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Evaluation of Low-quality Forages in a Winter Dietary Regimen of Western White-Face Ewes Used for Milk Production

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EVALUATION OF LOW-QUALITY FORAGES IN A WINTER DIETARY REGIMEN OF WESTERN WHITE-FACE EWES USED FOR MILK PRODUCTION

by

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Abstract

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by

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The evaluation of ammoniation of mature grass (1/3 Festuca sp, 1/3 Bromus sp, and 1/3 Dactylis sp) as a basal diet for pregnant ewes and its effects on ruminal fermentation were studied. Ammoniation increased the forage dry matter intake (DMI), crude protein (CP), and gross energy digestibility. Ruminal pH and total volatile fatty acid were not affected by ammoniation ($P > .05$). Individual VFA concentrations were affected significantly.

In a third experiment, ammoniated wheat straw was evaluated as a basal diet for wintering pregnant ewes. Ammoniated straw replaced grass hay in the diet. Dry matter intake was not different ($P > .05$). Final body weight, total gain, and fleece weight were higher for controls ($P < .05$). Lamb birth weight was not affected by forage type ($P > .05$).

A fourth experiment evaluated how rehydrating wheat

straws prior to ammoniation affected utilization by pregnant western white-face ewes. These treatments increased dry matter and crude protein intakes significantly ($P < .01$), and also improved body weight ($P < .05$). Lamb birth weight was not affected by treatment ($P = .874$) and fleece weight was increased ($P < .05$).

Nutritive value of 5 barley and 10 wheat straw varieties was evaluated for ruminants with the in situ technique. Fiesta and Kombar barley varieties exhibited the highest dry matter disappearance ($P < .05$). Malcom, Manning, Ute, and 1549-19 wheat varieties exhibited the highest dry matter disappearance ($P < .05$). These varieties were Dwarf type and presented higher nutrient availability for ruminants.

In a final study, nitrogen and energy balance was measured on lactating western white-face ewes during early and late lactation. Milk Production was .683 and .711 L/d during early and late lactation. Efficiency of milk production was .429 and .338 milk L/kg DM consumed for early and late lactation, respectively. Nitrogen balance was positive during both stages of lactation. Milk gross energy and metabolizable energy were 15.14 and 14.16% for early and late lactation, respectively.

(126 pages)

To
Raúl Ignacio
Pablo
Felipe

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CHAPTER I

INTRODUCTION

In general there is agreement in most countries of the world that the sheep industry is in crisis. Data from international agencies show that consumption per capita of red meat is decreasing. This is especially true for meats of sheep origin. These meats have been replaced by poultry and fish (Ahrens, 1979; Taylor, 1984).

The causes for the decreased consumption of red meat are not well defined because several complex factors are involved in this situation. One of the most important factors is that the general population is more conscious about health problems associated with diet (Hegarty, 1979). For example, it is fairly well known that in some people consumption of the saturated fatty acids associated with red meats will increase the blood level of low density lipoproteins, which is associated with heart disease. Price is another major factor, with poultry being less expensive than beef or lamb. Modern life-styles have also demanded more convenient ready-to-eat meats, which are more prevalent using fish, poultry, and pork compared to lamb or beef.

The situation for wool is no better. Although wool's characteristics are not easily imitated, the low price of synthetic fiber has decreased the demand, and therefore price, for wool. This was demonstrated during the petroleum crisis in the late 70's, when wool regained some of its position in the market (Ryder, 1984). Importation of cheaper wool from New

Zealand and Australia has also depressed the market for locally produced wool.

In addition to international factors, conditions specific to certain geographic areas have caused local crisess. The sheep producers of the western U.S.A. depend heavily on grazing public lands. Limitation on the grazing of these lands is due to new land-use priorities, and resultant changes in federal and state policies. Historically, sheep producers have depended on public lands for both summer and winter range. As public policy curtails the use of these lands for livestock grazing, sheep producers will be required to utilize privately owned lands (i.e., pastures, meadows, and crop residue), if they are going to survive.

Although the last 10 to 20 years have been marked by a great advance in technology for production from animal species, the sheep industry did not display the same level of improvement. Efficiency of production, level of production, and marketing were not improved proportionately to other livestock industries (Kruesi, 1985). This has not been due to lack of technology development, but rather to lack of technology transfer and adaptation. Several innovative technologies have been developed, including breeds with higher fecundity, identification of gene pools that provide increased lean tissue production (Callipyge), and systems to allow three lambing periods in 2 years. Perhaps the curtailment of the use

of public lands will either force or allow the use of more of these technologies.

In America, Australia, and New Zealand, the sheep industries is known for the production of meat and wool, but for centuries, the Mediterranean and Middle Eastern countries have been well known for the production of sheep milk and quality products derived from it (Hatziminaoglu, 1991). Production of sheep milk may be an alternative for some sheep/wool producers in the USA. Substantial amounts of sheep milk and sheep milk products are now being imported into the USA. If a sheep/wool producer were to consider the production of sheep milk, several questions would likely arise: would the western white-face ewes now in use efficiently produce adequate quantities of milk to maintain viability, and would these ewes adapt to a parlor milking? Brindley (1995) reported that most western white-face ewes would adapt to parlor milking and produce moderate amounts of milk. This study, however, did not determine the efficiency with which these ewes convert consumed nutrients to milk.

The purpose of the following studies was therefore two-fold: 1) to develop economic nutritional systems for ewes during the winter (dry period), which is of paramount importance for producers facing curtailment of winter range use; 2) to measure efficiency of nutrients utilization for milk production in western white-face ewes. Evaluation of

nutrition systems for the winter period emphasized the use of ammoniated cereal straw and mature grasses, along with variation among a variety of these crops now available. Efficiency of milk production involved balance studies with lactating western white-face ewes stationed in metabolism crates where nutrient inputs and outputs in the feces, urine, and milk were precisely measured.

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CHAPTER II

NUTRIENT VALUE OF HARVESTED AND AMMONIATED STANDING MATURE GRASS REMAINING AFTER MODERATE GRAZING BY SHEEP

Abstract

Impending curtailment of public land grazing may force increased utilization of irrigated pastures and meadows for sheep production. Selective grazing habits of sheep result in pastures prematurely advancing toward maturity. Clipping is often used to return the pasture to vegetative growth. The purpose of this study was to measure nutrient utilization of this mature biomass after harvesting and ammoniation. A 2.83-ha irrigated pasture composed of 1/3 Festuca arundinacea, 1/3 Bromus inermis, and 1/3 Dactylis glomerata was grazed by 75 ewes with lambs from May 15 through June 30. Standing biomass was then harvested and baled, yielding 1445 kg of dry matter (DM)/ha and every other bale was placed in one of two stacks. Both stacks were enclosed with plastic. One was ammoniated (3% of DM). After 42 d of ammonia treatment, bales were uncovered and coarsely ground. Six ewes (40 kg) housed in metabolism crates were supplemented with 106 g of alfalfa pellets and 54 g rolled barley and allowed ad libitum access to one of the two forages in a single reversal design. Ammoniation increased DM intake by 29% (773 g vs 598 g/d, $P < .01$). Digestibility of the forage was increased by 16% (53.9 vs 46.3) due to ammoniation ($P < .01$). As a result, ammoniation resulted in a

52% increase in digestible DM intake (420 vs 280 g/d, $P < .01$). Digestibility of crude protein (CP) and gross energy (GE) were also increased by ammoniation ($P < .01$). Ewes consuming treated biomass retained 10.4 g of nitrogen/d, while those consuming untreated forage retained 3.8 g/d ($P < .01$). This practice could improve pasture and winter forage for sheep.

Introduction

Phenologically mature forage plants yield relatively low digestible DM intake in ruminant animals due to high cell-wall content, lignification of the cell walls, and low nitrogen content (Minson, 1982).

Numerous chemical treatments have been used to improve digestibility and(or) intake of mature, low-quality forages. Anhydrous ammonia, sodium hydroxide, and calcium hydroxide have been used (Kernan et al., 1979; Lesoing et al., 1981). The chemical treatment used is presumed to act by breaking the covalent bonding between lignin and cell wall polysaccharides. This process improves the accessibility of these carbohydrates to ruminal microbial attack (Guggolz et al., 1971; Brice and Morrison, 1982; Buettner et al., 1982).

In addition to improving digestibility, chemical compounds like anhydrous ammonia have been used to improve the crude protein concentration of high-energy silages (Lomas et

al., 1982) and to preserve high-moisture hay by inhibiting fermentation (Weiss et al., 1982; Thorlacius and Robertson, 1984).

Although there have been relatively few studies regarding chemical treatment of mature grasses, positive results have been reported. Anhydrous ammonia treatment of Festuca arundinacea increased the total nitrogen. Approximately 55% of the nitrogen added during ammoniation was present after aeration at the end of the storage. Neutral detergent fiber and hemicellulose were decreased by ammoniation. Digestion coefficients for DM, NDF, ADF, cellulose, and hemicellulose were increased. Ad libitum intake of the ammoniated hay by sheep and heifers was increased (Buettner et al., 1982). Ammoniation of a grass mixture (Agrostis stolonifera, Lolium perenne, Poa spp and Alopecurus geniculatus) also increased digestibility of DM, organic matter, hemicellulose, cellulose, and nitrogen, and improved animal performance (Wylie and Steen, 1988).

Selective grazing by sheep allows pasture grass to rapidly advance to the phenological stage of seed production. This lowers nutrient availability. Mechanically clipping this material to restore vegetative growth results in the loss of feed resources. Ammonia treatment of this low-quality material may enhance its use by sheep during periods of limited resources, such as drought or for winter feed. This process

would increase the efficiency of resource use. The objective of this study was to determine the nutrient utilization of the forage produced under such a system.

Materials and Methods

Experiment 1

Seventy-five St. Croix ewes (52 Kg) with their lambs were allowed to graze a 2.83-ha irrigated, mixed-grass pasture from May 15 through June 30. The grass mixture consisted of 1/3 Festuca arundinacea, 1/3 Bromus inermis, and 1/3 Dactylis glomerata. Following the grazing period, standing biomass was mechanically harvested and baled (small rectangular) after air-drying. Bales were placed in two stacks on an every other bale basis (80 bales/stack). Stacks were separately enclosed with 6 mil black polyethylene. Anhydrous ammonia was applied to one stack at 3% of DM. Both stacks remained enclosed for 42 days at an average ambient temperature of 18° C. Polyethylene was then removed from the sides of the stacks to allow aeration. After aeration, 20 bales were removed from each stack. The stacks were five bales high, and four bales were removed from each level. Bales from treated and untreated stacks were separately ground and mixed in a grinder-mixer feed wagon and then stored in a shed until used.

Treated and untreated forages were fed to six yearling St. Croix ewe lambs (40 Kg) in a single reversal design. Ewe

lambs were housed in elevated metabolism crates designed for total collection and separation of feces and urine. Crates were maintained in a room with automated temperature, ventilation, and day-length control. Feeding times were 0700 and 1700 h daily. Ewe lambs received 106 g of alfalfa pellets and 54 g rolled barley per day as a supplement. The supplement was fortified with vitamins and minerals to meet NRC (1985) recommendations. The remainder of the diet was the respective forage treatment, fed on an ad libitum basis. Lambs were fed experimental diets for a 15-d adaptation period followed by a 5-d collection period. Nutrient composition of the experimental forages is presented in Table 1.

Measurements taken during the collection period were forage and water intake, and fecal and urine output. Diet sampling began one day prior to the beginning of fecal collections and proceeded for a 5-d period, two times a day. (am and pm). Fecal collections were weighed, mixed, and subsampled (approximately 10%). Subsamples were placed in a forced-air oven at 60° C for 72 h to determine DM content. Diets and Fecal samples were ground to pass a 1-mm screen, and then composited by day. Diets and fecal samples were analyzed for DM (105° C for 8 h), CP (Hach et al., 1985), ADF and NDF (filter bag system, Komarek, 1993), ADL (Van Soest, 1982), ash (AOAC, 1990), GE (AOAC, 1990), and ether extract (EE) (AOAC, 1990). Hemicellulose (Hc) was calculated by difference of NDF

Table 1. Nutrient composition of mature grasses treated with anhydrous ammonia, DM basis

Item	Control	Treatment	SEM[a]
Dry matter, %	91.34	89.15**	.34
Crude protein, %	5.30	13.85**	.32
Gross energy, Kcal/g	4107	4157[b]	12.4
Neutral detergent fiber, %	65.93	62.37**	.43
Acid detergent fiber, %	46.43	47.49[NS]	.37
Hemicellulose, %	19.51	14.88**	.36
Cellulose, %	34.46	38.90**	.89
Acid detergent lignin, %	8.40	8.01[b]	.38
Ether extract, %	1.53	1.36**	.05

[a]Standard error of mean.
[b]Not significantly different, ($P > .05$).
* Significantly different, ($P < .05$)
** Significantly different, ($P < .01$).

and ADF. Urine collections were stabilized with a saturated solution of mercuric chloride. Urine volume was measured daily. A 200-ml subsample was frozen at -20° C and subsequently freeze-dried. Dried urine samples were analyzed for DM (105° C for 8 h), CP (Hach et al., 1985), and GE (AOAC, 1990). Metabolizable energy of the diets was estimated by using the GE content of the diet, feces, and urine, with methane production estimated from Swift's equation (1948) utilizing the amount of carbohydrate digested. The digestion coefficients for the total diet and forage were separated using the method of Sauvant and Giger (1989). Table values for

alfalfa pellets and rolled barley were used in the estimates (NRC, 1985).

Experiment 2

Four mature ewes fitted with ruminal cannulas were placed in the metabolism crates and fed the same diets as in experiment 1, using a similar experimental design. Amount of supplement was increased proportional to body weight and respective forages were offered on an ad libitum basis. Daily rations were fed in two equal portions at 0700 and 1700 h. After a 15-d adaptation period, ruminal digesta samples were taken at 0, 2, 4, 6, and 8 h after the 0700 feeding.

Ruminal pH was determined immediately using a pH meter with combination electrode. A 10-mL aliquot of whole digesta was then mixed with 10 mL of 50% formalin solution using a wide-mouth pipette. These samples were used to determine ruminal protozoa concentrations (Dehorty, 1974). The remaining digesta was filtered through eight layers of cheese cloth and the filtrate centrifuged at 20,000 revolution/min for 10 min. Eighteen mL of supernatant was then fixed with 2 mL of 6 N HCL. These samples were used to analyze the concentration of ruminal VFA and ammonia using methods cited by Wiedmeier et al. (1992). A 50-mL aliquot of whole digesta was taken 4 h postfeeding and analyzed for total viable bacteria using the roll-tube method (Hungate, 1966).

Results were analyzed by ANOVA (tables are found in

Appendix A) utilizing the GLM procedure of SAS (1985). The diet analyses were analyzed using as a replication the sample of diet obtained from each of the five collection periods for each treatment. The model for nutrient metabolism data included treatment, period, and treatment x period interaction effects. The model for ruminal fermentation included treatment, period, hour, and treatment x hour interaction effects. Independent variables in both models were treated as discrete effects. Least square means estimated under both models were tested by standard t-test (Steel and Torrie, 1980).

Results and Discussion

Chemical Composition

All the nutritive variables measured were affected by ammoniation ($P < .01$), with the exception of ADF, and lignin content (Table 1). As expected, CP content increased due to the addition of ammonia nitrogen (261%). The proportion of NDF was likely reduced due to solubilization of Hc, which would account for the increased proportion of ADF in the ammoniated forage. Cellulose increased as a consequense of the ammonia effect on the cell wall. Many publications report similar results; others report inconsistencies. Wylie and Steen (1988) reported the same trend as in the present experiment when they added the same proportion of ammonia to a grasses mixture.

Buettner et al. (1982) measured inconsistent values in a similar experiment ammoniating Festuca arundinacea.

Digestion Coefficients

Intake and nutrient digestibilities associated with the forage portion of the diet and the entire diet are presented in Table 2. Water intake was not affected by forage treatment ($P = .64$). Forage DM intake and digestible DM intake were not significantly improved by ammoniation, although both tended to be improved ($P = .21$ and $P = .10$). Digestibility of DM and digestibility of forage structural carbohydrates, both NDF and ADF, increased due to the action of ammonia. Similar results have been reported by Buettner et al. (1982) and Wylie and Steen (1988). The lack of a significant increase in Hc digestibility may have been due to partial solubilization of this heteropolysaccharide by the ammoniation process. This is indicated in Table 1. The solubilized hemicellulose is highly fermentable. Hence, actual Hc digestibility was likely enhanced. As a consequence, it is safe to say that structural carbohydrate digestibility was increased by at least 70% as a result of the ammoniation process.

Ammoniation increased cellulose content of the forage by approximately 13% (Table 1). This is not likely an actual increase in cellulose, rather a change in overall proportion due to the solubilization of hemicellulose. Acid detergent

Table 2. Nutrient intake and utilization of mature grass treated with anhydrous ammonia, DM basis

Item	Control	Ammoniated	SEM[a]
Water intake, L/d	2.26	2.41[b]	.22
Forage digestibility, kg/kg	.46	.54*	.02
Forage digestible dry matter intake, kg/d	.31	.38[NS]	.05
Forage crude protein digestibility, kg/kg	.35	.56**	.02
Forage digestible energy, Mcal/kg	1.60	2.04**	.09
Forage metabolizable energy, Mcal/kg	1.24	1.88[NS]	.02
Forage NDF digestibility, kg/kg	.28	.361**	.02
Forage ADF digestibility, kg/kg	.15	.21**	.01
Forage hemicellulose digestibility, kg/kg	.13	.15[b]	.09
Diet N balance, g/d	3.77	10.35**	.74
Diet cellulose digestibility, kg/kg	.14	.21**	.01
Diet lignin digestibility, kg/kg	.01	.02[b]	.01
Diet ether extract digestibility, kg/kg	8.72	8.23[b]	.48

[a]Standard error of mean.
[b]Not significant (P > .05).
* significantly different (P < .05).
** significantly different (P < .01).

lignin was decreased by approximately 5% as a result of ammoniation. Lignin is negatively correlated with structural carbohydrate utilization due to covalent bonding with these

polysaccharides, which inhibits microbial fermentation. Bonding is usually more prevalent with hemicellulose rather than cellulose. Since hemicellulose is partially solubilized by ammoniation, it is not surprising that there is some loss of lignin. The solubilization of lignin and disruption of covalent bonding between it and hemicellulose are the major factors responsible for improved structural carbohydrate utilization. As a result of increased structural carbohydrate digestibility, DE was increased by approximately 27% ($P < .05$). Associated with these explanations, ammoniation of the mature grass only tended to increase the ME content by 52% ($P = .067$). It is possible that the lack of effect on ME was due to the level of error (C.V. = 33.6%).

Digestible CP of the forage was increased by ammoniation ($P = .001$). That fact, coupled with a significant improvement in nitrogen balance ($P = .0002$), indicated that non-protein nitrogen associated with ammoniation of forage was being efficiently converted to microbial protein. Assuming that the difference in nitrogen balance is due to ammoniation, the efficiency of nitrogen retention was 42.8% and 29.7% of the daily nitrogen consumption for treatment and control, respectively.

Although ether extract was increased as a chemical component, ammoniation does not affect the digestion coefficient of this component in treated grass.

Ruminal Fermentation

Ammoniation of the forage had no effect on ruminal pH (P = .51) (Table 3). Ruminal pH was within the range of normal rumen function. As expected, ammoniation of the forage increased ruminal ammonia concentration (P = .0001). Ammonia is a normal ruminal component. The ammonia concentration required for ruminal bacteria has been estimated in various studies to be from 0.35 to 29 mg/dL (Owen and Zinn, 1986). Concentrations in excess of 20-21.4 mg/dl ruminal fluid produce a degradation rate plateau (Wallace, 1979; Erdmann et al., 1986). Over 100 mg/mL and ruminal pH above 8 predisposes ruminants to ammonia toxicity (rapid breathing, tremors,

Table 3. Effects of anhydrous ammonia treatment of mature pasture grass on ruminal fermentation characteristics

Item	Control	Treatment	SEM[a]
pH	6.35	6.39[b]	.04
Ammonia, mg/dL	13.54	19.09**	.61
Total VFA, uM	92.93	91.97[b]	2.54
Acetate, umol/mL	63.31	66.20[b]	1.7
Butyrate, umol/mL	11.40	9.35**	.46
Isobutyrate, umol/mL	.79	.45**	.02
Isovalerate, umol/mL	.87	.47**	.03
Propionate, umol/mL	15.47	14.75[b]	.49
Valerate, umol/mL	1.09	.75**	.05
Ac:Pr ratio	4.22	4.56**	.07

[a]Standard error of mean.
[b]Not significantly different (P > .05).
**significantly different (P < .01).

excessive salivation, and slight incoordination followed by severe incordination) (Essing et al., 1986). As a consequence, both forages resulted in adequate ruminal ammonia, which was safe yet allowed for maximal microbial protein production.

Total ruminal VFA concentration was not affected by the ammoniation of mature grasses. However, the individual VFA concentrations were affected significantly (Table 3). Ammoniation resulted in a trend of increase in ruminal acetate concentration and a decrease in propionate. As a consequence, the acetate:propionate ratio increased ($P = .003$). The concentration of isobutyrate, isovalerate, and valerate decreased ($P = .001$). These branched-chain VFAs are specifically required by ruminal bacteria responsible for the majority of the ruminal digestion of structural carbohydrate. A reduction in concentration is surprising in view of the fact that structural carbohydrates digestion was increased due to ammoniation. It is also surprising that ammoniation did not increase ruminal concentrations of bacteria and ciliated protozoa (Table 4), again in view of increased digestibility. However, these are concentrations and neither rumen volume nor digesta rate of passage was measured. Ammoniation not only increased digestibility, but tended to increase intake, which would likely increase rumen volume and(or) rate of digesta passage. These factors could account for a reduction in

Table 4. Effect of anhydrous ammonia treatment of mature pasture grass on ruminal bacteria and protozoa

Item	Control	Treatment	SEM[a]
Viable bacteria[b]	33.00	27.25[d]	10.68
Ciliated protozoa[c]	.28	.20[d]	.07

[a]Standard error of mean.
[b]Billion/mL.
[c]Million/mL.
[d]Not significantly different (P > .05).

concentration, while actual production could have been increased.

Implication

This study shows that in situations where pasture grasses grow rapidly and(or) the stocking rate of sheep is low, allowing the plants to advance rapidly toward maturity rather than simply clipping the pasture to restore vegetative growth, the harvesting and ammoniation of this biomass will furnish an acceptable forage base for wintering pregnant ewes.

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CHAPTER III

UTILIZATION OF AMMONIATED WHEAT STRAW TO WINTER PREGNANT EWES

Abstract

Ammoniated cereal straw (ACS) is routinely being used to winter beef cows in many areas of the United States. Relatively little information is available on the wintering of ewes using this resource. Seventy-eight pregnant western white-face ewes (76 kg) were assigned to this study to evaluate the use of ACS diets. Ewes were randomly assigned to six pens (13 ewes/pens) and were assigned one of two diets (3 pens/diet). The control diet (C) was composed of meadow grass hay (56.6%), alfalfa hay (34.6%), corn silage (7.7%), and a vitamin-mineral premix (1.1%). The test diet (T) was similar except ACS replaced grass hay. Diets were isonitrogenous and similar in mineral content; all ingredients were ground and mixed. Diets were offered on an ad libitum basis for a 60-d wintering period. All ewes were switched to an alfalfa hay (70%) and barley grain (30%) diet 2 wk before lambing. DM intake did not differ ($P > .05$) at 1.63 and 1.59 kg/ewe/d for the C and T diet, respectively. Daily gain was reduced ($P < .05$) by the T diet, .15 versus .12 kg/d. Grease-fleece weights were also reduced ($P < .05$) by the T diet, 4.3 versus 3.7 kg. Lamb birth weight was not affected by treatment ($P = .40$). Although weight gain and fleece production were reduced by the

T diet, performance was adequate. Most importantly, lamb birth weight was not affected. If diets are properly balanced, ACS can account for a substantial proportion of the wintering diet.

Introduction

Sheep production in the Intermountain West has historically been highly dependent on the grazing of public lands. As the human population increases and priorities with regard to public land use change, curtailment of livestock grazing is likely. As a consequence, many producers will be required to investigate economically efficient ways to winter pregnant ewes on harvested feeds. Cereal straws have been used for this purpose for centuries in some areas. Their use is usually limited to early or midgestation when nutrient requirements are relatively low (Gordon et al., 1983).

Chemical treatments such as ammoniation of cereal straws can improve utilization (digestibility and [or] intake) to the point that these forages could be successfully used in the diets of ruminants into late gestation (Lesoing et al., 1981). Unfortunately, most-production oriented studies in the U.S. have focused on cattle (Lesoing et al., 1981; Lomas et al., 1982). Most studies investigating the use of ammoniated cereal straw using sheep have been digestion or metabolism oriented. Although these studies indicated that these forages could be

used in the diets of sheep during late gestation, verification under practical production conditions is needed.

The objective of this study was to measure the effect of feeding ammoniated wheat straw (AWS)-based diets to sheep during mid to late gestation on the ewe weight change, fleece weight, and lamb birth weight.

Materials and Methods

Seventy-eight pregnant western white-face ewes were randomly assigned to one of two diets. A control (C) diet was formulated using traditional feeds used to winter pregnant ewes, i.e., alfalfa hay and meadow grass hay. A test diet (T) was similarly formulated in which ACS (Sundstol et al., 1978), replaced the meadow grass hay portion of the diet (Table 5).

Diets were offered as total mixed rations with all ingredients ground and mixed in a screw-type, grinding/mixing feed wagon. Forages were ground to approximately 3 cm length. Corn silage was added to reduce dustiness.

The ewes (ages 2-5 years) were housed in six pens, using 13 ewes/pens. Pens were equipped with fence-line feeders and covered, bedded loafing areas. Past experience dictated that all ewes be fed the T diet for a 14-d adjustment period. It was suspected that ewes unaccustomed to AWS may experience low intake and weight loss until adaptation takes place. By feeding all ewes the T diets, this initial lag would be

Table 5. Ingredients and chemical composition of diets, used in the ammoniated straw evaluation, DM basis

Item	Control Grass hay	Test Ammoniated straw
Ingredients, %		
Alfalfa hay	34.6	34.6
Meadow grass hay	56.6	---
Ammoniated wheat straw	--	56.2
Corn silage	7.7	7.7
Dicalcium phosphate	.1	.5
Trace mineral salt[a]	.5	.5
Vitamin mix[b]	.5	.5
Chemical (actual)		
CP, %	13.4	13.6
ADF, %	33.6	45.2
Calcium, %	1.0	.8
Phosphorus, %	.22	.17
Sulfur, %	.17	.13
Copper, ppm	15.7	16.8

[a]Zinc, 3600 ppm; manganese, 3000 ppm; copper, 350 ppm: iodine, 90 ppm; cobalt, 50 ppm; selenium, 50 ppm.
[b]Vitamin A, 600 kiu/kg; vitamin D, 60 kiu/kg; vitamin E, 3000 kiu/kg.

overcome. After this adjustment period, ewes were weighed and 3 pens were randomly assigned to either the C or T diet. Diets were offered on an libitum basis. Daily adjustment was made as needed to insure that ewes were receiving all they could consume, yet were not sorting the most palatable portions of the diet. Unlike cattle, sheep are capable of sorting feeds in a total mixed ration. Intakes were recorded

on a daily basis.

Ewes were in the study during late gestation from mid-December through mid-February and were weighed every 28 d. The ewes were shorn at the end of the study period and individual fleece weight was recorded. All ewes were then placed on the C diet, which was reformulated to provide .22 kg of ground barley grain/hd/d until they lambed, starting approximately March 1. Lamb birth weights were recorded.

The in vivo digestibility of the diets was determinated using identical twin, St. Croix ewes, placed in metabolism cages for 19 d (14 d of adaptation and 5 d of samples collection). Sampling procedure and sample analysis were described by Meneses et al. (1994). The carbohydrate (CH) input and output were calculated by difference (CH=DM-ASH-CP-EE-LIG). No statistical analysis was possible.

Data were analyzed by ANOVA utilizing the GLM procedure of SAS (1985). The model included treatment, birth type (single, twin), and sex of lamb. Initial body weight was used as a covariant in analyzing ewe weight-change data. Least squares means were tested by t-test (Steel and Torrie, 1980).

Results and Discussion

Dry matter and CP intake (Table 6) of the two diets did not differ. As expected, ewes consuming the T diet consumed more ADF and were therefore required to extract more energy

Table 6. Nutrient intake of ewes

Item	Control Grass hay	Test Ammoniated straw	SEM
DM, kg/d	1.57	1.49[a]	.09
CP, kg/d	.21	.20[a]	.01
ADF, kg/d	.52	.67*	.03

SEM: Standard error of mean.
a : Not significantly different (P > .05).
* : Significantly different (P < .05).

via fermentation of structural carbohydrates. Similar and adequate amounts of CP consumed with both diets, indicated this was not a limiting factor with regard to ruminal fermentation. However, three percentage points of the CP associated with the T diets were from NPN (ammonia).

Digestibility of the T diet was lower for DM and CH (Table 7). ME content of the T diet was reduced by approximately 7%. As a consequence, ewes consuming the T diet gained 27% less wt. than those consuming the C diet (Table 8).

Table 7. Apparent nutrient digestibility and metabolizable energy content of experimental diets

Item	Control Grass hay	Test Ammoniated straw
Dry matter, %	62.15	57.13
Crude protein, %	93.72	94.62
Ether extract, %	33.66	32.48
Carbohydrate, %	66.05	59.06
Metabolizable energy, Mcal/kg	2.092	1.947

Even though DM intake of the two diets did not differ, digestibility of the diet must have been lower as was shown in the digestibility determination. Ewes consuming this diet gained 27% less weight during the wintering period. Ewes consuming the T diet were required to obtain a higher portion of daily energy from the fermentation of structural carbohydrates. As mentioned previously, CP intakes from the two diets were similar and adequate (NRC, 1985). However, it is possible that the response can be explained by the lower concentrations of branched-chain VFAs with the T diets since their source was amino acids with corresponding carbon skeletons. Due to the fact that nearly 25% of the CP associated with this diet is from NPN fixed during the ammoniation process, it would be expected to result in lower amounts of branched-chain VFA precursors. It is important to note that gains exhibited by

Table 8. Performance of the ewes

Item	Control Grass hay	Test Ammoniated straw	SEM[a]
Initial BW, kg	80.10	79.59[b]	2.03
Final BW, kg	92.81	89.80**	.68
Total gain, kg	12.91	10.14**	.69
Lamb birth weight, kg	5.11	4.89[b]	.24
Fleece weight, kg	4.26	3.65*	.20

[a]Standard error of mean.
[b]No significatively different (P > .05).
** Significatively different (P < .01).
* Significatively different (P < .05).

ewes on both diets were adequate for normal production (NRC, 1985).

Lamb birth weight is a reasonable indicator of ewe nutrition. There was no difference in the lambing rate between the ewes on the two diets, nor was there a difference in lamb birth weights (P = .40). Fleece weight was reduced by 1.17 kg or approximately 17% by the AWS diet (P = .014). This may also be explained by the NPN content of the T diet. Sulfur containing amino acids are required for proper wool growth. The two major sources of amino acids are microbial and undergraded protein. The high NPN content of the T diet may have limited both of these sources, and thereby reduced wool growth (Coombe, 1992; Riley et al., 1991). In addition, the sulfur content of the T diets (Table 5) was lower than the sulfur requirement recommended by the NRC (1985, .14-.26% of DM).

Implication

Ewes can be successfully wintered (mid through late gestation) on AWS-based diets. In some circumstances, this could reduce annual ewe costs and improve profitability. Caution should be exercised with regard to depending on the NPN added to the straw during the ammoniation process to meet all protein requirements. Natural protein supplementation may be required to optimize ewe weight gain and wool growth.

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CHAPTER IV

WINTERING PREGNANT EWES ON A DIET BASED ON REHYDRATED, AMMONIATED WHEAT STRAW

Abstract

Sixty-six pregnant western white-face ewes were used to evaluate the ammoniation of rehydrated cereal straw as the basis for a winter feeding program. Water was added to bales of wheat straw at a rate designed to increase the moisture content to 30%. The stack was then treated with anhydrous ammonia at 3% of original dry matter. A second stack was treated with anhydrous ammonia without addition of water. After an adaptation period of 10 d, the ewes were distributed randomly to six pens using 11 ewes per pen. All ewes were offered .9 kg of supplement and ad libitum access to either ammoniated wheat straw (AS) or rehydrated ammoniated wheat straw (RAS) using three pens per forage type. The supplement was composed of alfalfa hay (86.71%), corn silage (10.0%), and a vitamin-mineral premix (3.29%). The straw was offered directly from the bale and top-dressed with the supplement. Straw intake, ewe body weight, lamb birth weight and fleece weight were measured. Ewes consuming RAS increased DM and CP intake ($P < .01$) by 127.7 and 153.0%, respectively. As a result, those ewes consuming RAS gained more weight ($P < .01$) during the test period. Lamb birth weight was not affected by

forage type (P = .874), at 5.15 versus 5.08 kg for ewes consuming the AS and RAS diets, respectively. Fleece weight was increased by the RAS diet (P < .05) at 4.56 versus 4.01 kg. Rehydratation of wheat straw prior to ammoniation significantly improved the nutrient availability of this forage compared to ammoniation on an air-dried basis.

Introduction

The importance of the moisture content of animal feeds has been known for quite some time. Dalton et al. (1953) demonstrated that adding moisture to concentrates fed to dairy cows increased the rate of consumption and the rate of insalivation of the food bolus, and decreased chewing time. Holzer et al. (1975) reported increased feed intake by soaking a low-quality diet in water. They concluded that soaking diets high in fibrous roughages tended to improve digestibility and available energy in cattle. Ruminal fermentation was also changed with decreased acetate: propionate ratio. Chatturvedi et al. (1973) offered water-soaked straw to buffalo calves and Zebu cattle. Soaking straw with water increased intake in both animal species. Rate of VFA production and energy availability was also increased by soaking. Holzer et al. (1975) hypothesized that dry roughages require considerably more saliva secretion and chewing time than soaked roughages. Resultant increased energy expenditure associated with these

processes reduces available energy.

Treating low-quality forages such as cereal straws with anhydrous ammonia improves digestibility and(or) intake of these forages (Sundstol and Coxworth, 1984). Improvements are likely due to disruption at covalent bonding between lignin and cell wall carbohydrates, which improves ruminal microbial fermentation of cells walls. The extent of improvement depends on distribution of ammonia and the initial moisture content of the forage (Reddy et al., 1991). Since the formation of ammonium hydroxide from anhydrous ammonia and water associated with the forage is the key to successful forage treatment, a lack of forage moisture could limit the effectiveness of ammoniation. Rehydration of cereal straw prior to ammoniation should improve the effectiveness of the treatment as well as palatability. This combination should greatly improve digestibility of dry matter intake of these forage by ruminant animals. The objective of this study was to test this hypothesis in pregnant ewes.

Materials and Methods

Sixty-six pregnant western white-face ewes were used to evaluate the utilization of rehydrated cereal straw treated with anhydrous ammonia (RAS) as a basal diet during winter. Wheat straw was rehydrated in the stack. A steel pipe (3 m long, 1.2 cm inside diameter) with perforations throughout its

length was pushed into seams in the stack and tap water was injected. Flow rate through the pipe was measured. By evenly distributing injection sites, amount of water added to the stack was estimated to bring the moisture content to 30%. The stack was then enclosed in black plastic. Temperatures in the stack under polyethylene reached 55° C, facilitating the distribution of water in the stack. After 5 d, the rehydrated straw stack was ammoniated at 3% of original dry matter (Sundstol et al., 1978). A second stack of wheat straw from the same field was ammoniated on an air-dried basis without rehydratation to serve as a control. The chemical composition of the two stacks is reported in Table 9. To address nutrient deficiencies inherent in the straws, a supplement was formulated emphasizing alfalfa hay (Table 10), which is

Table 9. Chemical analyses of the straws, DM basis

	Ammoniated straw	
Nutrient	air-dried	rehydrated
Moisture, %	17.4	50.8
Dry matter	82.6	49.2
Crude protein	13.6	15.0
ADF, %	47.0	46.7
Calcium, %	.28	.35
Phosphorous, %	.02	.02
Sulfur, %	.11	.14
Copper, mg/kg	3.4	0

A value zero indicates values below detection limits.

Table 10. Ingredient and chemical composition of the supplement, DM basis

Items	Amount
Ingredients	
Alfalfa hay, %	92.64
Corn silage, %	3.56
Total mix salt[a], %	1.65
Dical-Phosphate, %	1.65
Vitamin mix[b], %	.50
Chemical (Actual)	
CP, %	15.8
ADF, %	33.4
Calcium, %	1.03
Phosphorous, %	.29
Sulfur, %	.23
Copper,ppm	11.9

[a]Zinc, 3600 ppm; manganese,3000 ppm; copper, 350 ppm: iodine 90 ppm; cobalt, 50 ppm; selenium, 50 ppm.
[b]Vitamin A 600 kiu/kg; Vitamin D 60 kiu/kg; Vitamin E 3000 iu/kg.

commonly used in most sheep operations. All ingredients were ground and mixed. Corn silage was added to reduce dustiness and ingredient separation in the mixed ration. The ewes aged 2-5 yr were randomily assigned to six pens with 11 ewes per pen. Pens were covered with a shed roof and had feeder access for each ewe in the pen. Pens were bedded with wood shavings. Fresh, clean water was available at all times from automated, frost-free waterers.

The ewes were managed as reported by Meneses et al.

(1995). All ewes were adapted to an air-dried ammoniated straw diet for 14 d. Ewes were then weighed. This insured that all ewes were accustomed to ammoniated straw and consuming it readily before initial weighing, which minimized body weight measurement error associated with gut fill and initial weight loss when a novel diet is presented. Pens were then randomly assigned to either a rehydrated ammoniated wheat straw (RAS) or an air-dried, ammoniated wheat straw (AS) diet using three pens per forage type. Diets were offered to each group daily at 1700. Forages were fed directly from the bales to mimic actual production conditions. The amount of baled forage offered was adjusted daily, allowing the ewes ad libitum consumption, but discouraging selection of only the most palatable portions of the forages. The alfalfa-based supplement was top-dressed on the straw to provide .9 kg/ewe/day.

The ewes were in the study for 81 d during late gestation. The initial weight was taken on January 6, the middle weight was on February 17, and the final weight was on March 28. After the final weight the ewes were switched to a lambing diet consisting of alfalfa hay, ground barley, meadow grass hay, corn silage, and vitamin-mineral supplements through the lambing period. Lamb birth weights were recorded. Ewes were sheared May 15 and fleece weights recorded.

The data were analyzed by ANOVA using the generalized

least square procedure of the SAS statistical system (1985), under completely randomized design (Appendix B). Ewe performance traits were analyzed using a nested design with pens within treatment as the error term for testing differences in treatment effect. Initial body weight was included in the model as a covariate. Lamb birth weights were analyzed using a mixed model, which included treatment, pens nested within treatments, sex of lambs, and birth type (single versus twins). Pens-within- treatment was the error term for testing differences in treatment effects.

Results and Discussion

Ewes consuming the RAS diet consumed more DM, CP, and ADF than those consuming the AS diet ($P < .01$, Table 11). Proportional straw represented 68.12 and 43.55% of the total diet for RAS and AS diets, respectively. As a result the RAS diet increased overall intake by 127.7% in this study and 130.4% compared to AS used in a similar study with the same flock of ewes (Meneses et al., 1995). In the previous study, AS was chopped and fed in a total mixed diet. In the present study, straw was fed directly from the bale with the supplement top dressed. This indicates increased intake would likely be sustained even in a practical production situation. As a consequence of increased RAS intake, overall intake of CP also increased ($P < .01$).

Table 11. Dry matter, crude protein and ADF intake of rehydrated and nonrehydrated cereal straw

Item	Ammoniated straw		
	air-dried	rehydrated	SEM[a]
Dry matter kg/anim/day	.851	1.938**	.0439
Crude protein kg/anim/day	.115	.291**	.0066
ADF kg/anim/day	.400	.905**	.0205

[a]Standard error of mean.
** Significantly different ($P < .01$).

According to NRC (1985), a 70-kg ewe requires 210 g crude protein per day. Ewes consuming the RAS diet received 434 g of crude protein per day, 291 g from straw and 143 g from supplement. It must be remembered however, that the ammoniation process increased the CP content of the original straw by 5 fold, with the addition being in the form of NPN. The increased intake measured with RAS was likely due to improved palatability and increased effectiveness of the ammoniation process, which would increase the rate and extent of fiber digestion (Dalton et al., 1953; Chatturvedi et al., 1973; Holzer et al., 1975).

As a consequence of higher intake with the RAS diet, more nutrients were available for the ewes. This resulted in higher body weight gains ($P < .01$). Ewes consuming the RAS diet exhibited a 60% improvement in rate of gain (Table 12). The

NRC (1985) has suggested that ewes in average body condition should be gaining approximately .227 kg/day at this time. Ewes consuming the RAS diet approached this level of gain while those on the AS diet did not.

The increased body weight gain of the ewes fed the RAS diet was not expressed in increased lamb birth weight (P = .874). The birth weights of the lambs from ewes wintered on either of the forage diets were similar to the lamb weight otained in a similar study using the same flock of ewes (Meneses et al., 1995). These lamb weights were in a range of normallity and represent an indicator of adequate ewe body condition at lambing, which insures enough milk for the first days of the lamb's life.

No previous studies have reported the effect of RAS diets on the productivity of ewes. Chatturvedi et al. (1973)

Table 12. Effect of ammoniation of rehydrated straw on performance of pregnant ewes

	Ammoniated straw		
Item	air-dried	rehydrated	SEM[a]
Middle weight, kg	79.01	82.85**	0.549
Final weight, kg	82.21	87.75**	0.239
Gain, kg/day	.128	.205*	.015
Lamb birth weight, kg	5.155	5.080[NS]	.527
Fleece weight, kg	4.015	4.562*	.139

[a]Standard error of mean.
** Significantly different (P < .01).
* Significantly different (P < .05).

reported several benefits of feeding water-soaked cereal straw to Zebu and buffalo calves. They reported much higher intake of CP, ME, and NFE (nitrogen free extract) in animals consuming the soaked versus unsoaked straw. ME available to the animals was higher in the animals offered soaked straw, as was production of total VFA and acetic acid. Thus some of the benefits of the RAS diet could be explained simply by increased intake associated with improved acceptability and palatability. However, increased intake alone cannot account for all the improvement in ewe performance.

The higher DM and CP intake of ewes fed the RAS diet resulted in a 13% increase in fleece weight ($P < .05$). The fleece weights resulting from the feeding of either diet are within the acceptable range. In a previous study utilizing the same flock (Meneses et al., 1995), ewes were fed a diet in which low fleece weights resulted as a result of lower diet acceptability. In the present study ewes receiving RAS had considerably more nutrients available to them, some of which were utilized for wool growth. Wool growth is highly dependent on sulfur-containing amino acids. Riley et al. (1991) reported improved wool quality and production with abomasal infusions of methionine. Hoaglund et al. (1992) also reported improved wool growth using supplements high in ruminally undegradable protein, such as extruded soybean meal and blood meal. Ewes in both groups received identical nutrition from the supplement,

and straw intake alone does not explain improved amino acid nutrition because most of the CP is associated with NPN fixed during ammoniation. Increased ruminal microbial production in ewes consuming the RAS may explain the slight improvement in wool production. Maintaining optimal N/S ratios and sulfur-containing amino acid nutrition is very important with respect to maintaining acceptable wool growth in ewes consuming ammoniated low-quality forage diets.

Implication

Rehydratation of wheat straw prior to ammoniation offers an inexpensive means of improving the nutrient availability of this low-quality forage to a degree that it can be the primary constituent of the diet of ewes, even during late gestation when nutrient requirements are relatively high.

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CHAPTER V

NUTRITIVE QUALITY OF STRAW FROM BARLEY AND WHEAT CULTIVARS FOR RUMINANTS

Abstract

The in situ ruminal digestibility of five barley and 10 wheat cultivars was evaluated and compared with the digestibility of alfalfa and ammoniated Steptoe barley straw. The barley cultivars were Columbia, Fiesta, Kombar, Russell, and Rollo. The wheat cultivars were Cache, Daws, Dusty, Hansel, Malcom, Manning, Survivor, Ute, Weston, and 1549-19. The evaluations involved five varieties at time. All samples were ground to pass through a 2-mm screen and were placed in polyester monofilament bags. The bags were placed in perforated PVC tubes (29 x 5 cm) capable of containing eight bags. Four PVC tubes were placed in each of three ruminal-fistulated nonlactating Holstein cows. Four bags by variety and replication were used to evaluate disappearance at 6, 12, 24, and 48 h of fermentation. One bag of each variety and replication (0 h) was frozen without entering the rumen. Dry matter disappearance was evaluated. Residual NDF, ADF, and hemicellulose were determined from the in situ dry matter.

Of the barley cultivars, Fiesta and Kombar had the highest DM disappearance rate and lower NDF and ADF values ($P < .05$). These values were equivalent to those of ammoniated straw and lower than the values associated with alfalfa ($P <$

.05). Of the wheat cultivars, Malcom, Manning, Ute, and 1549-19 had the highest DM disappearance rates and the lowest NDF and ADF values ($P < .05$). The DM disappearance of these wheat varieties was lower than alfalfa and was equivalent to that of Kombar barley. The most digestible varieties were dwarf plants. The better digestibility of some barley and wheat varieties indicated that selection could improve the nutritional value of straw.

Introduction

Treatment with ammonia can improve the digestibility of low quality forages such as straw (wheat, barley, rice), coastal bermuda grass hay (Grotheer and Cross, 1986), tall fescue hay (Buettner et al., 1982), grass hay (Agrostis stolonifera, Lolium perenne, Alopecurus geniculatus) (Wylie and Steen, 1988), and mature grass (Festuca arundinacea, Bromus inermis and Dactylis glomerata) (Meneses et al., 1994). Ammonia is also used to preserve high moisture hay (Thorlacius and Robertson, 1984) and improve the nitrogen content and preserve corn silage (Lomas et al., 1978).

In general, ammonia treatment increases the DM digestibility 45 to 60% or more in sheep; treatment also increases the nitrogen content and improves enzyme degradation of several high fiber forages (Waiss et al., 1972). As a preservative treatment, ammonia also decreases heat damage and

mold growth, and increases the nutritive quality of conventional and high moisture silage (Thorlacius and Robertson, 1984).

Straw ammonia treatment produces a relatively negative effect; in fact, about 50% of the anhydrous ammonia used in the treatment of straw is lost to the atmosphere. In the atmosphere, ammonia nitrogen is transformed to nitrous oxide (Matson and Vitousek, 1990) and can precipitate as an acid or in a dry form (Vitousek, 1992). Nitrogen gas, like carbonic oxide, chlorofluoro-carbons, and methane, contributes to the greenhouse effect (Broecker, 1987). The slow increase in atmospheric nitrogen from 294 to 310 ppbv the last 40 years is implicated in global climatic change (Vitousek, 1992).

Although the ingestion of ammoniated straw increased the ruminal ammonia concentration in between the normal range (Meneses et al., 1994), concern is shown by some people for the possibility of ammonia residual in the meat for human consumption (L. McNeal, personal communication).

Plant breeding could improve the digestibility of straw remaining from the harvest of cereal grains. Breeding programs generally seek to improve the quality and quantity of the grain and resistance to pests and diseases, but not to improve straw digestibility. Some new varieties have stronger stems, and are less digestible than others. Kernan et al. (1979) found the straw of Canadian cereal grains and of varieties

differed in CP, in vitro digestibility, organic matter, and crude fiber.

This study evaluated the nutrient digestibility of the straw of several barley and wheat cultivars to ascertain whether improving the nutritional value of straw through selection and breeding could be an alternative to treating straw with ammonia, and decrease the negative effect that may be produced by the straw ammoniation treatment in the environment.

Materials and Methods

The nutrient digestibility of straw from five barley and ten wheat varieties (Table 13) developed at Utah State University was evaluated and compared with the digestibility of alfalfa and ammoniated straw (Steptoe barley variety), which served as positive and negative controls, respectively.

The straw of the different varieties was collected from

Table 13. Barley and wheat varieties used in the study

Barley varieties	Wheat varieties	
	Group 1	Group 2
1. Colombia	1. Cache	6. Manning
2. Fiesta	2. Daws	7. Survivor
3. Kombar	3. Dusty	8. Ute
4. Russel	4. Hansel	9. Weston
5. Rollo	5. Malcom	10. 1549-19

an agronomic evaluation trial. All varieties had been similarly managed (irrigation, fertilization, insecticide, and herbicide application). All forages were ground to pass a 2-mm screen using a Wiley mill.

White polyester monofilament bags (7 x 13 cm) (Bar Diamond Inc., Parma, ID) with an average pore size of 50 μm were filled with 20 mg/cm^2 (3.6g) of forage (Nocek, 1988). The bags were placed in perforated rigid plastic tubes (25 x 5 cm), each with a capacity of eight bags.

Three nonlactating, fistulated cows were used in the study. The cows were allowed to adapt to a diet consisting of 2.5 kg of alfalfa hay plus straw ad libitum and mineral-vitamin supplementation for 3 wk prior to the study.

Four plastic tubes were placed in each cow, which represented a replication. Thus, four tubes contained 32 bags, which contained five varieties of either barley or wheat straw, were used. Control forages were alfalfa hay, ammoniated straw and Malcom wheat straw for barley straw groups, but Kombar barley straw was used variety instead Malcom wheat straw groups. Each tube contained eight bags (four bags/variety). One of four bags per variety was collected at 6, 12, 24, and 48 h after tubes were placed in the rumen. The procedure was repeated three times to evaluate the five barley and 10 wheat varieties (five at a time). Cows rested for 3 d between experiments.

The bags were frozen at 20° C upon removal until the chemical analyses were performed. The contents of one bag of each variety were frozen without entering the rumen and represent the control (time 0).

After trial completion, all bags were rinsed twice for 2 min in a conventional washing machine to remove debris (Cherney et al., 1990).

The bags were placed in a forced air oven at 60° C for 72 h to determine DM. Samples were analyzed for NDF, and ADF by the filter bag system (Komareck, 1993). Due to the small amount of residual sample, sequencial analysis was used to determine NDF and ADF. The rate of disappearance was calculated as the difference between time 0 and the other sample times.

The data were analyzed by ANOVA utilizing the GLM procedure of SAS (1985). The model included the effect of variety, time, replication and the interaction of variety with time. The control (0 h) sample was not analyzed when determining rate of disappearance. Differences among means were determined by standard t-test (Steel and Torrie, 1980).

Results

Barley Varieties

There were differences between varieties, time, and replication effect ($P < .01$) in dry matter disappearance

(DMD), NDF, and Hc residual. Interaction varieties x time was significant for NDF and ADF residual ($P < .01$).

At 48 h, the DMD of Russell was significantly lower ($P < .05$) than that of Fiesta. The DMD of the other varieties was similar to that of ammoniated straw and Malcom wheat (Table 14).

The residual NDF at 48 h in Fiesta and Kombar was similar to that of treated straw, Malcom wheat and alfalfa. Rollo, Columbia, and Russell contained the highest residual NDF ($P < .05$) (lowest NDF disappearance). These results suggest Fiesta, Kombar, and Malcom wheat contained similar levels of NDF and lower levels than Rollo, Russell, and Columbia ($P < .05$)

TABLE 14. DMD, NDF, ADF, and Hc residual of barley varieties, ammoniated straw, and Malcom wheat, after 48 h (%)

Variety	DMD	NDF	ADF	Hc
Columbia	49.23^{bc}	88.73^{c}	62.78^{c}	25.95^{c}
Fiesta	55.68^{b}	83.63^{ab}	56.65^{ab}	26.98^{c}
Kombar	47.46^{bc}	85.65^{ab}	58.98^{ab}	26.67^{c}
Russell	40.94^{c}	86.22^{bc}	59.67^{ab}	26.55^{c}
Rollo	46.77^{bc}	87.50^{c}	60.74^{ab}	27.25^{c}
Ammoniated straw	53.98^{bc}	83.28^{a}	63.07^{c}	20.21^{b}
Alfalfa	71.38^{a}	85.16^{ab}	70.31^{d}	14.84^{a}
Malcom wheat	63.98^{ab}	83.44^{ab}	56.82^{a}	26.61^{c}
SEM	4.09	.974	1.080	.917

Means in column with different letters differ ($P < .05$).
SEM = Standard error of the mean.

(Table 15).

The residual ADF content, which was higher in Columbia than the other barley straws ($P < .05$), is the portion that contain lignin, which is the insoluble compound of the cell wall. However, the ADF content of all straws was similar at 0 h (Table 15).

The ammoniation of straw increased the cell wall solubility, as ADF proportions were higher in untreated straw.

There were no differences in residual Hc levels in control (0 h) or digested (48 h) barley straws.

The disappearance rates of ADF and NDF for barley varieties were not different in time, but replication effects

Table 15. NDF, ADF, and Hc proportion of barley varieties, ammoniated straw, alfalfa, and Malcom wheat, at 0 h of digestion (%)

Variety	NDF	ADF	Hc
Columbia	90.74^{c}	62.17^{bc}	28.57^{c}
Fiesta	89.21^{bc}	58.95^{b}	30.25^{c}
Kombar	88.28^{bc}	59.71^{bc}	28.58^{c}
Russell	90.86^{c}	61.57^{bc}	29.28^{c}
Rollo	90.16^{c}	61.21^{bc}	28.95^{c}
Ammoniated straw	86.23^{b}	63.84^{c}	22.39^{b}
Alfalfa	75.44^{a}	58.97^{a}	16.46^{a}
Malcom wheat	89.09^{bc}	60.22^{bc}	28.87^{a}
SEM	.974	1.080	.917

Means in column with different letters differ ($P < .05$).
SEM = Standard error of the mean.

and variety differences and variety interaction x time effect differed ($P < .01$). Instead, Hc presented difference in varieties, time, and interaction effect ($P < .01$).

It is difficult to interpret the results due to the variability in the factors studied. However, there were occasionally differences in the NDF rate of disappearance (e.g. Fiesta, at 6 h and Malcom at 12, 24, and 48 h) and in the rate of ADF disappearance (e.g., Fiesta, at 6 h, Kombar at 12, and Malcom at 12, 24, and 48 h) (Tables 16 and 17). Except for Fiesta at 6 h, there were no significant differences in the Hc disappearance rate (Table 18).

Table 16. NDF disappearance rate (g/h) for barley varieties, ammoniated straw, alfalfa, and Malcom wheat

Variety	TIME, h			
	6	12	24	48
Columbia	.021^{bc}	.019^{b}	.025^{b}	.021^{ab}
Fiesta	.084^{a}	.028^{b}	.026^{ab}	.023^{ab}
Kombar	.030^{bc}	.037^{b}	.031^{ab}	.021^{ab}
Russell	.018^{bc}	.026^{b}	.027^{ab}	.018^{b}
Rollo	.024^{bc}	.019$_{b}$	.025^{ab}	.021^{ab}
Amoniated straw	.077^{c}	.023^{b}	.033^{ab}	.024^{ab}
Alfalfa	.031^{b}	.020^{b}	.017^{b}	.015^{b}
Malcom	.035^{b}	.061^{a}	.042^{a}	.040^{a}
SEM	.0064	.0064	.0064	.0064

Means in column with different letters differ ($P < .05$).
SEM = Standard error of the mean.

Table 17. ADF disappearance rate (g/h) for barley, ammoniated straw, alfalfa, and Malcom wheat

Variety	TIME, h			
	6	12	24	48
Columbia	.016^{bc}	.019^{bc}	.016^{bc}	.014^{ab}
Fiesta	.047^{a}	.017^{bc}	.017^{ab}	.015^{ab}
Kombar	.017^{bc}	.026^{ab}	.021^{ab}	.014^{ab}
Russell	.011^{bc}	.015^{bc}	.017^{ab}	.012^{b}
Rollo	.019^{bc}	.012^{bc}	.016^{ab}	.014^{ab}
Ammoniated straw	.002^{c}	.016^{bc}	.023^{ab}	.017^{ab}
Alfalfa	.014^{bc}	.011^{c}	.011^{b}	.011^{b}
Malcom wheat	.021^{b}	.040^{a}	.028^{a}	.027^{a}
SEM	.0047	.0047	.0047	.0047

Means in column with different letters differ ($P < .05$).
SEM = Standard error of the mean.

Wheat Varieties

The first group of wheat varieties presented differences in the effects of varieties, time, and interaction for DMD, NDF, and ADF ($P < .01$). No difference was obtained between replication. Dry matter disappearence was higher at 48 h of ruminal fermentation for all varieties ($P < .05$).

The DMD of Malcom after 48 h of ruminal fermentation was equivalent to that of ammoniated straw and Kombar barley (Table 19). These results are consistent with the result of the study involving barley varieties.

Table 18. Hc disappearance rate (g/h) for barley varieties, ammoniated straw, alfalfa, and Malcom wheat

Variety	TIME, h			
	6	12	24	48
Columbia	.0049[b]	.0009[c]	.0086[a]	.0070[a]
Fiesta	.0037[c]	.0103[b]	.0090[a]	.0085[a]
Kombar	.0130[ab]	.0105[b]	.0102[a]	.0075[a]
Russell	.0074[ab]	.0106[b]	.0100[a]	.0066[a]
Rollo	.0058[b]	.0069[bc]	.0084[a]	.0073[a]
Ammoniated straw	.0052[b]	.0066[bc]	.0103[a]	.0068[a]
Alfalfa	.0176[a]	.0095[bc]	.0036[a]	.0044[a]
Malcom	.0139[ab]	.0208[a]	.0140[a]	.0132[a]
SEM	.0030	.0030	.0030	.0030

Means in column with different letters differ (P < .05).
SEM = Standard error of the mean.

TABLE 19. Dry matter disappearance, NDF, ADF, and Hc residual of wheat varieties, ammoniated straw, alfalfa, and Kombar barley at 48 h (%)

Variety	DMD	NDF	ADF	Hc
Cache	40.14[c]	90.20[d]	60.48[b]	28.79[c]
Daws	46.39[cd]	85.32[c]	56.26[a]	29.05[cd]
Dusty	46.56[cd]	84.81[bc]	55.38[a]	29.43[d]
Hansel	42.20[dc]	90.03[d]	59.28[b]	30.75[d]
Malcom	55.48[b]	84.36[bc]	55.12[a]	29.23[cd]
Ammoniated straw	57.14[b]	76.82[a]	55.08[a]	21.73[b]
Alfalfa	72.01[a]	81.77[b]	65.48[c]	16.78[a]
Kombar	53.36[bc]	86.49[c]	57.73[ab]	29.14[cd]
SEM	1.816	1.181	1.202	1.000

Means in column with different letters differ (P < .05).
SEM = Standard error of the mean.

Cache had the lowest DMD ($P < .05$). Its DMD value was similar to that of Russell barley.

After 48 h of digestion, Malcom, Dusty, and Daws had the lowest NDF residual of wheat varieties tested ($P < .05$), but not as low as ammoniated straw NDF ($P < .05$). The residual NDF content of Malcom and Kombar was within 1% of the values obtained during the study of barley varieties. The NDF levels were highest in Cache and Hansel ($P < .05$).

The NDF content of the straw varieties at 0 h did not differ ($P > .05$) (Table 20).

The residual ADF levels were lowest in Malcom, Dusty, and Daws, and highest in Cache and Hansel ($P < .05$). These levels

TABLE 20. NDF, ADF, and Hc content of wheat varieties, ammoniated straw, alfalfa, and Kombar barley, at 0 h of digestion (%)

Variety	NDF	ADF	Hc
Cache	90.90^{b}	59.59^{bc}	31.31^{cd}
Daws	88.67^{b}	59.88^{bc}	28.79^{bc}
Dusty	88.17^{b}	76.51^{c}	31.45^{cd}
Hansel	91.39^{b}	58.81^{b}	32.57^{d}
Malcom	89.18^{b}	58.79^{b}	30.59^{cd}
Ammoniated Straw	89.32^{b}	63.06^{b}	26.25^{b}
Alfalfa	72.60^{a}	51.62^{a}	20.99^{a}
Kombar	89.00^{b}	59.47^{b}	29.53^{c}
SEM	1.181	1.202	1.000

Means in column with different letters differ ($P < .05$).
SEM = Standard error of the mean.

were similar to those in ammoniated straw and Kombar barley.

The ADF values were approximately 2.5% lower for Malcom and Kombar and 12.5% lower for ammoniated straw than the values in the study involving barley varieties.

As with the initial NDF composition, initial ADF values of wheat straws did not differ (Table 20).

Cache had the lowest residual Hc ($P < .05$) and the highest NDF and ADF, similar to the trend associated with Columbia barley. The residual Hc values for Malcom, ammoniated straw, and Kombar were higher than those obtained in the study involving barley.

The disappearance rate of the first wheat group was different for varieties, time, replications, and interaction variety x time effect ($P < .01$), with the exception of Hc, which was not significant ($P > .05$). The rate of disappearance of NDF and ADF increased between 12 and 24 h ($P < .01$).

The NDF disappearance rate of straw differed only at 6 and 12 h (Table 21). The lowest rate was for Daws and Cache, and the highest rate was for Malcom, at these times, respectively ($P < .05$).

There were differences in the ADF disappearance rates between varieties at various times (Table 22). At 12 h, ADF disappearance rates were lowest in Cache and Dusty ($P < .05$).

Hemicellulose disappearance rate differed only in Hansel at 48 h ($P < .05$) (Table 23).

Table 21. NDF disappearance rate (g/h) for wheat varieties ammoniated straw, alfalfa, and Kombar barley

	TIME, h			
Variety	6	12	24	48
Cache	.0063^{c}	.0195^{c}	.0216^{b}	.0202^{ab}
Daws	-.0009^{d}	.0312^{bc}	.0272^{ab}	.0226^{ab}
Dusty	.0021^{c}	.0212^{c}	.0257^{ab}	.0222^{ab}
Hansel	.0106^{bc}	.0310^{bc}	.0242^{ab}	.0233^{ab}
Malcom	.0022^{b}	.0387^{ab}	.0303^{ab}	.0318^{ab}
Ammoniated straw	.0176^{bc}	.0466^{a}	.0356^{a}	.0328^{a}
Alfalfa	.0588^{a}	.0381^{ab}	.0256^{ab}	.0166^{b}
Kombar	.0169^{bc}	.0386^{ab}	.0327^{ab}	.0264^{a}
SEM	.0028	.0028	.0028	.0028

Means in column with different letters differ ($P < .05$).
SEM = Standard error of the mean.

The results with the second group of wheat varieties were very similar to trends noted in the analyses of the first group of wheat varieties, except DMD did not differ by replication ($P > .05$), nor was there a significant interaction for Hc. The same trend characterized the barley varieties, except ADF did not differ between fermentation times.

These varieties also demonstrated significant differences in DMD, and residual levels of NDF, ADF, and Hc after 48 h of rumen fermentation. Of the wheat varieties tested, the DMD was significantly ($P < .05$) higher in Manning, Ute, and 1549-19 after 48 h of ruminal fermentation. These varieties were similar to the DMD in Kombar barley and ammoniated straw, but

Table 22. ADF disappearance rate (g/h) for wheat varieties, ammoniated straw, alfalfa, and Kombar barley

Variety	Time, h			
	6	12	24	48
Cache	.0053^{cd}	.0102^{c}	.0132^{b}	.0126^{b}
Daws	.0058^{cd}	.0232^{ab}	.0197^{ab}	.0159^{ab}
Dusty	-.0015^{d}	.0144^{c}	.0146^{b}	.0139^{b}
Hansel	.0034^{cd}	.0174^{bc}	.0131^{b}	.0144^{b}
Malcom	.0209^{ab}	.0258^{a}	.0204^{ab}	.0166^{ab}
Ammoniated straw	.0039^{cd}	.0296^{a}	.0235^{a}	.0229^{a}
Alfalfa	.0290^{a}	.0170^{bc}	.0147^{b}	.0103^{b}
Kombar	.0121^{bc}	.0247^{ab}	.0205^{ab}	.0177^{ab}
SEM	.0028	.0028	.0028	.0028

Means in column with different letters differ ($P < .05$).
SEM = Standard error of the mean.

Table 23. Hc disappearance rate (g/h) for wheat varieties, ammoniated straw, alfalfa, and Kombar barley

Variety	Time, h			
	6	12	24	48
Cache	.0009^{a}	.0093^{a}	.0084^{a}	.0075^{b}
Daws	-.0151^{a}	.0080^{a}	.0075^{a}	.0067^{b}
Dusty	.0039^{a}	.0067^{a}	.0110^{a}	.0082^{b}
Hansel	.0073^{a}	.0136^{a}	.0111^{a}	.0428^{a}
Malcom	.0124^{a}	.0129^{a}	.0099^{a}	.0106^{b}
Ammoniated straw	.0138^{a}	.0164^{a}	.0120^{a}	.0099^{b}
Alfalfa	.0044^{a}	.0211^{a}	.0108^{a}	.0063^{b}
Kombar	.0049^{a}	.0138^{a}	.0121^{a}	.0086^{b}
SEM	.0129	.0129	.0129	.0129

Means in column with different letters differ ($P < .05$).
SEM = Standard error of the mean

Manning, Ute, and 1549-19 was similar than in Daws and Dusty, although the variation makes it difficult to directly compare the results. For example, the alfalfa DMD was similar to that obtained in the preceding evaluation, but the DMD of ammoniated straw was lower.

Table 24. Dry matter disappearance, NDF, ADF, and Hc residual of wheat varieties, ammoniated straw, and Kombar barley, after 48 h (%)

Variety	DMD	NDF	ADF	Hc
Manning	47.05^{bc}	85.46^{a}	56.87^{ab}	28.59^{c}
Survivor	39.25^{d}	88.27^{b}	58.32^{ab}	29.95^{cd}
Ute	46.84^{bc}	84.43^{a}	53.80^{a}	30.63^{d}
Weston	42.19^{cd}	89.52^{c}	60.17^{c}	29.34^{cd}
1549-19	45.20^{bcd}	84.58^{a}	54.44^{a}	30.14^{cd}
Ammoniated straw	45.54^{bcd}	83.93^{a}	60.33^{c}	23.60^{b}
Alfalfa	72.73^{a}	85.05^{a}	66.76^{d}	18.29^{a}
Kombar	50.96^{b}	84.94^{a}	56.46^{ab}	28.47^{c}
SEM	2.430	.999	1.103	.693

Means in column with different letter differ ($P < .05$).
SEM = Standard error of the mean.

Manning, Ute, and 1549-9 also contained significantly lower percentages of cells wall ($P < .05$), which were similar to levels in the ammoniated straw, in Kombar barley, and in the varieties Malcom and Dusty.

As with the barley straw and the first group of wheat straws, the initial cell wall content (time 0 h) of the second group of wheat straw did not differ ($P > .05$) (Table 25). Similarities in residual cell wall of Manning, Survivor, Ute,

and 1549-19 suggested that the differences in digestibility between varieties were due to the differences in ruminal dissolution. The residual NDF in Manning, Ute, and 1549-19 was similar to those in Malcom and Dusty.

There was relatively little variation in the residual levels of the constituents measured in the straws. Survivor had low DMD and high NDF but the residual ADF was similar to levels found in Manning, Ute, 1549-19, and Kombar barley. The high residual ADF and NDF levels in Weston are reflected in the variety's relatively low DMD.

Straw did not differ in residual Hc levels, which was a characteristic of the barley and other wheat varieties studied.

Table 25. NDF, ADF, and Hc content of wheat varieties, ammoniated straw, alfalfa, and Kombar barley (%)

Variety	NDF	ADF	Hc
Manning	88.23^{bc}	58.16^{cde}	30.07^{c}
Survivor	91.36^{d}	58.33^{cde}	33.03^{e}
Ute	87.14^{b}	54.32^{ab}	32.82^{de}
Weston	90.92^{cd}	59.83^{de}	31.09^{cde}
1549-19	86.54^{b}	55.39^{bc}	31.15^{cd}
Ammoniated straw	86.67^{b}	61.23^{e}	25.44^{b}
Alfalfa	70.15^{a}	51.27^{a}	18.88^{a}
Kombar	87.33^{b}	57.06^{bcd}	30.27^{cd}
SEM	.999	1.103	.693

Means in column with different letters differ ($P < .05$).
SEM = Standard error of the mean.

The average disappearance rate of NDF, ADF, and Hc differed between varieties and replications.

The NDF disappearance rate of Kombar barley was significantly higher at 6 h ($P < .05$) (Table 26).

Table 26. NDF disappearance rate (g/h) for wheat varieties, ammoniated straw, alfalfa, and Kombar barley

Variety	Time, h			
	6	12	24	48
Manning	.0021[b]	.0057[b]	.0048[a]	.0061[a]
Survivor	.0022[b]	.0050[b]	.0060[a]	.0049[a]
Ute	.0023[b]	.0052[b]	.0088[b]	.0056[b]
Weston	.0074[b]	.0069[ab]	.0053[a]	.0054[a]
1549-19	.0029[b]	.0069[ab]	.0056[a]	.0053[a]
Ammoniated straw	.0073[b]	.0069[ab]	.0075[a]	.0058[a]
Alfalfa	.0072[b]	.0094[ab]	.0066[a]	.0055[a]
Kombar	.0151[a]	.0110[a]	.0077[a]	.0066[a]
SEM	.0016	.0016	.0016	.0016

Means in column with different letters differ ($P < .05$).
SEM = Standard error of the mean.

Acid detergent fiber rate of disappearance exhibited the same tendencies characteristic of NDF. The only differences ($P < .05$) were the lower rates of Survivor and Ute at 12 h and 48 h, respectively (Table 27). The uniformity of ADF disappearance was similar to results obtained with the barley and other wheat varieties.

Hc rate of disappearance of Manning wheat was lower ($P < .05$) at 6 and 12 h (Table 28).

Table 27. ADF disappearance rate (g/h) for wheat varieties, ammoniated straw, alfalfa, and Kombar barley

Variety	Time, h			
	6	12	24	48
Manning	.0027[b]	.0044[a]	.0032[a]	.0039[ab]
Survivor	.0003[b]	.0019[b]	.0033[a]	-.0001[b]
Ute	.0001[b]	.0028[b]	.0051[a]	.0033[ab]
Weston	.0036[ab]	.0046[a]	.0030[a]	.0034[ab]
1549-9	-.0001[b]	.0039[a]	.0034[a]	.0039[ab]
Ammoiated straw	.0034[ab]	.0036[a]	.0050[a]	.0039[ab]
Alfalfa	.0035[ab]	.0055[a]	.0043[a]	.0038[ab]
Kombar	.0078[a]	.0069[a]	.0044[a]	.0042[a]
SEM	.00126	.00126	.00126	.00126

Means in column with different letters differ ($P < .05$).
SEM = Standard error of the mean.

Table 28. Hc disappearance rate (g/h) for wheat varieties, ammoniated straw, alfalfa, and Kombar barley

Variety	Time, h			
	6	12	24	48
Manning	-.0006c	.0012c	.0016b	.0021b
Survivor	.0018b	.0030b	.0026a	.0050a
Ute	.0022b	.0023b	.0036a	.0023b
Weston	.0030b	.0023b	.0022a	.0020b
1549-19	.0030b	.0030ab	.0022a	.0019b
Ammoniated straw	.0038b	.0034ab	.0025a	.0018b
Alfalfa	.0037b	.0039ab	.0022a	.0017b
Kombar	.0072a	.0045a	.0032a	.0024b
SEM	.00077	.00077	.00077	.00077

Means in column with different letter differ ($P < .05$).
SEM = Standard error of the mean.

Discussion

Barley and wheat varieties differed in digestibility. Kernan et al. (1979) also reported that invitro digestible organic matter (IVDOM) varied from 43.1 to 47.7% for different straw varieties. Thus selection could improve the average feed value of straw.

Because of the higher CP content of barley (Kernan et al., 1979), it has been assumed that barley straw is more nutritive than wheat straw. Our results did not consistently support this assumption, because some wheat varieties presented higher nutritive value than barley, which is consistent with the finding of White et al. (1981), who studied the IVMD of 45 straw cultivars; the dwarf cultivars were more digestibility than the taller cultivars. Capper (1988) suggested that the higher digestibility of dwarf and simidwarf barley cultivars reflected the higher proportion of leaves to steams. The leaf/steam ratios of the varieties evaluated in this study were not known, although Columbia, Fiesta, and Kombar barley, and Daws, Dusty, Malcom, Manning, Ute, and 1549-19 wheat varieties are classified as short varieties. Rollo, Cache, Hansel, Survivor, and Weston are classified as tall varieties. Russell and Steptoe are classified as medium tall varieties (Albrechtsen et al., 1990, 1992). Many short varieties had a significantly higher DMD; DMD's of Colombia, Dust, and Daws were intermediate. Tall and

medium tall varieties, like Rollo, Cache, and Survivor, had a low DMD, as did Steptoe, in which DMD is due to the effect of ammonia treatment. Apparently, our finding seemed to support the hypothesis that digestibility increases with the proportion of leaves. In fact, it has long been known that the leaves are more digestible than stems (Mowat et al., 1965).

The nutritive quality of a feedstuff is usually first assessed by studying the chemical composition and proportion of the cell wall. However, in this study barley or wheat varieties with similar NDF and ADF levels often differed in solubility. Additional studies are warranted to compare the disappearance of different components of the straws.

Selection to increase digestibility of straw can improve the efficiency of utilization. Capper (1986) fed Awassi sheep with straw of different quality. A 4% increase in straw DM digestibility increased intake by 4.8 g/kg $W^{0.75}$ per day and metabolizable energy intake by 2.1 MJ/d (0.5019 Mcal/d), 29.17 % of the estimated maintenance requirement.

Implication

Selecting barley and wheat varieties whose straws are more digestible may improve production efficiency, decreasing problems associated with the use of ammonia. These findings should also be considered by cereal breeders to select and improve the future cereal varieties.

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CHAPTER VI

NITROGEN AND ENERGY BALANCE OF WESTERN WHITE-FACE EWES USED FOR MILK PRODUCTION

Abstract

The production of ewe milk may be a good alternative to increase the profitability of sheep producers. Large numbers of farmers are interested in this type of production system. The objective of the present research was to determine the efficiency of CP and energy utilization by commercial range ewes used for milk production. Eight ewes in late lactation and four ewes in early lactation were placed in metabolism crates housed in a room with automated temperature, ventilation, and day-length control. During early lactation, the ewes had ad libitum access to a diet containing 13.89% CP and 4.3 Mcal/kg GE and composed of alfalfa hay, corn silage, soybean meal, and ammoniated straw. During late lactation the ewes received a supplement composed of corn, barley, and molasses (9.17% CP and 4.04 Mcal/kg GE), plus alfalfa hay (17.39% CP and 4.4 Mcal/kg GE), each comprising 50% of the diet. Diet intake, feces, urine, and milk output were measured for 20 d after a 14-d adaptation period. Diet and feces were analyzed for DM, CP, NDF, ADF, ADL, Ash, GE, and EE. Urine was analyzed for CP and GE. Milk was analyzed for GE along with standard Dairy Herd Improvement Association (DHIA) analysis. Methane emission was calculated based on apparent carbohydrate

digestion. During early lactation, .429 L of milk was produced per Kg of DM consumed. The ratio was .338 in late lactation. Nitrogen balance was positive during both lactation periods. Thirty-two percent of the CP consumed was secreted in milk during early lactation, only 26% during late lactation. Conversions of diet ME to milk GE was 15.14 and 14.16% for the same period. The relatively low efficiency of nutrient conversion to milk might have occurred because the range ewes were not fully adapted to dairy management techniques.

Introduction

Production of ewe milk may be a profitable alternative for sheep producers faced with a shift in resource base from public range to privately owned pasture and meadows, or for producers with access to only small parcels of highly productive land. For centuries, Mediterranean countries have been economically successful in the production of ewe milk. They have genetically developed breeds of sheep specially for milk production. Examples are the Awassi of Israel and Sarda of Sardinia, Italy (Hatziminaoglu, 1991).

Production of ewe milk is a very new enterprise in the United States. Research to evaluate the potential of ewe dairy production was initiated in the early 1980's (Boylan, 1984). Recently, Brindley (1995) evaluated western white-face range ewes for this purpose. She concluded that western white-face

ewes can be a good milking breed to initiate a ewe dairy industry in United States. She reported .821 Kg of fluid milk/ewe, daily during 70 d, equivalent to .808 L/ewe, daily (density 1.0161). The Navajo Churro breed was also evaluated and produced much less, .485 Kg/ewe, daily during 50 d, equivalent to .477 L/ewe, daily (density 1.0161). Interestingly, this breed's European ancestor, the Spanish Churro, has been selected for fluid milk production. These levels of milk production are very low compared to other breeds. For example, the Assaf of Israel produces .521 to 2.45 L/ewe, daily in 100 to 117 d, or the Awassi, also of Israel, produces .722 to 1.35 L/ewe, daily in 144 to 260 d after weaning and does not include the amount of milk consumed by the lambs (Boylan, 1984; Sakul and Bradford, 1991).

Ewe milk production is affected by several factors. The nutritional condition of the ewe is one of the most important. This is especially true during the last third of pregnancy and during early lactation when nutritional status is reflected in the growth and development of lambs (Gardner et al., 1964; Hadjipieris et al., 1966).

Gardner and Hogue (1964), Van Es (1975), and Tissier et al. (1980) reported the efficiency of nutrient conversion to milk was 60 to 70% in sheep, which is higher than in cattle. This is mainly due to higher solids content of ewe milk. These measurements were made on ewes in a ewe-lamb production system

using the oxytocin evacuation technique. This method may overestimate milk produced in practical situations by 19 to 20% (Coombe et al, 1960; Hussein and Jordan, 1990).

To be meaningful for a producer contemplating a shift to ewe milk production, data regarding total milk production and production efficiency should be measured in more typical situations normal endogenous actuation of neuro-hormonal reflexes. It has been reported that there can be from 7.4 to 27% residual milk remaining in the mammary gland subsequent to natural stimulation (Heap et al., 1986).

The objective of this study was to generate baseline data on the efficiency of utilization of ME and CP for milk production in western white-face ewes, which are commonly used by range ewe-lamb operations in the western United States.

Materials and Methods

The evaluations of ewes were made during early and late lactation from May 10 to June 14, 1995, and July 21 to August 18, 1994, respectively.

Early Lactation

Four ewes in their third lactation were housed in elevated metabolism crates designed for collection and separation of feces and urine. According to production records, the ewes were from 4 to 10 d into lactation. Milking of the ewes was accomplished with an electrically powered,

pulsating vacuum system similar to that used in commercial cow milk production but scaled in size for sheep (La Paysanne Inc., Gascoigne Milking Equipment Ltd., Minniapolis, MN).

Crates were housed in a room with automated temperature, ventilation, and day-length control. Feeding and milking times were 0700 and 1700 daily. Ewe had ad libitum access to a total mixed ration composed of alfalfa hay, corn, soybean meal and ammoniated straw. Amount offered was adjusted daily to allow the consumption of a majority of the diet, minimizing the rejection to a value not higher than 5%. The diets were fortified with vitamins and minerals to meet NRC (1985) recommendations (Table 29). Ewes were fed experimental diets for a 14-d adaptation period, followed by a 12-d evaluation period. The early lactation period for each animal started at d 27 of lactation.

During the evaluation period, diet and water intake were measured, as well as fecal, urine, and milk output. Diet

TABLE 29. Chemical composition of the experimental diet used during evaluation of early lactation, DM basis

Nutrient	Amount
Dry matter, %	83.86
Crude protein, %	13.89
NDF, %	48.39
ADF,%	23.29
GE, Mcal/Kg	4.396
Ash, %	6.89

sampling began one day prior to the beginning of the fecal collection and proceeded throughout the experimental period. Daily fecal collections were weighed, mixed, and subsampled (approximately 10%). Subsamples were placed in a forced-air oven at 60° C for 72 h to determinate DM. Both diet and fecal samples were ground to pass a 1 mm screen and then composited for each 2-d period. The experimental diet and feces were analyzed for DM (105° C for 8 h), CP (Hach et al., 1985), NDF and ADF (filter bag system, Komarek, 1993), ADL (Van Soest, 1982), ASH (AOAC, 1990), GE (AOAC, 1990) and EE (AOAC, 1990). Urine collections were stabilized with a saturated solution of mercuric chloride. Urine volume was measured daily and a 200 mL subsamples were frozen at -20° C and subsequently freeze-dried. Dried urine samples were analyzed for CP (Hach et al., 1985) and GE (AOAC, 1990). Metabolizable energy of the diets was estimated from the GE content of the diet and urine, with methane production estimated from Swift's equation (1948) using amount of carbohydrate digested. Milk volume was measured daily at 0700 and 1700. From each milking, 20 ml of milk were placed in a sterile polyethylene bag containing a preservative (Microtabs®; Bronopol and Natamycin). Milk samples were analyzed by the Logan DHIA for CP. Simultaneously, a 100 ml milk subsample was immediately frozen at -20° C and subsequently freeze-dried. Dried milk samples were analyzed for GE (AOAC, 1990). One ewe was eliminated from

the study because she failed to adapt to the metabolism crates and(or) milking procedures and ceased milk production.

Late Lactation

Eight western white-face ewes, in their third lactation, and between days 95 and 105 of lactation, were used. Similar materials and methods were used as in the early lactation evaluation, except for the diet.

In this case, the ewes received ad libitum access to a diet composed of alfalfa hay and a commercial grain supplement composed of rolled corn and barley with added molasses (Table 30). The alfalfa was chopped and top-dressed with the supplement. The proportion of hay and supplement was adjusted each day to remain at 50:50 with rejections limited to 5% of that amount offered. The diet was fortified with vitamins and minerals to meet NRC (1985) recommendations.

Ewes were fed the diet for a 14-d adaptation period, followed by a 23-d evaluation period. The measurements and chemical analyses made were similar to those in the early lactation evaluation, except the samples were composited by each 3-d period.

Two ewes were eliminated from the analyses and from the experiment because they did not adapt to the experimental protocol.

Means and standard deviations (SD) were calculated for each ewe, considering all the measurements of early and late

TABLE 30. Chemical composition of the diet used during late lactation evaluation, DM basis

Nutrient	Amount	
	Alfalfa hay	Commercial supplement
Dry matter, %	89.65	84.78
Crude protein, %	17.39	9.17
NDF, %	48.58	46.46
ADF, %	36.01	5.91
GE, Mcal/Kg	4.435	4.042
Ash, %	10.35	3.59

lactation. Means and SD were calculated as a total for all ewes in each period.

Results and Discussion

Early Lactation

Diet intake and milk yield between days 27 and 39 of lactation are presented is Table 31. Intake is within the normal range type of ewe. Milk yields were lower than those reported by Brindley (1995), who used sheep from the same flock in her evaluation, reporting .808 L/d produced during a 70-d period. These yields are also much lower than those of milking ewes breeds, even though the data represent the highest yielding period of lactation. These ewes were housed in metabolism crates, which may have affected milk production.

The low milk yield resulted in a low milk efficiency (L/kg DM consumed). In the case of the Karagouniko breed in

TABLE 31. Diet intake and milk production of ewe during early lactation

Ewe No.	Diet intake, Kg		Milk yield, L		Milk/Int, L/Kg	
	Mean	SD	Mean	SD	Mean	SD
1	1.769	.205	.878	.174	.492	.060
2	1.327	.375	.649	.174	.496	.044
3	1.652	.077	.522	.087	.316	.029
Total	1.583	.229	.683	.180	.429	.112

Greece, Fegeros et al. (1995) reported an efficiency of .583 L/kg. Both are lower than the 1.5 L/kg approximated for dairy cows (Kung et al., 1993; Coomer et al., 1993).

The CP balance during the evaluation period was always positive (Table 32), even though the ewes were in the period of lactation in which it is presumed that they use body CP to produce milk. In other words, the consumption of dietary CP was adequate to produce the milk measured. Both CP and ME were within requirement levels for 40-Kg ewes suckling single lambs (NRC, 1985).

An explanation for this nutritional behavior can be found in the efficiency of CP and ME utilization with respect to milk production (Table 33). The milk CP efficiencies reported here are similar to those reported by Fegeros et al. (1995). They reported 20.07 and 17.98% for control and treatment of Karagouniko ewes, respectively. The control consisted of alfalfa hay plus a concentrate and the treatment consisted of

TABLE 32. Ewe early lactation crude protein and energy balance

	CP balance, Kg		Metabolizable Energy, Mcal	
Ewe No.	Mean	SD	Mean	SD
1	.153	.023	5.017	.679
2	.137	.033	4.401	.659
3	.110	.048	4.235	.409
4	.164	.057	5.079	1.385
Total	.142	.028	4.777	.470

TABLE 33. Ewe early lactation crude protein and energy utilization efficiency.

	Milk CP/Intake CP, %		Milk GE/ME, %	
Ewe No.	Mean	SD	Mean	SD
1	19.95	2.11	15.73	2.17
2	21.25	5.05	19.75	6.14
3	13.70	5.21	9.93	2.78
Total	18.30	4.03	15.14	4.94

wheat straw plus the same concentrate, but contained dried citrus pulp. Both diets were isonitrogenous and isoenergetic. These values are lower than those normally reported for dairy cows, which are around 24.61 to 37.78% (Christensen et al., 1993; Coomer et al., 1993; Meijer et al., 1995).

Late Lactation

The lactation curve of ewes is similar to that of cows and goats. Milk production of ewes reaches a peak between weeks 3 and 4 and gradually decreases until the end of

lactation (Geenty, 1979). It is interesting that milk yields during late lactation (about 95 d) in this study were higher than those measured during early lactation (Table 34). This may be explained by the fact that different ewes and diets were used in the measurements. However, it is interesting that efficiency was higher during early lactation even though production was lower.

As in early lactation, CP balance was always positive, but with higher CP retention (Table 35). During late lactation, it is normal to measure increased CP retention because CP in milk decreases, which increases the availability of CP for body maintenance. This may also explain the lower ME extraction. In this case, the ME was lower than that of early lactation, but with higher milk yield.

The CP efficiencies were not different from those measured during early lactation (Table 36). These

TABLE 34. Diet intake and milk production of ewes during late lactation

	Diet intake, Kg		Milk yield, L		Milk/Int, L/Kg	
Ewe No.	Mean	SD	Mean	SD	Mean	SD
1	2.202	.438	.533	.176	.237	.093
2	2.352	.375	1.043	.151	.460	.107
3	2.195	.519	.511	.195	.258	.127
4	2.034	.486	.809	.264	.435	.155
5	2.240	.619	.657	.229	.309	.081
Total	2.205	.114	.711	.221	.339	.103

efficiencies are low compared to some reported in the literature (Tissier et al., 1980).

The low efficiency measured in this evaluation is likely a result of the relatively low milk production of this sheep breed. However, the low milk yield could also be a consequence of higher residual milk retained by the ewes. Heap et al. (1986) reported that 7.4 to 27.2% of the total milk was retained by Friesland ewes, especially during high yield periods.

The completeness of milk removal during milking depends on a neuro-hormonal reflex, which produces oxytocin that affects the letdown of milk from the sinuses. This neuro-hormonal reflex, can be affected by various factors. Sustained lactation apparently exists in many of the breeds selected for dairy production, and affects the letdown of milk (Louca, 1972). Sustained lactation patterns have been found

TABLE 35. Ewe late lactation crude protein and energy balance

	CP balance, Kg		Metabolizable Energy, Mcal	
Ewe No.	Mean	SD	Mean	SD
1	.203	.048	3.412	.794
2	.230	.0820	3.484	.874
3	.197	.038	3.090	1.053
4	.168	.045	2.888	.7545
5	.191	.061	3.502	1.279
Total	.198	.022	3.5752	.2729

TABLE 36. Ewe late lactation crude protein and energy utilization efficiency

	Milk CP/Intake CP, %		Milk GE/ME, %	
Ewe No.	Mean	SD	Mean	SD
1	15.14	5.22	10.85	5.00
2	22.45	7.07	19.61	5.80
3	17.07	6.45	9.51	3.81
4	22.44	7.27	17.80	7.90
5	20.02	14.24	13.05	4.65
Total	19.42	4.10	14.16	4.38

in dairy type crossbred ewes when managed for milk production or when suckling lambs (Louda and Doney, 1976). Black-face ewes produced lower milk yield during the second half of lactation than East Friesland x Blackface ewes (Doney et al., 1979; Doney et al., 1981). These may be an explanation to the low milk production obtained during these evaluations. The ewes utilized during the early lactation portion of the present study were being milked for the first time. As a consequence, their production and efficiency were likely affected by environment, i.e., being housed in metabolism crates, diets, and exposure to milking machines. Western white-face ewes are socialized animals and are not very adapted to crates. The ewes used in the late lactation portion of the study had been milked during the previous lactation in the other milking study. This previous experience likely aided them with respect to overall adaptation to the experiment and

resulted in higher milk production.

Implication

A long period of adaptation is needed to accurately measure milk production efficiency and nutrient partitioning in ewes, longer than is possible in a traditional metabolism crate. Ewes not previously managed or bred for milk production may not express potential milk production by interfering with milk letdown. Producers contemplating a switch from a traditional ewe-lamb operation to a ewe dairy operation should consider this fact when selecting ewes for the operation. It may be advantageous to purchase ewes adapted both genetically and environmentally to a dairy situation rather than trying to adapt ewes bred and reared in a different environment.

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CHAPTER VII

CONCLUSIONS

The ammoniation of mature grass is a good alternative to increase the efficiency of the grass utilization. The ammoniation increases the digestibility of grass DM, allowing a higher availability of nutrients for ewe nutrition. The increased ruminal ammonia concentration as a consequence of ammoniation was within the normal range as reported in the literature (Owen and Zinn, 1988). This level is well within the safety range for the animal health (Essing et al., 1988).

The utilization of ammoniated straw during the last trimester of gestation is an alternative to decrease winter feeding costs. Although the treatment did not improve the body weight of the ewes and did not enhance the wool growth, it can be a good alternative because the lamb birth weight was not affected.

The response to the utilization of ammoniated straw can be improved if the straw is rehydrated before the ammoniation. The ammoniation of rehydrated straw increases its acceptability and palatability. As a consequence, feed intake, body weight, and wool growth of ewes during the last phase of pregnancy were increased.

There are some barley and wheat varieties with higher than average straw digestibility. This situation may be a good alternative to the utilization of ammonia. Apparently the

straw of dwarf or semidwarf varieties has higher digestibility due to the higher proportion of leaves.

The level of milk production of western white-face ewes is low; consequently, the CP and ME utilization is not efficient. It is probable that the low efficiency is a consequence of lack of adaptation by the ewes to the conditions used to measure the nutrient input and output. Farmers interested in starting a milking ewe production system need to consider the costs in time and effort of adapting ewes to milking management.

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APPENDICES

Appendix A.

Analysis of Variance Tables for Chapter II.

Dependent Variable: Dry Matter, %.

Source	DF	SS	MS	F value	Pr>F
Treatment	1	14.38830	14.38830	21.07	.0018
Phase	1	17.71470	17.71470	25.94	.0009
Interaction	1	1.03253	1.03253	1.51	.2538
Error	6	5.46333	.68291		
Corrected Total	11	38.59886			

Dependent Variable: Crude protein, %

Source	DF	SS	MS	F value	Pr>F
Treatment	1	219.051	219.051	354.07	.0001
Phase	1	1.14700	1.14700	1.85	.2104
Interaction	1	.35705	.35705	.58	.4692
Error	8	4.94933	.61866		
Corrected Total	11	225.50449			

Dependent Variable: Gross Energy, Kcal/g.

Source	DF	SS	MS	F value	Pr>F
Treatment	1	7400.3333	7400.33333	8.02	.0221
Phase	1	1200.0000	1200.00000	1.30	.2872
Interaction	1	21.3333	21.33333	.02	0.8829
Error	8	7383.3333	922.91666		
Corrected Total	11	16005.0000			

Dependent Variable: Neutral Detergent Fiber, %.

Source	DF	SS	MS	F value	Pr>F
Model	1	38.12767	38.1276	34.18	.0004
Phase	1	1.17187	1.17187	1.05	.3353
Interaction	1	1.86440	1.8644	1.67	.2321
Error	8	8.92280	1.11535		
Corrected Total	11	50.08680			

Dependent Variable: Acid Detergent Fiber, %.

Source	DF	SS	MS	F value	Pr>F
Model	1	3.36020	3.36020	3,98	.0812
Phase	1	26.85020	26.85020	31.79	.0005
Interaction	1	9.810208	9.81020	11.62	.0092
Error	8	6.75686	.84460		
Corrected Total	11	46.77749			

Dependent Variable: Hemicellulose, %

Source	DF	SS	MS	F value	Pr>F
Treatment	1	64.31070	64.31070	82.65	.0001
Phase	1	16.8981	16.8981	21.72	.0016
Interaction	1	3.16213	3.16213	4.06	.0786
Error	8	6.22473	.77809		
Corrected Total	11	90.59570			

Dependent Variable: Cellulose, %

Source	DF	SS	MS	F value	Pr>F
Treatment	1	59.05203	59.05203	12.36	.0079
Phase	1	29.95680	29.95680	6.27	.0367
Interaction	1	24.71070	24.71070	5.17	.0525
Error	8	38.21346	4.77668		
Corrected Total	11	151.93000			

Dependent Variable: Lignin, %.

Source	DF	SS	MS	F value	Pr>F
Treatment	1	.46020	.4602	.53	.4873
Phase	1	31.5252	31.5252	36.31	.0003
Interaction	1	.00607	.0060		
Error	8	6.94553	.8681		
Corrected Total	11	38.93702			

Dependent Variable: Ether Extract, %

Source	DF	SS	MS	F value	Pr>F
Treatment	1	.09187	.09187	7.38	.0264
Phase	1	.08840	.08840	7.11	.0286
Interaction	1	.00187	.00187	.15	.7080
Error	8	.09953	.01244		
Corrected Total	11	.28168			

Dependent Variable: Water, L.

Source	DF	SS	MS	F value	Pr>F
Treatment	1	.06992	.06992	.23	.6469
Phase	1	1.58704	1.58704	5.20	.0520
Interaction	1	1.54944	1.54944	5.08	.0542
Error	8	2.44025	.30503		
Corrected Total	11	5.64665			

Dependent Variable: Dry Matter Intake, Kg/Kg.

Source	DF	SS	MS	F value	Pr>F
Treatment	1	.09100	.08269	1.83	.2134
Phase	1	.07192	.07192	1.44	.2638
Interaction	1	.08517	.08517	1.71	.2273
Error	8	.39837	.04979		
Corrected Total	11	.64647			

Dependent Variable: Digestible Dry Matter, Kg/Kg.

Source	DF	SS	MS	F value	Pr>F
Treatment	1	.01725	.01725	6.86	.0307
Phase	1	.00003	.00003	.01	.9156
Interaction	1	.00095	.00095	.38	.5550
Error	8	.02011	.00251		
Corrected Total	11	.03834			

Dependent Variable: Digestible Dry Matter Intake, Kg/Kg.

Source	DF	SS	MS	F value	Pr>F
Treatment	1	.06192	.06192	13.52	.0974
Phase	1	.01702	.01702	.97	.3539
Interaction	1	.02412	.02412	1.37	.2752
Error	8	.14063	.01757		
Corrected Total	11	.24370			

Dependent Variable: Crude protein Digestibility, Kg/Kg.

Source	DF	SS	MS	F value	Pr>F
Treatment	1	.13589	.05033	16.89	.0001
Phase	1	.00969	.00960	3.25	.1090
Interaction	1	.00541	.00541	1.82	.2145
Error	8	.02384	.00298		
Corrected Total	11	.17484			

Dependent Variable: Digestible Energy, Mcal/Kg.

Source	DF	SS	MS	F value	Pr>F
Treatment	1	.56342	.56342	11.87	.0088
Phase	1	.04826	.04862	1.02	.3428
Interaction	1	.13091	.01309	2.76	.1354
Error	8	.37976	.0475		
Corrected Total	11	1.12236			

Dependent Variable: Metabolizable Energy, Mcal/Kg.

Source	DF	SS	MS	F value	Pr>F
Treatment	1	1234476.94	1234476.94	4.49	.0670
Phase	1	438421.64	438421.64	1.59	.2424
Interaction	1	82797.53	82797.53	.30	.5983
Error	8	2201528.54	275191.06		
Corrected Total	11	3957224.66			

Dependent Variable: Neutral detergent Fiber, Kg/Kg.

Source	DF	SS	MS	F value	Pr>F
Treatment	1	.01912	.01912	13.19	.0067
Phase	1	.00066	.00066	.46	.5188
Interaction	1	.00052	.00052	.36	.5657
Error	8	.01159	.00144		
Corrected Total	11	.03189			

Dependent Variable: Acid Detergent Fiber, Kg/Kg.

Source	DF	SS	MS	F value	Pr>F
Treatment	1	.01104	.001104	12.32	.008
Phase	1	.00381	.00381	4.26	.0729
Interaction	1	.00001	.00001	.01	.9404
Error	8	.00716	.00089		
Corrected Total	11	.02203			

Dependent Variable: Hemicellulose, Kg/Kg.

Source	DF	SS	MS	F Value	Pr>F
Treatment	1	.00110	.00110	2.46	.1557
Phase	1	.00130	.00130	2.90	.1268
Interaction	1	.00042	.00042	.94	.3615
Error	8	.00358	.00044		
Corrected Total	11	.00641			

Dependent Variable: Cellulose Digestibility, Kg/Kg.

Source	DF	SS	MS	F value	Pr>F
Treatment	1	.013994	.013994	76.46	.0001
Phase	1	.001425	.001425	7.79	.0235
Interaction	1	.000352	.000352	1.92	.2029
Error	8	.00146	.00018		
Corrected Total	11	.01723			

Dependent Variable: Lignin Digestibility, Kg/Kg.

Source	DF	SS	MS	F value	Pr>F
Treatment	1	.00030	.00030	2.45	.1565
Phase	1	.00035	.00035	2.81	.1320
Interaction	1	.00004	.00004	.33	.5814
Error	8	.00100	.00012		
Corrected Total	11	.00170			

Dependent Variable: Nitrogen Balance, gr.

Source	DF	SS	MS	F value	Pr>F
Model	1	129.757	129.757	39.61	.0002
Phase	1	12.080	12.080	3.69	.0911
Interaction	1	.294	.294	.09	.7719
Error	8	26.208	3.2766		
Corrected Total	11	168.340			

Dependent Variable: Ether Extract Digestibility, Kg/Kg.

Source	DF	SS	MS	F value	Pr>F
Treatment	1	.70567	.70567	.51	.4935
Phase	1	5.34667	5.34667	.39	.0837
Interaction	1	.01540	.01540	.01	.9182
Error	8	10.96653	1.37081		
Corrected Total	11	17.03429			

Dependent variable: Rumen PH.

Source	DF	SS	MS	F value	Pr>F
Treatment	1	.01521	.01521	.44	.5114
Phase	1	.23409	.23409	6.82	.0148
EWE	3	.24717	.08239	2.40	.0906
HR	4	1.16769	.29192	8.51	.0002
Interaction	4	.02714	.00678	.20	0.9373
Error	26	.89209	.03431		
Corrected Total	39	2.58339			

Dependent Variable: Rumen NH^3, mg/dL.

Source	DF	SS	MS	F value	Pr>F
Treatment	1	309.247	309.247	41.25	.0001
Phase	1	15.750	15.750	2.10	.1592
Ewe	3	90.824	30.274	4.04	.0175
HR	4	1153.303	288.325	38.46	.0001
Interaction	4	198.845	49.711	6.63	.0008
Error	26	194.926	7.497		
Corrected Total	39	1962.897			

Dependent Variable: Rumen Total Volatile Fatty Acid, uM.

Source	DF	SS	MS	F value	Pr>F
Treatment	1	8.973	8.973	.07	.7938
Phase	1	15.849	15.849	.12	.7284
Ewe	3	279.197	93.065	.72	.5471
HR	4	4616.972	1154.243	8.97	.0001
Interaction	4	537.287	134.321	1.04	.4035
Error	26	3344.02395			
Corrected Total	39	8802.30504			

Dependent Variable: Rumen Acetate, umol/mol.

Source	DF	SS	MS	F value	Pr>F
Treatment	1	83.700	83.700	1.45	.2398
Phase	1	5.354	5.355	.09	.7633
Ewe	3	124.194	41.398	.72	.5515
HR	4	2242.924	560.731	9.70	.0001
Interaction	4	191.584	47.896	.83	.5194
Error	26	1503.668	57.833		
Corrected Total	39	4151.426			

Dependent Variable: Rumen Propionate, umol/mol.

Source	DF	SS	MS	F value	Pr>F
Treatment	1	5.178	5.178	1.09	.3069
Phase	1	7.500	7.500	1.57	.2209
Ewe	3	110.595	36.864	7.73	.0007
HR	4	223.355	55.838	11.71	.0001
Interaction	4	43.706	10.926	2.29	.0865
Error	26	123.961	4.767		
Corrected Total	39	514.296			

Dependent Variable: Rumen Isobutyrate, umol/mol.

Source	DF	SS	MS	F value	Pr>F
Treatment	1	1.138	1.138	181.95	.0001
Phase	1	.235	.236	37.70	.0001
Ewe	3	.494	.165	26.38	.0001
HR	4	.081	.020	3.24	.0276
Interaction	4	.011	.0027	.43	.7831
Error	26	.162	.0062		
Corrected Total	39	2.212			

Dependent Variable: Rumen Butyrate, umol/mol.

Source	DF	SS	MS	F value	Pr>F
Treatment	1	42.164	42.1648	9.91	.0041
Phase	1	9.202	9.202	2.16	.1533
Ewe	3	7.715	2.572	.60	.6179
HR	4	37.233	9.308	2.19	.0983
Interaction	4	10.586	2.646	.62	.6508
Error	26	110.590	4.253		
Corrected Total	39	217.493			

Dependent Variable: Rumen Isovalerate, umol/mol.

Source	DF	SS	MS	F value	Pr>F
Treatment	1	1.585	1.585	109.78	.0001
Phase	1	.164	.164	11.40	.0023
Ewe	3	.811	.270	18.73	.0001
HR	4	.598	.149	10.35	.0001
Interaction	4	.011	.003	.20	.9367
Error	26	.375	.014		
Corrected t	39	3.546			

Dependent Variable: Rumen Valerate, umol/mol

Source	DF	SS	MS	F value	Pr>F
Treatment	1	1.100	1.1008	25.14	.0001
Phase	1	.231	.231	5.28	.0298
Ewe	3	.364	.121	2.78	.0613
HR	4	.859	.464	10.61	.0001
Interaction	4	.349	.087	2.0	.1247
Error	26	1.138	.043		
Corrected Total	39	5.045			

Dependent Variable: Rumen Acetate/Propianate ratio.

Source	DF	SS	MS	F value	Pr>F
Treatment	1	1.153	1.153	11.03	.0027
Phase	1	.753	.753	7.20	.0125
Ewe	3	5.917	1.972	18.87	.0001
HR	4	1.523	.380	3.64	.0174
Interaction	4	1.153	.028	2.76	.0490
Error	26	2.717	.104		
Corrected Total	39	13.219			

Dependent Variable: Viable Bacteria, billion/ml.

Source	DF	SS	MS	F value	Pr>F
Treatment	1	66.124	66.124	0.14	.7228
Phase	1	1995.013	1995.013	4.37	.1048
Interaction	1	48.347	48.347	0.11	.7612
Error	4	1825.833	456.458		
Corrected Total	7	3935.319			

Dependent Variable: Ciliate Protozoa, Million/ml.

Source	DF	SS	MS	F value	Pr>F
Treatment	1	6.997E+10	6.997E+10	3.48	.073
Phase	1	4.304e+08	4.304E+10	.02	.8848
Ewe	3	1.270E+11	4.235E+10	2.11	.1236
HR	4	2.783E+10	6.957E+09	.35	.8442
Interaction	4	8.677E+10	2.169E+10	1.08	.3868
Error	26	5.224E+11	2.00933E+10		
Corrected Total	39	8.344E+11			

Appendix B

Analysis of Variance Tables for Chapter III.

Dependent Variable: Diet intake, Kg

Source	DF	SS	MS	F value	Pr>F
Treatment	1	.00933	.00933	.36	.5793
Error	4	.10286	.02571		
Corrected Total	5	.11219			

Dependent variable: Crude protein intake, kg.

Source	DF	SS	MS	F value	Pr>F
Treatment	1	.00007	.00007	.17	.7030
Error	4	.00188	.0004		
Corrected Total	5	.0019			

Dependent variable: ADF intake, Kg.

Source	DF	SS	MS	F value	Pr>F
Treatment	1	.03245	.03245	.38	.0376
Error	4	.01383	.00345		
Corrected total	5	.04629			

Dependent Variable: Initial weight, Kg.

Source	DF	SS	MS	F Value	Pr>F
Treatment	1	31.893	31.892	.08	.7818
Pen (trt)	4	2160.222	540.055	1.31	.2758
Type of birht	3	1189.229	396.409	.96	.4164
Error	64	26384.317	412.254		
Corrected Total	72	29842.082			

Dependent Variable: Final weight, Kg.

Source	DF	SS	MS	F value	Pr>F
Treatment	1	812.547	812.547	17.75	.0001
Inwt	1	32322.703	32322.703	706.21	.0001
Error	70	3203.854	45.769		
Corrected Total	72	36525.780			

Dependent Variable: Gain, Kg.

Source	DF	SS	MS	F Value	**Pr>F**
Treatment	1	689.380	689.380	14.32	.0003
Inwt	1	45.894	45.894	.95	.3322
Error	70	3368.807	48.125		
Corrected Total	72	4110.438			

Dependent Variable: Lambs birth weight, Kg.

Source	DF	SS	MS	F value	Pr>F
Treatment	1	1.352	1.352	.72	.3979
Sex	1	1.219	1.219	.65	.422
Type of birth	2	4.592	2.296	1.22	.298
Error	110	206.512	1.877		
Corrected Total	114	213.734			

Dependent Variable: Fleece, Kg.

Source	DF	SS	MS	F value	Pr>F
Treatment	1	5.339	5.339	6.39	.0144
Inwt	1	1.527	1.527	1.83	.1818
Error	55	45.940	.835		
Corrected Total	57	53.030			

Appendix C

Analysis of Variance Tables for Chapter IV.

Dependent Variable: Dry matter intake, Kg.

Source	DF	SS	MS	F value	Pr>F
Treatment	1	1.77235	1.77235	305.26	.0001
Error	4	.02322	.00580		
Corrected Total	5				

Dependent Variable: Crude protein intake, kg.

Source	DF	SS	MS	F value	Pr>F
Treatment	1	.04611	.04611	351.11	.0001
Error	4	.00052	.00013		
Corrected Total	5				

Dependent Variable: Acid detergent fiber (ADF) intake, kg.

Source	DF	SS	MS	F value	Pr>F
Treatment	1	.38253	.38253	301.09	.0001
Error	4	.00508	.00127		
Corrected Total	5	.38761			

Dependente Variable: Middle Weight, kg.

Source	DF	SS	MS	F value	Pr>F
Treatment	1	229.577	229.5778	23.11	.0086
Pen (treat)	4	39.729	9.9324	1.07	.3794
Initial weight	1	7243.061	7243.0613	781.20	.0001
Error	56	519.218	9.2717		

Dependent Variable: Final weight, kg.

Source	DF	SS	MS	F value	Pr>F
Treatment	1	382.111	382.111	257.66	.0001
Pen (treat)	4	5.932	1.483	0.12	.9756
Initial weight	1	4173.968	4173.968	330.40	.0001
Error	43	543.223	12.633		

Dependent Variable: Gain, Kg/d.

Source	DF	SS	MS	F value	Pr.F
Treatment	1	115.142	115.142	14.58	.0188
Pen (treat)	4	31.595	7.898	1.62	.1862
Initial weight	1	.871	.871	.18	.674
Error	43	209.460	4.871		

Dependent variable: Birth weight, kg.

Source	DF	SS	MS	F value	Pr>F
Treatment	1	.5321	.5321	.03	.8740
Pen (treat)	4	74.5549	18.6387	4.80	.0017
Sex	1	.0003	.0003	.00	.9920
Birth Type	1	24.3683	24.3683	6.28	.0144
Error	74	287.0640			

Dependent variable: Fleece weight, kg.

Source	DF	SS	MS	F value	Pr>F
Treatment	1	2.9778	2.9778	14.87	.0182
Pen (treat)	4	.8012	.2003	.49	.7454
Initial weight	1	.8086	.8086	1.96	.1696
Error	36	14.8159	.4115		

Appendix D.

Analysis of Variance Tables for Chapter V.

Dependent Variable; Barley varieties DM dissapareance, %

Source	DF	SS	MS	F value	Pr>F
Variety	7	.79002	.11286	22.45	.0001
Time	4	1.63535	.40883	81.31	.0001
Replication	2	.05918	.02959	5.89	.0042
Var x Time	28	.16935	.00604	1.20	.2588
Error	78	.39225	.00502		

Dependent Variable: Barley varieties NDF residual, %.

Source	DF	SS	MS	F value	Pr>F
Variety	7	.08868	.01266	44.48	.0001
Time	4	.00922	.00230	8.10	.0001
Replication	2	.00679	.00339	11.93	.0001
Var x Time	28	.03721	.00132	4.67	.0001
Error	78	.02231	.00028		

Dependent Variable: Barley varieties ADF residual, %.

Source	DF	SS	MS	F value	Pr>F
Variety	7	.05907	.00843	24.10	.0001
Time	4	.00081	.00020	0.58	.6777
Replication	2	.00924	.00462	13.20	.0001
Var X Time	28	.03920	.00140	4.0	.0001
Error	78	.02731	.00035		

Dependent Variable: Barley varieties Hc residual, %.

Source	DF	SS	MS	F value	Pr>F
Variety	7	.24502	.03500	138.62	.0001
Time	4	.00762	.00190	7.55	.6777
Replication	2	.00206	.00103	4.10	.0203
Var x Time	28	.00227	.00008	0.32	.9994
Error	78	.01969	.00025		

Dependent Variable: Barley varieties NDFD rate, g/h.

Source	DF	SS	MS	F value	Pr>F
Variety	7	.00655	.00093	7.45	.0001
Time	3	.00074	.00024	1.98	.1276
Replication	2	.00009	.00004	.39	.6802
Var X Time	21	.00776	.00036	2.94	.0007
Error	54	.00678	.00012		

Dependent Variable: Barley varieties ADFD rate, g/h.

Source	DF	SS	MS	F value	Pr>F
Variety	7	.00255	.00036	5.42	.0001
Time	3	.00023	.00007	1.14	.3400
Replication	2	.00016	.00008	1.25	.2944
Var X Time	21	.00278	.00013	1.97	.0236
Error	54	.00363	.00006		

Dependent Variable: Barley varieties HcD rate, g/h.

Source	DF	SS	MS	F value	Pr>F
Variety	7	.00114	.00016	6.05	.0001
Time	3	.00026	.00008	3.23	.0294
Replication	2	.00002	.00001	.50	.6082
Var X Time	21	.00159	.00007	2.81	.0012
Error	54	.00145	.00002		

Dependent Variable: Wheat varieties (first group) DMD, %.

Source	DF	SS	MS	F value	Pr>F
Variety	7	1.26669	.18095	182.71	.0001
Time	4	1.76013	.44003	444.29	.0001
Replication	2	.00277	.01387	14.01	.0001
Var X Time	28	.08837	.00315	3.19	.0001
Error	77	.07626	.00099		

Dependent Variable: Wheat varieties (first group) NDF residual, %

Source	DF	SS	MS	F value	Pr>F
Variety	7	1.13223	.01889	45.16	.0001
Time	4	.20208	.00505	12.08	.0001
Replication	2	.00073	.00046	1.12	.6611
Var X Time	28	.05325	.00190	4.55	.0001
Error	77	.03220	.00041		

Dependent Variable: Wheat varieties (first group) ADF residual, %.

Source	DF	SS	MS	F value	Pr>F
Variety	7	.03348	.00478	11.03	.0001
Time	4	.01332	.00333	7.68	.0001
Replication	2	.00036	.00018	.42	.6611
Var X Time	28	.06434	.00229	5.30	.0001
Error	77	.03339	.00043		

Dependent Variable: Wheat varieties (first group) Hc residual, %.

Source	DF	SS	MS	F value	Pr>F
Variety	7	.00414	.00059	8.77	.0001
Time	4	.00298	.00099	14.76	.0001
Replication	2	.00139	.00069	10.33	.0002
Var X Time	28	.00514	.00024	3.63	.0001
Error	77	.00371	.0006		

Dependent Variable: Wheat varieties (first group) NDF disappearance rate, g/h.

Source	DF	SS	MS	F value	Pr>F
Variety	7	.00142	.00020	8.08	.0001
Time	3	.00106	.00035	14.08	.0001
Replication	2	.00086	.00043	10.33	.0002
Var X Time	21	.00165	.00007	3.63	.0001
Error	55	.00138	.00002		

Dependent Variable: Wheat varieties (first group) ADF disappearance rate, g/h.

Source	DF	SS	MS	F value	Pr>F
Variety	7	.00142	.00020	8.08	.0001
Time	3	.00106	.00035	14.08	.0001
Replication	2	.00086	.00043	10.33	.0002
Var X Time	21	.00165	.00007	3.63	.0001
Error	55	.00138	.00002		

Dependent Variable: Wheat varieties (first group) Hc disappearance rate, g/h.

Source	DF	SS	MS	F value	Pr>F
Variety	7	.10742	.01534	46.18	.0001
Time	3	.04687	.01562	47.02	.0001
Replication	2	.00066	.00033	1.01	.3716
Var X Time	21	.34123	.01591	47.88	.0001
Error	55	.01827	.00033		

Dependent Variable: Wheat varieties (second group) DM disappearance rate, g/h.

Source	DF	SS	MS	F value	Pr>F
Variety	7	1.10991	.15855	89.49	.0001
Time	4	1.36978	.34244	193.28	.0001
Replication	2	.07119	.03559	20.09	.0001
Var X Time	28	.06442	.00230	1.30	.1841
Error	78	.13819	.00177		

Dependent Variable: Wheat varieties (second group) NDF residual rate, %.

Source	DF	SS	MS	F value	Pr>F
Variety	7	.13810	.01972	65.83	.0001
Time	4	.01000	.00250	8.35	.0001
Replication	2	.00051	.00025	.85	.4304
Var X Time	28	.04374	.00156	5.21	.0001
Error	78	.02337	.00029		

Dependent Variable: Wheat varieties (second group) ADF residual, %.

Source	DF	SS	MS	F value	Pr>F
Variety	7	.5719	.00817	22.35	.0001
Time	4	.01224	.00306	8.37	.0001
Replication	2	.00319	.00159	4.37	.0158
Var X Time	28	.04128	.00147	4.03	.0001
Error	78	.02851	.00036		

Dependent Variable: Wheat varieties (second group) Hc residual, %.

Source	DF	SS	MS	F value	Pr>F
Variety	7	1.25974	.17996	123.63	.0001
Time	4	1.06427	.26606	182.78	.0001
Replication	2	.06007	.03003	20.63	.0001
Var X Time	28	.04590	.00163	1.13	.3327
Error	78	.11354	.00145		

Dependent Variable: Wheat varieties (second group) NDF disappearance rate, g/h.

Source	DF	SS	MS	F value	Pr>F
Variety	7	.00025	.00003	4.29	.0008
Time	3	.00003	.00001	1.28	.2907
Replication	2	.00023	.00011	13.46	.0001
Var X Time	21	.00227	.00001	1.25	.2467
Error	55	.00047	.00000		

Dependent Variable: Wheat varieties (second group) ADF disappearance rate, g/h.

Source	DF	SS	MS	F value	Pr>F
Variety	7	.000063	.000009	5.00	.0002
Time	3	.000006	.000002	1.22	.3115
Replication	2	.000001	.000008	4.43	.0164
Var X Time	21	.000008	.000003	2.11	.0140
Error	55	.00009	.000001		

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EXPERIENCE

Animal Scientist and Extensionist since 1977 at Los Vilos Sub-Experimental Station, Instituto de Investigaciones Agropecuarias (INIA), Los Vilos, Chile.
Teaching, Forage Managment and Animal Nutrition, since 1989. For Agricultural Technician, Agronomer and Veterinary Medicine students.

TECHNICAL PUBLICATION

Meneses R. 1990. Goat supplementation with alfalfa hay during lactation. Agricultura Técnica, (Chile) 50:159.

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AWARDS

INIA Scholarship 86/88 to obtain Master Science degree.

FAO, Santiago, Chile, recognition. World day of Food and Agriculture, October 1991.

INIA Scholarship 92/95 to obtain PhD degree.

Allan N. and Hellen Adams Award. College of Agriculture, Animal Dairy and Veterinary Sciences Department, Utah State University, Logan, Utah.