01$). This result may be explained by the fact that concentrates are usually more digestible than roughages. The previous reports have also indicated that digestibilities of DM (EL Hag and Greenhalgh, 1982) and CP (Colucci et al., 1982) increased with levels of concentrates in the rations.

**Table 3.** Effects of different levels of concentrate in complete rations on nutrient digestibilities (%; Means ± SEM) in sheep

| Concentrate (%) | DM[1] | CP[2] | EE[3] | NDF | ADF |
|---|---|---|---|---|---|
| 35 | 53 ± 1.7 | 68 ± 2.1 | 66 ± 3.5 | 39 ± 4.8 | 32 ± 4.3 |
| 50 | 60 ± 2.4 | 73 ± 1.9 | 71 ± 0.4 | 40 ± 5.0 | 32 ± 4.8 |
| 65 | 69 ± 1.3 | 76 ± 0.8 | 75 ± 1.0 | 39 ± 2.4 | 30 ± 2.1 |
| 80 | 73 ± 1.3 | 76 ± 2.2 | 80 ± 0.8 | 39 ± 2.9 | 31 ± 3.4 |

[1] $Y = 0.459X + 37.28$ ($R^2 = 0.94$, $p < 0.01$).
[2] $Y = 0.180X + 62.83$ ($R^2 = 0.72$, $p < 0.01$).
[3] $Y = 0.296X + 56.24$ ($R^2 = 0.88$, $p < 0.01$).

However, levels of concentrates did not influence the digestibilities of NDF and ADF of the complete rations. This tendency is somewhat different from the previous reports of Uden (1984) and Goetsch and Owens (1982) who reported that NDF and ADF digestibility decreased with increasing levels of concentrates in the rations of beef steers. Howere, Colucci et al. (1982) reported that ADF digestibility of high concentrate rations (68%) was higher than that of low concentrate rations (17%) for dry cows, although NDF digestibility was opposite. In addition, Reynold et al. (1991) showed that digestibility of both the NDF and ADF was greater for heifers fed 75% concentrate rations than those fed 75% alfalfa rations. Thus, it is considered that fiber digestibility does not always decrease by increasing levels of concentrate in the rations.

Ruminal fluid measurements on pH, concentrations of $NH_3$-N and VFA are presented in table 4. The tendency in the concentrations of VFA influenced by feeding was opposite to pH change. Ruminal pH in this study decrased with increasing concentrate levels in the rations from 35% to 65%, which was the similar result to those of Hernandz-Urdneta et al. (1976) who reported that ruminal pH went down with increased levels of concentrate in the rations, concurrently with enhanced production of VFA. However, our results showed that measures of ruminal pH were similar in sheep fed complete rations containing 65% or 80% concentrate. Even though decrease in ruminal pH due to increasing levels of concentrate in the rations might cause the depression of fiber digestibility, resulting from the reduced celluloytic activity (Robinson et al., 1986), the result of the present study indicated that fiber digestibility was similar in sheep fed the rations containing either high or low levels of concentrate. This result may be supported by the previous reports, in which Mackie et al. (1978) observed that numbers of cellulolytic bacteria remained constant regardless of concentrate to roughage ratio in the rations, and Leedle et al. (1982) reported that no change in numbers of cellulolytic bacteria in the rumen over a range of concentrate levels fed.

Ruminal ammonia concentration increased linearly ($p < 0.05$) at 6 hr after feeding with increasing levels of concentrate from 35% to 80%, suggesting that the dietary proteins in the rations containing high levels (65% and 80%) of concentrate were more degraded into ammonia, which was confirmed by the following *in sacco* experiment (table 5). This result was in agreement with the report of Krohn et al. (1983) who observed increased concentration of ruminal ammonia due to higher concentrate levels in the rations.

The levels of concentrate in complete rations did not influence ruminal concentratinos of acetic and butyric acid. However, the change in concentrations of propionate and total VFA in response to concentrate levels was quadratic ($p < 0.05$). This result may be confirmed by the previous study (Bauman et al., 1971), which indicated that concentrate level did not affect acetic acid production, but that higher concentrate in the rations boosted propionate and total VFA production. And also, the same tendency in VFA concentrations by high levels of concentrate has been reported by Robinson (1986).

Consequently, the result of this study indicated that the increased concentration of total VFA for sheep fed the high-concentrate ration was the result of an increase in propionate production rather than a decrease in acetate production. This shift toward more ruminal propionate production may have resulted in the improvement of growth performance in growing ruminants since propionate is more effciently utilized by host animals, possibly due to the fact that it has a lower heat increment than acetate and butyrate (Blaxter and Wainman, 1964).

**Table 4.** Effects of different levels of concentrate in complete rations on ruminal pH and concentrations (Means ± SEM) of ruminal pH, $NH_3$-N and VFA at 6hr postfeeding in sheep

| Concentrate (%) | pH[1] | $NH_3$-N[2] (mg/100ml) | $C_2$ | $C_3$[3] | $C_4$ | Total VFA[4] |
|---|---|---|---|---|---|---|
| | | | ..... mM/L ..... | | | |
| 35 | 6.43 ± 0.17 | 14.5 ± 0.10 | 42.9 ± 3.33 | 22.9 ± 3.35 | 14.7 ± 2.29 | 81.9 ± 8.89 |
| 50 | 6.17 ± 0.12 | 15.2 ± 2.93 | 46.3 ± 0.97 | 22.9 ± 2.81 | 20.5 ± 2.34 | 90.9 ± 4.60 |
| 65 | 5.71 ± 0.09 | 22.7 ± 0.10 | 43.3 ± 1.10 | 42.4 ± 6.12 | 23.5 ± 1.79 | 114.0 ± 5.16 |
| 80 | 5.75 ± 0.10 | 24.9 ± 3.61 | 44.7 ± 2.10 | 37.6 ± 1.92 | 14.6 ± 2.68 | 99.6 ± 3.54 |

[1] $Y = -0.017X + 6.97$ ($R^2 = 0.81$, $p < 0.01$).
[2] $Y = 0.258X + 4.50$ ($R^2 = 0.77$, $p < 0.05$).
[3] $Y = -0.0052X^2 + 1.027X - 8.774$ ($R^2 = 0.49$, $p < 0.05$).
[4] $Y = -0.026X^2 + 3.497X - 11.216$ ($R^2 = 0.51$, $P < 0.05$).

**Table 5.** Effects of different levels of concentrate in complete rations on disappearance rates (%; Means ± SEM) of dry matter (DM) and nitrogen (N) using the nylon bag technique at two different time points (6 and 12hr) in sheep

| Concentrate (%) | DM | | N | |
|---|---|---|---|---|
| | 6hr[1] | 12hr[2] | 6hr[3] | 12hr[4] |
| 35 | 47.3 ± 0.32 | 56.3 ± 2.14 | 56.3 ± 0.27 | 71.3 ± 1.40 |
| 50 | 50.9 ± 1.14 | 55.4 ± 0.53 | 59.5 ± 0.94 | 68.5 ± 0.37 |
| 65 | 59.7 ± 0.74 | 63.1 ± 0.24 | 71.8 ± 0.52 | 75.9 ± 0.15 |
| 80 | 66.1 ± 1.35 | 72.8 ± 1.35 | 71.9 ± 1.24 | 81.5 ± 0.92 |

[1] $Y = 0.435X + 30.98$ ($R^2 = 0.97$, $p < 0.01$).
[2] $Y = 0.383X + 39.87$ ($R^2 = 0.89$, $p < 0.01$).
[3] $Y = 0.394X + 42.23$ ($R^2 = 0.92$, $p < 0.01$).
[4] $Y = 0.255X + 59.64$ ($R^2 = 0.84$, $p < 0.01$).

### *In sacco* DM and N disappearance

DM and N disappearance rates estimated by the *in sacco* nylon bag technique are presented in table 5. DM disappearance was linearly increased ($p < 0.01$) as concentrate levels in the rations increased. Results from 6 hr incubation was similar with those from 12hr incubation. N disappearance was also linearly increased ($p < 0.01$) as concentrate levels in the rations increased.

Therefore, the results suggested that the enhanced *in sacco* degradability of DM and N with increasing levels of concentrate in the rations resulted in the increase of total tract digestibility of both nutrients, which is presumably leading to elevating bioavailability of nutrients from the rations to the animal.

### Feeding trial

Results of feeding trial with Korean native bulls are shown in table 6. Daily body wight gains of the bulls receiving the complete rations containing 35, 50, 65, and 80% concentrate were 0.89, 0.98, 1.06, and 1.21 kg/d, respectively, which was linear response ($p < 0.01$) to concentrate levels in the complete rations. Improved digestibility of DM, CP and EE (table 3) and higher propionate production due to increased levels of concentrate in the rations (table 4) are the causative factors toward improved growth rate of the bulls.

**Table 6.** Effects of different levels of concentrate in complete rations on complete rations on growth performance (Means ± SEM) in Korean native bulls

| Concentrate (%) | Initial body weight (kg) | Final body weight (kg) | Weight gain (kg) | Gain (kg/d)[1] | Intake (kg/d) | Intake/gain[2] |
|---|---|---|---|---|---|---|
| 35 | 157.8 ± 5.65 | 258.0 ± 9.30 | 100.2 ± 4.32 | 0.89 ± 0.04 | 6.17 ± 0.30 | 6.91 ± 0.29 |
| 50 | 154.4 ± 6.56 | 264.6 ± 11.64 | 110.2 ± 6.06 | 0.98 ± 0.06 | 6.20 ± 0.34 | 6.32 ± 0.13 |
| 65 | 153.4 ± 6.68 | 272.0 ± 10.67 | 118.6 ± 5.39 | 1.06 ± 0.05 | 5.79 ± 0.20 | 5.48 ± 1.10 |
| 80 | 154.8 ± 5.24 | 289.8 ± 9.74 | 135.0 ± 7.14 | 1.21 ± 0.06 | 5.84 ± 0.36 | 4.84 ± 0.78 |

[1] $Y = 0.618X + 0.644$ ($R^2 = 0.73$, $p < 0.01$).
[2] $Y = -0.74X + 7.644$ ($R^2 = 0.92$, $p < 0.05$).

In the present study, ruminal propionate concentration of sheep fed complete rations containing 65 and 80% concentrate was similar, but daily weight gains of Korean native bulls fed complete rations with 80% concentrate were significantly higher ($p < 0.05$) than those with 65% concentrate. This result suggested that increased production of propionate due to elevated levels of concentrate in the rations is not the only positive factor for growth performance in Korean native bulls.

The major limiting factors associated with the use of low quality roughage including rice straw as a feed for ruminant animals are low nutrient content and poor digestibility, resulting in low nutrient intake and subsequently reduced animal performance (Jackson, 1977). However, the present study showed that daily feed intake of complete containing 45.5 or 35% rice straw by Korean native bulls was higher than those containing 24.5 or 14% rice straw (table 6). This may be explained by the facts that grinding and pelleting of the diets accelerated the passage of roughage through the gut, and that increase in flow maintained intake of complete rations including rice straw (Bines, 1976). Therefore, the present results also

suggested that supplementation with processed roughage in complete rations can overcome the low intake of low quality roughage, to a certain degree.

Daily feed intake increased with increasing levels of concentrate in previously reported studies (Macleod et al., 1983 ; Bull et al., 1976), whereas in other study there was no significant increase in DM intake (Emery et al., 1969). In the present study, the influence on daily feed intake by dietary concentrate level was marginal, although intake declined with increased concentrate levels. Percentage of TDN of complete rations with concentrate levels 35, 50, 65 and 80% was 53, 58, 63 and 68%, respectively. Thus, it is obvious that the bulls fed high concentrate rations consumed more energy than those fed low concentrate rations.

In overall conclusion, the results of the present study showed that increasing concentrate level upto 80% in the complete rations containing rice straw as roughage source improved growth performance of Korean native bulls, possibly resulting from the improved nutrient digestibility, the increased production of propionate, and higher energy availability. In addition, we can not rule out the possibility of the efficient engrgy utilization in the high concentrate rations since Reynold et al. (1991) observed that heifers fed 75% concentrate ration produced less heat energy and retained more tissue energy than when fed 75% alfalfa ration. Therefore, there is benefit in incorporating high levels of concentrate into complete rations for Korean native bulls.

## REFERENCES


Association of Official Agriculture Chemists. 1984. Official Methods of Analysis (14th edn.). Washington, DC.

Bauman, D. E., C. L. Davis, and H. F. Bucholtz. 1971. Propionate production in the rumen of cow fed either control or high-grain, low-fiber diet. J. Dairy Sci. 54:1282-1287.

Bines, J. A. 1976. Regulation of food intake in dairy cows in relation to milk production. Livest. Prod. Sci. 3:115-128.

Blaxter, K. L. and F. W. Wainman. 1964. The utilization of the energy of different rations by sheep and cattle for maintenance and fattening. J. Agri. Sci. (Camb,) 63:113-121.

Bull, L. S., B. R. Baumgardt and M. Clancy. 1976. Influence of caloric density on energy intake by dairy cows. J. Dairy Sci. 59:1078-1086.

Chaney, A. L. and E. P. Marbach. 1962. Modified reagents for determination or urea and ammonia. Clin. Chem. 8:130-139.

Colucci, P. E., L. E. Chase and P. J. Van Soest. 1982. Feed intake, apparent digestibility and rate of particulate passge in dairy cattle. J. Dairy Sci. 65:1445-1456.

Crawford, R. J., Jr. W. H. Hoover, C. J. Sniffen. and B. A. Crooker. 1978. Degradation of feedstuff nitrogen in the rumen vs nitrogen solubility in three solvent. J. Anim. Sci. 46:1768-1779.

EL Hag, H. M. A. and J. F. D. Greednalgh. 1982. Intake and digestibility in sheep fed on alkali treated straw and concentrates as complete diets of separate feeds. Anim. Feed Sci. Technol. 7:271-276.

Emery, R. S., H. D. Hafs, D Armstrong and W. W. Snyder. 1969. Prepartum grain feeding Effects on milk production, mammary edema and incidence of diseases. J. Dairy Sci. 52:345-351.

Erwin, E. S., G. J. Marcro and F. M. Emery. 1963. Volatile fatty acid analysis of blood rumen fluid by gas chromatography. J. Dairy Sci. 44:1768-1776.

Goering, H. K. and P. J. Van Soest. 1970. Forage fiber analyses. U. S. D. A., A. R. S. Agric. Handbook, No. 379.

Goetsch, A. L. and F. N. Owens. 1985. Effects of level and diurnal variation digetary concentrate on digestion and passage rate in beef steers. Livest. Proc. 13:267-277.

Hernandez-Urdaneta, A., C. E. Coppock, R. E. McDowell, D. Gianola and N. E. Smith. 1976. Change in forage-concentrate ratio of complete feeds for dairy cows. J. Dairy Sci. 59-695-707.

Jackson, M. G. 1977. Review article: the alkali treatment of straws. Anim. Feed Sci. Technol. 2:105-130.

Krohn, C. C., T. Hvelplund, and P. E. Anderson. 1983. The effect on performance of different energy concentrations in complete rations for first lactation cows before and after calving. Livest. Prod. Sci. 10:223-237.

Leedle, J. A. Z., M. P. Bryant and R. B. Hespell. 1982. Diurnal variations in bacterial numbers and fluid parameters in ruminal contents of animals fed low-or high-forage diets. Appl. Environ Microbiol. 44:402-412.

Mackie, R. I., F. M. C. Gilchrist, A. M. Roberts, P. E. Hannah and H. M. Schwartz. 1978. Microbiological and chemical changes in the rumen during the step-wise rumen adaptation of sheep to high concentrate diets. J. Agr. Sci. (Camb.) 90:241-254.

Macleod, G. K., D. G. Grieve and I. McMillan. 1983. Performance of first lactation dairy cows fed complete rations of several ratios of forage to concentrate. J. Dariy Sci. 66:1668-1674.

Murphy, T. A, S. C. Loerch and F. E. Smith. 1994. Effects of feeding high concentrate diets at restricted intakes on digestibility and nitrogen metabolism in growing lambs. J. Anim. Sci. 72:1583-1592.

Preston, T. R. and R. A. Leng. 1984. Supplementation of diets based on fibrous residues and byproducts. In: F. Sundstol and E. Owen (Editors), Straw and other Fibrous By-products as feed. Elsevier, Amsterdam, pp. 373-413.

Reynold, C. K., H. F. Tyrell and P. J. Reynold. 1991. Effects of diet forage-to-concentrate ratio and intake on energy emtabolism in growing beef heifers: whole body energy and nitrogen balance and visceral heat production. J. Nutr. 121:994-1003.

Robinson, P. H., S. Tamminga. and A. M. Van vuuren. 1986. Influence of declining level of feed intake and varying the proportion of starch in the concentrate on rumen fermentation in dairy cows. Livest Prod. Sci. 15:249-271.

Sip, M. L. and R. H. Pritchard. 1991. Nitrogen utilization by ruminants during restricted intake of high-concentrate diets. J. Dairy Sci. 69:2655-2662.

Steel, R. G. D. and J. H. Torrie. 1980. Principles and Procedures of Statistics. 2nd edn. McGraw-Hill, New York, pp. 88-156.

Tremere, A. W., W. G. Merrill and J. K. Lossli. 1968. Adaptation to high-concentrate feeding as elated to acidosis and digestive disturbances in dairy heifers. J. Diary Sci. 51:1065-1072.

Uden, P. 1984. The effect of intake and hay: concentrate ratio upon digestibility and digesta passage. Anim. Feed Sci. Technol. 11:167-179.

Walker, C. K. and J. M. Elliot. 1969. Effect on early lactation of feeding a milk fat-depressing ration prepartum. J. Dairy Sci. 52:1582-1587.