AN ABSTRACT OF THE THESIS OF

Imdad Hussain for the degree of Doctor of Philosophy

in Animal Sciences presented on October 21, 1993.

Title: EVALUATION OF LOW QUALITY ROUGHAGES AND AGRICULTURAL BY-PRODUCTS AS LIVESTOCK FEED.

Redacted for Privacy

Approved: _____

Peter R. Cheeke

Nine feeding trials and four laboratory scale experiments were conducted in this study. The study consisted of: (1) use of grass straw:corn juice (CJ) silages with fishmeal and/or alfalfa hay supplementation in beef heifers, sheep, pregnant dairy heifers, water buffaloes and Hereford cows; (2) use of cull onions:grass straw silages in sheep and their laboratory scale evaluation; and (3) evaluation of yucca extract (Deodorase) as a supplement in cattle and rabbits feeds for improving utilization of low-quality roughage-based diets. The straw:corn juice (CJ) silages proved to be similar to medium quality grass hay in terms of weight gain and feed efficiency (FE). Use of ammoniated straw:CJ silages proved even better than grass hay, and with fishmeal (FM) and/or alfalfa hay supplementation further improved their feeding value. Digestibility of ammoniated fescue straw:CJ silage was higher than grass hay in sheep. The digestibility of ryegrass straw:CJ silage was significantly higher in water buffaloes vs Hereford cows. In dairy heifers the FE of this silage plus 125 g FM per head per day (SA) was similar to grass hay and it was better in SA compared to simple silage (S). Post-partum milk production and composition did not differ among 3 treatments. In cull

onions:grass straw silages (laboratory scale), use of 0.1% raw soybean (RSB) in urea treatment, significantly improved CP and OM content. In other two experiments, CP was significantly higher in straw:onion silages treated with 3% urea than non-treated straw:onion silages, and higher in 5% urea treated vs 3% urea treated silages. The IVDMD was significantly lower in control than 3% and 5% urea treated silages. Feeding of onion:straw silage to sheep resulted in weight loss and supplementation with alfalfa pellets did not stop weight loss, and blood packed cell volume decreased from 40% to 34% after feeding onion:straw silage. Spraying of corn juice on straws did not give much improvement except that CP contents of straws sprayed with CJ mixed with 3% urea were significantly higher than plain CJ sprayed straws. In cattle and rabbits diets, use of yucca extract (YE) improved weight gain and reduced rumen ammonia-N, plasma ammonia-N and plasma urea-N levels in most of the cases especially the feeds containing urea. These results indicate that grass straw and corn juice can be successfully ensiled and can serve as substitute for medium quality grass hay on nutritional grounds. Use of ammoniated straw:CJ silage or supplementation with small quantity of FM and/or alfalfa hay has even better feeding performance than grass hay. The straw and cull onions can also be ensiled successfully. Use of YE as supplement to high-roughage diets with urea can improve ADG and FE and reduce rumen ammonia-N and plasma urea-N and thus improve N metabolism in cattle and rabbits.

EVALUATION OF LOW QUALITY ROUGHAGES AND AGRICULTURAL BY-PRODUCTS AS LIVESTOCK FEED.

by

Imdad Hussain

A THESIS

submitted to

Oregon State University

in partial fulfillment of

the requirements for the

degree of

Doctor of Philosophy

Completed October 21, 1993

Commencement June, 1994.

APPROVED

Redacted for Privacy

Professor of Animal Sciences in charge of major

Redacted for Privacy

Head of department of Animal Sciences

Redacted for Privacy

Dean of Graduate School

Date thesis is presented: October 21, 1993

Typed by: Imdad Hussain

ACKNOWLEDGEMENTS

I would like to thank Dr. P. R. Cheeke, my chief academic advisor for giving me the opportunity to complete this work. Dr. Cheeke was always full of ideas and I always enjoyed his very nice personality. I also would like to thank Dr. H. S. Nakaue and Dr. D. W. Weber for serving on my committee and being interested in my progress. I thank Dr. D. E. Johnson for serving on my committee and in teaching me different computer packages. Dr.Johnson has been extremely helpful in some of my data analysis. Thanks also to Dr.Frank S. Conklin for serving as Graduate Council representative and providing information on Western Oregon straw production and utilization.

I also would like to thank members of the Animal Sciences Department, in particular Mark Keller for assistance in lab work, Helen Chesbrough for help in word processing that made my job very easy. I also appreciate the assistance of Troy Downing, Marvin Martin, Bob Klinger, Lucy Painter and others from farm services who helped in different phases of my research. Thanks to Stanley Taylor for helping on different computer related questions. The list could certainly continue. I thank everyone in the Animal Sciences Department. I have really enjoyed being a part of Oregon State University.

Thanks to Mr. A. Wakefield of Agripac, Inc, for providing corn juice, straw:corn juice silage and cull onion:straw silage used in various studies. Thanks to Mr. and Mrs. Mike Braet of Sandy, Oregon, for allowing us to use their water buffaloes. Financial support for corn juice-straw silage experiments was provided by the Linn-Benton Regional Strategy Commission. Ms. Flaxen Conway of this commission was very helpful in the initiation of this work. Thanks are expressed to Alltech Biotechnology, Inc., Nicholasville, KY for providing the yucca extract used in these studies.

I also wish to thank my friends, Khalidullah, Nahashon, Woldu and Ismail for all their help. I also would like to express my most appreciation to the Government of Islamic

Republic of Pakistan, Pakistan Agricultural Research Council, Islamabad and USAID for providing financial assistance for the completion of this degree.

Last but not least, I would like to thank all my family members for their love, support and understanding during the course of this work.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 1

EVALUATION OF LOW QUALITY ROUGHAGES AND AGRICULTURAL BY-PRODUCTS AS LIVESTOCK FEED.

LITERATURE REVIEW

INTRODUCTION

The Willamette Valley of Oregon produced greater than one million tons of grass seed straws in 1990 (CH_2M Hill and O.S.U., 1991), and at least six million gallons of corn juice (CJ) are currently available each year (A.Wakefield, Agripac, Inc., Personal Communication, 1989). Because of air and water pollution concerns, disposal of these products is becoming increasingly regulated. The traditional methods of their disposal have been or may be prohibited.

Depending on fluctuations in market price and produce quality, considerable quantities of cull onions are discarded in landfills or fed to livestock. The principal disposal method of macerating, returning to the fields and plowing under is expensive and may also increase dispersal of white rot disease. Since landfills may no longer be available for cull onions, some value added methods of their disposal also need to be investigated.

Most of the low quality roughages (LQR) like straws are low in crude protein (CP) digestible energy and many minerals. Therefore, both energy and nitrogen supplementations are needed to support animal production with diets based on LQR. On the other hand CJ and cull onions have reasonable contents of CP and soluble carbohydrates and are high in moisture. Cull onions have approximately the same nutritional value as barley grain on a DM basis (NRC, 1984). For making silage from straw, it is necessary to add a minimum of 30% water, a source of fermentable carbohydrate, and nitrogen. Cull onions and CJ could serve as

a source of these nutrients. Therefore, if straws are mixed with CJ or cull onions in the right proportions, a good quality silage may be prepared.

Chemical treatment such as anhydrous ammoniation of LQR has been shown to increase their nutritive value and digestibility (Ward and Ward, 1987; Chestnut et al., 1988.). However, anhydrous ammonia treatment requires the need for air-tight storage, poses potential danger in handling ammonia gas or may not be available in many areas. Urea has been used as a source of ammonia with similar improvements in digestibility (Craig et al., 1988; Hunt et al., 1990). Chiquette et al. (1992) reported that ammoniation of mature timothy increased energy released from structural carbohydrates which resulted in improved overall DM digestibility.

An alternate approach to achieve increased utilization of LQR is through supplementation with rumen by-pass proteins. Protein supplementation of LQR has been shown to improve the use of these feeds (McCollum and Galyean, 1985). Feeding small quantities of fishmeal (FM) as a supplement to grass silage can improve ADG in cattle (Sanderson et al., 1992). Klopfenstein and Owen (1981) and Mosi and Butterworth (1985) reported improved utilization of LQR with alfalfa hay supplementation.

There may be species differences among ruminants in their ability to utilize LQR. Many researchers (Singh and Mudghal, 1967; Poonappa et al., 1971; Razdan et al., 1971; Katiyar and Bisth, 1989) have reported higher digestibility of fibrous feeds in water buffaloes than in cattle, while others (Naga and Al-Shazly, 1969; Cheturvedi et al., 1973) reported no digestibility differences between two species. Usmani and Inskeep (1989) reported higher yields of milk and milk fat for first 75 days of lactation in water buffaloes on higher pre-partum feeding levels. However, Wiley et al. (1991) reported no effects of pre-partum nutrition on post-partum milk production.

Yucca extract (YE) which is the extract of *Yucca schidigera*, contains glycosylated compounds which can bind ammonia (Headon, 1990). Dietary YE reduces atmospheric ammonia levels in rabbit (Al-Bar et al., 1992) and broiler (Johnston et al., 1981; Al-Bar et al., 1993) confinement housing. Dietary YE increased growth rate in rabbits (Al-Bar et al., 1992), lowered rumen ammonia-N (Grobner et al., 1982; Gibson et al., 1985) and lowered plasma urea-N (Preston et al., 1987) and had no effects on total VFA production (Wu et al., 1993). Through its N-binding properties, YE might have effects on N metabolism in the rumen and the utilization of LQR.

AMMONIATION OF LOW QUALITY ROUGHAGES (LQR)

The mode of action of alkali substances such as anhydrous ammonia in improving digestion is still not completely understood. Some scientists (Mason et al., 1990) suggest that the increase in cell wall digestibility could result from the breakage of ester linkages between cell wall carbohydrates and phenolic acids, while others (Chesson and Orskov, 1984) suggest that lignin itself could be fragmented. Hvelplund (1989) suggested that chemical treatments of straw release cell wall bound N, which is normally unavailable to ruminants. Theander (1981) suggests that alkali treatment may cleave the linkages between lignin and other cell wall carbohydrates and cause partial solubilization of hemicellulose (HC) and lignin. Ammonia treatment may improve nutritional value of straws by swelling the cellulose moiety, thus improving dry matter digestibility (DMD) (Saenger et al., 1982). Furthermore, the N that is added to the forage as a result of treatment is used by the increased ruminal microbial population when more energy becomes available (Waagepetersen and Thomsen, 1977). In any case the result is an increase in accessibility of rumen microbes to cell wall constituents as observed by Spencer and Akin (1980) and Grenet and Barry (1990).

Saenger et al. (1983) found an increase in crude protein (CP) and decrease in HC content, when they treated wheat straw with anhydrous ammonia (3% of DM). DelCurto et al. (1991) found an increase in CP (5.75 to 14.82%) and decrease in neutral detergent fiber (NDF) content (71.2 to 69.8 %) in tall fescue straw treated with 3% urea. Llamas-Lamas and Comb (1990) found that ammoniation of wheat straw (3.5% DM) decreased NDF concentration from 86.9% to 80.6% and increased CP content from 3.6 to 11.1 %. Buettner et al.(1982) demonstrated solubilization of HC when fescue hay was treated with ammonia. Dryden and Leng (1988), and Van Soest et al. (1984) also reported decreases in HC as a result of ammoniation. Brown (1988) reported that ammoniation with anhydrous ammonia increased total N and IVOMD and reduced NDF concentrations of stargrass hay. Kunkle et al.(1980) reported that the DM digestibility of chopped corn plant residue was increased by 5 percentage units by ammoniation before ensiling at 3.5% of DM. Paterson et al. (1979) reported that the DM digestibility of corn plant residue ammoniated at 3% of DM before ensiling was increased 13.9 percentage units.

Nelson et al. (1985) reported that ammoniation or protein supplementation of LQR had no effect on DMI. Hunt et al. (1990) reported that DMI was numerically greater for beef steers consuming untreated vs urea treated hay. Naseeven and Kincaid (1992) found that ammoniation (3% of DM) of wheat straw did not significantly increase DMI compared to untreated straw but improved ADG. The decreased consumption of urea treated straws may be because of some palatability problem, because urea is not palatable, and some residual urea may depress feed intake. However many workers have reported increase in FI as a result of ammoniation (Brown, 1988; Llamas-Lamas and Comb, 1990).

Perdok and Leng (1987) reported that roughages with a high content of soluble carbohydrates prior to ammoniation, appeared to be particularly liable to cause

hyperexcitability when fed after ammoniation. Toxins such as imidazole appear to be formed by chemical reactions involving ammonia, reducing sugars and heat. However, hyperexcitability was not seen when straw temperatures remained below 70^{0}C during treatment, and also no such problems occurred when they ensiled straw with urea as a source of ammonia.

SUPPLEMENTATION OF LQR WITH FISHMEAL

For higher levels of production, the supply of amino acids from ruminally-synthesized microbial protein is inadequate for optimal productivity. Therefore, supplementary sources of rumen escape protein often increase animal growth rate and forage DM digestion (Mc Collum and Galyean, 1985; DelCurto et al., 1990a, 1990c). Because of its high protein content, excellent amino acid balance and low degradability in the rumen, FM is a very effective source of by-pass protein (NRC, 1985; Newbold et al., 1987). Growing cattle usually need more metabolizable protein than they obtain from microbial protein (NRC, 1985). Anderson et al. (1988) reported that gain was increased by 0.13 kg per day when FM was fed to steers grazing smooth bromegrass. Nicholson et al. (1992) found that DM intake was similar with all supplements while cattle fed the FM supplement tended to gain faster and were more efficient in feed conversion. Gill et al. (1987), reported that young growing steers offered high quality silage (14% CP) on ad libitum basis had increased WG in response to 150 g FM per kg DM with no increase in FI. Gill and Beever (1982) previously reported similar responses when 100 g FM per kg silage DM was fed to young calves but no improvements occurred with a lower level of supplementation (50 g FM/kg silage DM). Gibb and Baker (1987) when supplementing either grass silage or ammoniated grass hay diets for steers with 0.75 g FM/kg LW, found improved WG by 148 and 88 g for the silage and hay diets,

respectively, compared to controls. Steen (1992) reported that the response in WG to the inclusion of FM in a supplement was 580 g per kg FM. Singh and Mehra (1990) found that urea ensiled straw and mixed with molasses when supplemented with FM (25 to 200 g per day) improved WG in buffalo calves.

SUPPLEMENTATION OF LQR WITH ALFALFA HAY

Feeding value of crop residues is limited by deficiencies of CP, ME, minerals and vitamins (Owen, 1985). Another way of improving the utilization of such crop residues is by proper supplementation with leguminous forages (Mosi and Butterworth, 1985). Owens et al. (1991) reported that adequate rumen ammonia is critical for the metabolic activity of cellulolytic bacteria which populate the floating fiber mat in the rumen. However, because much of the free ammonia is found in the liquid fraction, not in the fiber mat, there may be advantages to feeding proteinaceous forages rather than concentrates as supplements. Supplemental forages will join the fiber of the basal forage in the fiber mat, bringing their additional N with them, thereby providing a ready supply for local microbes. Ndlovu and Buchanan Smith (1985) reported that alfalfa supplementation (30% of total feed) increased in sacco rate of fiber digestion. Adding a by-pass protein to a diet of low digestibility depresses metabolic heat production or heat increment of feeding which may improve the overall efficiency of the animal (Meang et al., 1989). Many researchers (Tiwari et al., 1990; DelCurto et al., 1990c; Klopfenstein and Owen, 1981), however, reported increased FI as a result of by-pass protein supplementation of LQR.

SUPPLEMENTATION OF LQR WITH SOLUBLE CARBOHYDRATES

Soluble carbohydrates given at moderate levels increase the amount of energy in the

diet, improve the utilization of N in the rumen and may increase ruminal outflow rate (Khalili and Huhtanen, 1991a). Khalili (1993) reported positive effects of molasses supplementation on N utilization, gluconeogenesis and on the supply of glucose precursors, which could improve the utilization of forage-based diets. Similar results were reported by Ahmed and Kay (1975) and England and Gill (1985) with molasses or sucrose supplementation. Results of molasses supplementation of LQR are relevant because corn juice and molasses are similar in being sources of readily available carbohydrates.

UTILIZATION OF LQR IN WATER BUFFALOES VS CATTLE

Contradictory observations regarding superiority of buffaloes over that of cattle in the efficiency of feed utilization are available in literature. Wahid (1973) reported that buffaloes are excellent scavengers and can utilize coarse forages more efficiently than cattle. He also noted that buffalo calves have higher birth weight, grow at a faster rate and can utilize coarse feeds more efficiently than cattle, thus they can produce beef more economically. Cockrill (1980) reported that because buffalo can better utilize roughage, meat can be produced at lower cost than in the case of cattle. Katiyar and Bisth (1989) fed oat-hay based rations to buffaloes and cattle and found significantly higher digestibility of fibrous matter by buffaloes. Ranjhan (1991) in most of the experiments he reviewed found that buffaloes are superior to cattle in VFA production in the rumen and ability to digest the organic matter.

FEEDING CULL ONIONS TO LIVESTOCK

Depending on fluctuations in market price and produce quality, considerable quantities of onions are either discarded in disposal areas or fed to livestock, mainly sheep, which will eat them both fresh and spoiled. Disposal of cull onions, particularly those infected with the

disease white rot, is a problem in many onion-producing areas including the Willamette Valley of Oregon. The principal disposal method is a costly one whereby the cull onions are macerated, returned to the fields and plowed under. This procedure is important in increasing the dispersal of white rot disease. Since landfills will no longer accept cull onions, some value added methods of their disposal are needed. Nutritionally, onions have approximately the same nutritional value as barley grain on a DM basis (NRC, 1984). The main difference between the two feeds is in the moisture content. Onions have about 85% moisture vs 12% for barley.

John and Marie (1979) observed decrease in packed cell volume PCV as a result of feeding cull onions to sheep. Studies by James and Binns (1966) and Van Kampen et al. (1970) on ewes fed wild onions demonstrated decreases in PCV. Onions contain hemolytic agents such as n-propyldisulfide which may cause red blood cell hemolysis and reduce PCV (Cheeke and Shull, 1985). The toxin is a membrane oxidant which increases the requirement for reducing agent (hydrogen) generated by the enzyme glucose-6-phosphate-dehydrogenase in the metabolic chain within the erythrocytes. The erythrocytes containing Heinz bodies are removed from the circulation by the reticuloendothelial system of the spleen. If large numbers of erythrocytes are removed, a hemolytic anemia will develop.

SUPPLEMENTATION OF LQR WITH YUCCA EXTRACT

Yucca extract (Deodorase) contains glycosylated components which can bind ammonia (Headon, 1991). The yucca plant contains several steroid saponins known collectively as sarsaponins (S). Goodall and Matsushima (1978) found that S (40 ppm) can improve nutrient digestibility (6%) and reduce feed intake (7%) in yearling steers. Goodall et al. (1982) reported that with 66 ppm S in the diet the gains of cattle receiving high concentrate diets

containing 10% CP were increased, but performance did not respond to S with a 17% CP diet. Goetsch and Owens (1985) fed dairy cows on sorghum silage (67% of diet DM) with 44 ppm S and noted increased digestion coefficients for OM, starch and N for S diet. Johnston et al. (1981) reported that YE feeding (63 ppm) improved WG and FE in broilers and Al-Bar et al. (1993) found similar results in replacement pullet chicks and rabbits. Ryan et al. (1993) reported that YE did not affect rumen pH. Grobner et al. (1982) found lower rumen ammonia nitrogen (RAN) concentrations with YE supplementation. Gibson et al. (1985) found that RAN level was reduced by 27% when YE was fed to cattle in diets containing 0.87% urea, although DM digestibility was not influenced by YE supplementation. Ellenberger et al. (1985) noted a decrease in vitro ruminal urease activity with YE supplement. Ryan et al. (1993) and Wu et al. (1993) found that addition of YE had no effect on RAN. Preston et al. (1987) reported decreased plasma urea nitrogen (PUN) in rats supplemented with YE. Cai et al. (1993) reported that with increasing ME intake, there was a linear decrease in PUN. Tagari et al. (1964) reported that there is an inverse correlation between PUN and the amount of N retained in the body. Wu et al. (1993) reported that addition of YE via the ruminal cannulae (0, 2, 4, 6, 8 g per day) had no effect on VFA and rumen pH. Ryan et al. (1993) reported that addition of YE decreased total VFA production compared to control.

REFERENCES

Ahmad, F.A. and Kay, M., 1975. A note on the value of molasses and tapioca as energy supplements to forage for grazing steers. Anim. Prod., 21: 191-194.

Al-Bar, A., Cheeke, P.R. and Nakaue, H.S., 1992. Effect of yucca extract (deodorase) on environmental ammonia levels and growth performance of rabbits. J. Appl. Rabbit Res., 15: 1105-1112.

Al-Bar, A., Ismail, A., Cheeke, P.R. and Nakaue, H.S., 1993. Effect of dietary *Yucca schidigera* extract (deodorase) on environmental ammonia and growth performance of chickens and rabbits. Proc. West. Sec. Am. Soc. Anim. Sci., 44: 106-108.

Anderson, S.J., Klopfenstein, T.J. and Wilkinson, V.A., 1988. Escape protein supplementation of yearling steers grazing smooth brome pastures. J.Anim.Sci., 66: 237-242.

Brown, W.F., 1988. Maturity and ammoniation effects on the feeding value of tropical grass hay. J. Anim. Sci., 66: 2224-2232.

Buettner, M.R., Lechtenberg, V.L., Hendrix, K.S. and Hertel, J.M., 1982. Composition and digestion of ammoniated tall fescue (Festuca arundinaces Schreb.) hay. J. Anim. Sci., 54: 173-178.

Cai, Y., Zimmerman, D.R. and Ewan, R.C., 1993. Responses of plasma urea and free amino acid concentrations in pigs of two breed combinations to energy intakes. J. Anim. Sci., 71 (Suppl. 1): 318.

CH_2M Hill and Oregon State Univ., 1991. Opportunities in grass straw utilization, Corvallis, OR. USA.

Chaturvedi, M.L., Singh, U.B. and Ranjhan, S.K., 1973. Effect of feeding chopped and ground wheat straw on the utilization of nutrients and VFA production in growing cow calves and buffalo calves. Indian J. Anim. Sci., 43: 382-385.

Cheeke, P.R. and Shull, C.R., 1985. Natural Toxicants in Feeds and Poisonous Plants. Avi. Pub. Co. Inc., Westport, CT.

Chesson, A. and Orskov, E.R., 1984. Microbial degradation in the digestive tract. In: F. Sundstol and E. Owen (Editors), Straw and Other Fibrous By-products as Feed. Developments in Animal and Veterinary Sciences, Elsevier, Amsterdom, pp 305-339.

Chestnut, A.B., Berger, L.L. and Fahey,Jr. G.C., 1988. Effects of conservation methods and anhydrous ammonia or urea treatment on composition and digestion of tall fescue. J. Anim. Sci., 66: 2044-2056.

Chiquette, J., Flipot, P.M. and Vinet, C.M., 1992. Effects of ammoniation and urea addition on chemical composition and digestibility of mature timothy hay, and rumen fluid

characteristics of growing steers. Can. J.Anim. Sci., 72: 299-308.

Cockrill, W.R., 1980. The ascendant water buffalo - key domestic animal. World Anim. Rev., 33: 2-12.

Craig, W.M., Ulloa, J.A., Watkins, K.L. and Nelson, B.D., 1988. Effects of level, form and time of urea application on the nutritive value of Alicia bermuda grass. J.Anim. Sci., 66: 185-193.

DelCurto, T., Barton, R.K., Cheeke, P.R. and Turner, H.A., 1991. Urea-ammoniation and (or) supplementation strategies to improve the nutritive value of tall fescue straw for beef cattle production. Proc. West. Sec. Am. Soc. Anim. Sci., 42: 241-244.

DelCurto, T., Cochran, R.C., Harmon, D.L., Beharka, A.A., Jacqes, K.A., Towne, G. and Vanzant, E.S., 1990a. Supplementation of dormant tallgrass-prairie forage: 1. Influence of varying supplemental protein and (or) energy levels on forage utilization characteristics of beef steers in confinement. J. Anim. Sci., 68: 515-531.

DelCurto, T., Cochran, R.C., Nagaraja, T.G., Corah, L.R., Beharka, A.A. and Vanzant, E.S., 1990c. Comparison of soybean meal/sorghum grain, alfalfa hay and dehydrated alfalfa pellets as supplemental protein sources for beef cattle consuming dormant tallgrass-prairie forage. J. Anim. Sci., 68: 2901-2915.

Dryden, G.McL. and Leng, R.A., 1988. Effects of ammonia and sulphur dioxide gases on the composition and digestion of barley straw. Anim. Feed Sci. Technol., 19: 121-133.

Ellenberger, M.A., Rumpler, W.V., Johnson, D.E. and Goodall, S.R., 1985. Evaluation of the extent of ruminal urease inhibition by sarsaponin and its fractions. J. Anim. Sci. 61 (Suppl. 1): 491.

England, P. and Gill, M., 1985. The effect of fishmeal and sucrose supplementation on the voluntary intake of grass silage and liveweight gain of young cattle. Anim. Prod., 40: 259-265.

Gibb, M.J. and Baker, R.D., 1987. Performance of young steers offered silage or thermo-ammoniated hay with or without fishmeal supplement. Anim.Prod. 45: 371-381.

Gibson, M.L., Preston, R.L., Pritchard, R.H. and Goodall, S.R., 1985. Effect of sarsaponin and monensin on ruminal ammonia levels and in vitro dry matter digestibilities. J. Anim. Sci., 61 (Suppl. 1): 492.

Gill, M., Beever, D.E., Buttery, P.J., England, P., Gibb, M.J. and Baker, R.D., 1987. the effect of oestradiol-17b implantation on the response in voluntary intake, liveweight gain and body composition, to fishmeal supplementation of silage offered to growing calves. J. Agric. Sci. (camb.)., 108: 9-16.

Gill, M. and Beever, D.E., 1982. The effect of protein supplementation on digestion and glucose metabolism in young cattle fed on silage. Br. J. Nurt., 48: 37-47.

Goetsch, A.L. and Owens, F.N., 1985. Effects of sarsaponin on digestion and passage rates in cattle fed medium to low concentrates. J. Dairy Sci., 68: 2377-2384.

Goodall, S.R., Brady, P., Horton, D. and Beckner, B., 1982. Steam flaked versus high moisture corn rations with and without sarsaponin for finishing steers. J. Anim. Sci. West.Sec. Procd., 45 (Abstr.).

Goodall, S.R. and Matsushima, J.K., 1978. The effects of sarsaponin on ruminant digestion and rates of passage. J.Anim.Sci.(suppl. 1):363.

Grenet, E. and Barry, P., 1990. Microbial degradation in the rumen of wheat straw and anhydrous ammonia treated wheat straw observed by electron microscopy. Reprod. Nutr. Devel., 30: 533-540.

Grobner, M.A., Johnson, D.E., Goodall, S.R. and Benz, D.A., 1982. Sarsaponin effects on in vitro continuous flow fermentation of a high grain diet. J. Anim. Sci., 55 (Suppl. 1): 491.

Headon, D.R., 1991. Glycofractions of the Yucca plant and their role in ammonia control. In: Biotechnology in the Feed Industry. Proc. 7th Alltech Symposium, Alltech Technical Publications, Nicholasville, KY, pp 95-108.

Hunt, C.W., Loeseke, J.A., Kivioja, D.A. and Haenny, S.C., 1990. Efficiency of urea application as a means of ammoniation of cool season forage. Proc.West Sec. ASAS., 41: 304-306.

Hvelplund, T., 1985. Digestibility of rumen microbial protein and undegraded dietary protein estimated in the small intestine of sheep and by in sacco procedure. Acta Agric. Scavd., 25(suppl.): 133-134.

James, L.F. and Binns, W., 1966. Effects of feeding wild onions (Allium validum) to bred ewes. J. Am. Vet. Med. Assoc., 149: 512-514.

John, H.K. and Marie, S.B., 1979. Effects of feeding cull domestic onions (Allium cepa) to sheep. Am. J. Vet. Res., 40: 397-399.

Johnston, N.L., Quarles, C.L., Fagerberg, D.J. and Caveny, D.D., 1981. Evaluation of yucca saponin on broiler performance and ammonia suppression. Poul. Sci., 60: 2289-2292.

Katiyar, R.C. and Bisth, G.S., 1989. Nutrient utilization in Murrah buffalo and Hariana cattle - A comparative study with oat-hay based rations. Proc. World Buffalo Congress., II: 189-193.

Khalili, H., 1993. Supplementation of grass hay with molasses in crossbred (Bos taurus * Bos indicus) non-lactating cows: effect of level of molasses on feed intake, digestion, rumen fermentation and rumen digesta pool size. Anim. Feed Sci. Technol., 41: 23-38.

Khalili, H. and Huhtanen, P., 1991a. Sucrose supplements in cattle given grass silage-based diets. 1. Digestion of organic matter and nitrogen. Anim. Feed Sci. Technol., 33: 247-261.

Klopfenstein, T. and Owen, F.G., 1981. Value and potential use of crop residues and by-products in dairy rations. J. Dairy Sci., 64: 1250-1268.

Kunkle, W.E., Leffel, E.C., Escobar, E.N. and Smith, L.W., 1980. Effect of method of harvest, anhydrous ammonia treatment and supplemental protein on the feeding value of corn residue. J. Anim. Sci., 52 (Suppl.1) : 241.

Llamas-Lamas, G. and Combs, D.K., 1990. Effects of environmental temperature and ammoniation on utilization of straw by sheep. J. Anim. Sci., 68: 1719-1725.

Mason, V.C., Cook, J.E., Dhanoa, M.S., Keene, A.S., Hoadley, C.J. and Hartley, R.D., 1990. Chemical composition, digestibility, in-vitro biodegradability of grass hays oven treated with different amounts of ammonia. Anim. Feed Sci. Technol., 29: 237-249.

McCollum, F.T., and Galyean, M.L., 1985. Influence of cotton seed meal supplementation on voluntary intake, rumen fermentation and rate of passage of prairie hay in beef steers. J. Anim. Sci.,60: 570-577.

Meang, W.J., Cheng, M.B., Yun, H.S. and Choi, I., 1989. Dilution rate effect on the efficiency of rumen microbial growth in continuous culture. Asian-Australasion J. Anim.Sci., 2(3): 477-480.

Mosi, A.K. and Butterworth, M.H., 1985. The voluntary intake and digestibility of cereal crop residues and legume hay for sheep. Anim. Feed Sci. Technol., 12: 241-251.

Narang, M.P. and Pradhan, K., 1974. Studies on improving the utilization of poor quality roughages: Ensiling wheat straw with cowpea (Vigna linensis). Indian J. Anim.Sci.,44:14-17.

Naseeven, M.R. and Kincaid, R.L., 1992. Ammonia and sulfur dioxide treated wheat straw as a feedstuff for cattle. J. Anim. Feed Sci. Technol., 37: 111-128.

National Research Council., 1985. Ruminant nitrogen usage. National Academy Press, Washington, D.C.

National Research Council., 1984. Nutrient requirements of beef cattle. 6th ed. NAS-NRC, Washington, D.C.

Ndlovu, L.R. and Buchanan-Smith, J.G., 1985. Utilization of poor quality roughages by sheep: effects of alfalfa supplementation on ruminal parameters, fiber digestion and rate of passage from the rumen. Can. J. Anim. Sci., 65: 693-703.

Nelson, M.L., Klopfenstein, T.J., Britton, R.A. and Lowery, S.R., 1985. Protein supplementation of ammoniated roughages. III. Corncobs supplemented with a blood-

meal-corn gluten meal mixture in steer studies. J. Anim. Sci., 61: 1567-1575.

Nicholson, J.W.G., Charmley, E. and Bush, R.S., 1992. The effect of supplemental protein source on ammonia level in rumen fluid and blood and intake of alfalfa silage by beef cattle. Can. J. Anim. Sci., 72: 853-862.

Owen, E., 1985. Crop residues as animal feeds in developing countries, use and potential use. p.25-42. In: Wanapat, M. and Devendra, C. (eds.). Relevance of crop residues as animal feeds in developing countries. Proc.Int. Workshop, Thailand.

Paterson, J.A., Klopfenstein, T.J., and Britton, R.A., 1979. Ammonia treatment of corn residues. J. Anim. Sci., 49: 270(Abstr.)

Perdok, H.B. and Leng, R.A., 1987. Hyperexcitability in cattle fed ammoniated roughages. Anim. Feed Sci. Technol., 17: 121-143.

Poonappa, C.G., Nooruddin, M.D. and Raghavan, G.V. 1971. Rate of passage of food and its relation to digestibility of nutrients in Murrah buffaloes and Hariana cattle. Indian J.Anim. Sci., 41: 1026-1031.

Preston, R.L., Bartle, S.J., May.T. and Goodall, S.R., 1987. Influence of sarsaponin on growth, feed and nitrogen utilization in growing male rats fed diets with added urea or protein. J.Anim.Sci.,65: 481-487.

Ranjhan, S.K., 1991. Comparative efficiency of utilization of feeds and forages in Indian cattle and buffaloes. Proc. Third World Buffalo Congress. I: 160.

Razdan, M.N., Sharma, D.D., Bhargava, P.K. and Chawala, M.S. 1971. Utilization of urea and water metabolism by zebu cattle and buffalo under tropical conditions. J. Dairy Sci., 54: 1200-1207.

Ryan, J.P. Leek, B.F. and Jacques, K., 1993. The complementary effects of *Saccharomyces cerevisiae* yeast culture (Yaa-Sacc 1026) and yucca schidigera extract (solid de-odorase) on ruminal metabolism in sheep. J. Anim. Sci., 71 (Suppl. 1): 287.

Saenger, P.F., Lemenager, R.P. and Hendrix, K.S., 1983. Effects of anhydrous ammonia treatment of wheat straw upon its in vitro digestion, performance and intake by beef cattle. J. Anim. Sci., 56: 15-20.

Saenger, P.F., Lemenager, R.P. and Hendrix, K.S., 1982. Anhydrous ammonia treatment of corn stover and its effects on digestibility, intake and performance of beef cattle. J. Anim. Sci., 54: 419-425.

Sanderson, R., Thomas, C. and McAllan, A.B., 1992. Fish-meal supplementation of grass silage given to young growing steers: effects on intake, apparent digestibility and live-weight gains. Anim. Prod., 55: 389-396.

Singh, U.B. and Mehra, V.R., 1990. Utilization of wheat straw given in a feed block and

supplemented with varying quantities of fishmeal and oil-extracted rice bran. J. Anim. Feed Sci. Technol., 28: 129-134.

Singh, B.K.and Mudgal, V.D., 1967. The comparative utilization of feed nutrients from lucerne hay in buffalo and crossbred zebu heifers. Indian J. Dairy Sci., 20: 142-148.

Spencer, R.R. and Akin, D.E., 1980. Rumen microbial degradation of potassium hydroxide-treated coastal bermudagrass leaf blades examined by electron microscopy. J. Anim. Sci., 51: 1189-1196.

Steen, R.W.J., 1992. A comparison of soya-bean meal, fishmeal and maize gluten feed as protein sources for calves offered grass silage ad libitum. Anim. Prod., 54: 333-339.

Tagari, H., Dror, Y., Ascarelli, I. and Bondi, A., 1964. The influence of levels of protein and starch in rations of sheep on the utilization of protein. Br. J. Nutr., 18: 333-356.

Theander, O., 1981. Chemical composition of low quality roughages as related to alkali treatment. In: J.A. Kategile, A.N., A.N. Said, and F. Sundstol (Editors). Utilization of low quality roughages in Africa. Rep.1, AUN-Agri. Development, Aas, Norway, 1-106.

Tiwari, S.P., Singh, U.B. and Mehra, U.R., 1990. Urea molasses mineral blocks as a feed supplement: Effect on growth and nutrient utilization in buffalo calves. Anim.Feed Sci.Technol., 29: 333-341.

Usmani, R.H. and Inskeep, E.K., 1989. Effect of prepartum feeding on milk yield and calf growth rate in limited-suckled and non-suckled buffaloes. J. Dairy Sci., 72: 2087-2094.

Van Soest, P.J., Mascarenhas, F.A. and Hartley, R.D., 1984. Chemical properties of fiber in relation to nutritive quality of ammoniated forages. Anim.Feed Sci.Technol., 10: 155-164.

Waagepetersen, J. and Thomsen, K.V., 1977. Effect on digestibility and nitrogen content of barley straw of different ammonia treatments. Anim. Feed Sci. Technol., 2: 131-136.

Wahid, A., 1973. Pakistani buffaloes. World Anim. Rev., 7:22-28.

Ward, M.G. and Ward, J.K., 1987. Ammoniation of warm-season grass hay for gestating beef cows. J.Anim.Sci., 65: 359-365.

Wiley, J.S., Petersen, M.K., Ansotegni, R.P. and Bellows, R.A., 1991. Production from first-calf heifers fed a maintenance or low level of prepartum nutrition and ruminally undegradable or degradable protein postpartum. J. Anim. Sci., 69: 4279-4293.

Wu, Z., Sadik, M., Huber, J.T., Sleiman, F.T., Simas, J. and Pessarakli, M., 1993. Influence of yucca extract (Deodorase) on ruminal metabolism in cows. J. Anim. Sci., 71 (Suppl. 1): 266.

CHAPTER 2

EVALUATION OF GRASS STRAW:CORN JUICE SILAGE AS A RUMINANT FEEDSTUFF : DIGESTIBILITY, STRAW AMMONIATION AND SUPPLEMENTATION WITH BY-PASS PROTEIN.

I.Hussain and P.R.Cheeke

Animal Sciences Department

Oregon State University, Corvallis, OR 97331

Abstract

Three experiments were undertaken to determine the feeding value of grass seed straw:corn juice silages compared to grass hay. In experiment 1 (70 d) the four basal diets were: 1) Grass hay (GH) used as control treatment; 2) Tall fescue straw:corn juice silage (50:50 wt/wt)(FCJ); 3) Urea treated tall fescue straw:corn juice silage (50:50, wt/wt)(UFCJ); and 4) Annual ryegrass straw:corn juice silage (65:35, wt/wt)(RCJ). Ammoniation was performed by spraying the straw with urea solution having 1% raw soybean extract (urease source), to provide 3% urea (dry matter basis). Thirty-six beef heifers (9 per treatment) were fed these roughages ad libitum with a concentrate supplement (1.36 kg h^{-1} d^{-1}). Out of nine heifers allotted per treatment, four were fed individually while the remaining five were group-fed. Feed intake(FI), average daily gain (ADG) (kg h^{-1} d^{-1}) and feed efficiency (FE) (kg kg^{-1} BWG) in individually-fed heifers in experiment 1 were: 5.16, 0.671, 7.97; 5.40, 0.557, 10.00; 4.84, 0.58, 8.41; and 4.54, 0.523, and 8.92 for GH, FCJ, UFCJ, and RCJ, respectively. In group-fed heifers FI and ADG were: 8.33, 0.71; 5.54, 0.564; 5.41, 0.568; and 5.92, and 0.38 for GH, FCJ, UFCJ, and RCJ, respectively. No differences ($P > .05$)

were observed in any trait, except that ADG in group-fed animals on GH treatment was significantly higher ($P < .05$) than RCJ treatment. In experiment 2 (57 d) the same animals and same roughages were used but supplementation was changed in FCJ, UFCJ, and RCJ treatments. In these 3 treatments the concentrate was reduced to 682 g h^{-1} d^{-1}, and alfalfa hay was offered at 1.36 kg h^{-1} d^{-1}. The UFCJ group also received fishmeal at 125 g h^{-1} d^{-1} as a source of by-pass protein.The FI, ADG (kg h^{-1} d^{-1}) and FE (kg) in individually-fed heifers were: 7.99, 0.91, 8.80; 8.89, 0.81, 11.33; 7.60, 0.97, 7.87; and 7.83, 0.76 and 10.37 for GH, FCJ, UFCJ, and RCJ, respectively. The ADG was higher ($P < .05$) in UFCJ vs RCJ and FE was higher ($P < .05$) in FCJ vs UFCJ. In group-fed animals FI and ADG (kg h^{-1} d^{-1}) were: 8.43, 0.76; 7.19, 0.67; 6.79, 0.70; and 7.14, and 0.55 for GH, FCJ, UFCJ, and RCJ, respectively. The ADG was higher ($P < .05$) in GH vs RCJ. In experiment 3, 12 sheep were used to determine in vivo digestibility of the four basal feeds (without supplementation) used in the first two experiments. Percent apparent digestibility of dry matter (DM), gross energy (GE), crude protein (CP), NDF, and ADF was: 60, 55, 59, 55; 59, 56, 60, 56; 46, 51, 74, 30; 52, 46, 51, 43; and 56, 49 57, 50 for GH, FCJ, UFCJ and RCJ, respectively. Differences between GH and UFCJ were not significant ($P > .05$) for DM, GE, NDF, and ADF digestibilities, however, CP digestibility differed ($P < .05$). A similar pattern was noted between FCJ and RCJ. All digestibility parameters were higher ($P < .05$) in UFCJ vs FCJ. The digestible energy (Kcal/kg) was: 2316, 2287, 2409 and 2275 for GH, FCJ, UFCJ and RCJ, respectively. Feed intake was similar among 4 treatments. On the basis of these results it is concluded that straw:corn juice silages are about equal to medium quality grass hay in feeding value. Supplementation with alfalfa hay and fishmeal further improved performance. Therefore, these two waste products (grass straws and corn juice) can be combined to replace grass hay in beef cattle and sheep feeding especially if supplemented with small quantities of

by-pass protein. One case of suspected ammoniated hay toxicosis was observed with the UFCJ silage. Imidazoles formed by reaction of ammonia with reducing sugars may be the toxic factors. Because of the high sugar content of corn juice, special cautions would be needed when ensiling urea-treated straw with corn juice.

Introduction

In 1990, greater than one million tons of grass seed straw were produced in the Willamette Valley of Oregon (CH_2M Hill and O.S.U., 1991), and at least six million gallons of corn waste water (corn juice), containing proteins, sugars and starch, are currently available annually in the Willamette Valley (A.Wakefield, Agripac Inc, Personal Communication, 1989). Because of increasing concern about air (field burning of grass residues) and water (corn juice) pollution, disposal of these products is becoming increasingly regulated, and traditional methods of their disposal (e.g. open field burning of straw, and direct discharge of corn juice into sewage treatment plants) have been or may be prohibited. Conversion of these waste products into useful feed resources would aid in overcoming waste disposal problems, improving air and water quality, and providing increased feedstuffs for livestock production.

Some of the main constraints to greater use of low quality roughages (LQR) by the livestock industry are their low digestibility, low digestible energy and protein, prolonged rumen retention time, bulkiness, low palatability and thus low intake over time (Campling, 1966; Aitchison et al; 1986). These LQR are limited in the supply of energy, amino acids and glucose precursors which may limit gluconeogenesis and utilization of acetate (Cronje et al; 1991). Therefore, both energy and protein supplements are needed to support animal production with diets based on LQR. Including moderate levels of soluble carbohydrates in these LQR diets will increase molar proportions of propionate (Sutton, 1968) at the expense of acetate and balance the availability of nitrogen and carbohydrates in the rumen.

Chemical treatment such as anhydrous ammoniation of the LQR has been shown to increase their nutritive value and digestibility (Ward and Ward, 1987; Chestnut et al; 1988).

However, anhydrous ammonia treatment requires the need for air-tight storage, poses potential danger in handling ammonia gas and may not be available in many areas. Urea has been used as a source of ammonia with similar improvements in digestibility (Chestnut et al; 1988; Craig et al; 1988; Hunt et al; 1990).

Protein supplementation of LQR has been shown to improve the use of these feeds (McCollum and Galyean, 1985). Good responses in the performance of young, growing cattle have been obtained in a number of experiments when grass silage or silage-based diets have been supplemented with fishmeal (Garstang et al.,1979; England and Gill, 1985). Ndlovu and Buchanan Smith (1985) reported that alfalfa supplementation of LQR improved their in sacco rate of fiber digestion. Klopfenstein and Owen (1981) and Mosi and Butterworth (1985) also reported improved utilization of LQR with alfalfa supplementation.

No study has been done in the past on the utilization of corn juice : straw silage Therefore, the objectives of the study were to determine if these two products can be ensiled, if ammoniation of the straw improves the feeding value of the silage, if there are any benefits of supplementing these silages with alfalfa hay and fishmeal; and are there any differences in their digestibility when compared with grass hay as a control diet.

Materials And Methods

Silage Preparation

The annual ryegrass straw:corn juice silage (RCJ) was prepared by mixing ground straw with corn juice in a wagon mixer. The ratio of straw:corn juice was 65:35 (wt./wt.). The tall fescue straw:corn juice silage (FCJ) was prepared by mixing plain fescue straw and corn juice in the ratio of 50:50 (wt/wt). The ammoniated tall fescue straw:corn juice silage (UFCJ) was prepared by mixing ammoniated tall fescue straw and corn juice in the ratio of 50:50 (wt/wt). After mixing, the materials were packed into large plastic silage bags (Ag Bag) and allowed to ferment for about 2 months which resulted in good quality silages, because they were of good color, aroma and pH was below 4. The control group was fed chopped grass hay (GH) which consisted primarily of native cool season mature grass hay produced in the Willamette Valley of Oregon. These four basal feeds were fed free choice in the three experiments.

Ammoniation of the tall fescue straw used in UFCJ treatment was performed by spraying a 50%, volume to weight (50 liters water mixed with 50 kg of urea) water / urea solution on straw windrows just prior to baling at a 6% rate (6 liters of urea solution on 94 kg of straw). Moisture content of straw was maintained at 13 to 15 %. This was necessary to insure the proper conditions to facilitate the urease reaction, for the conversion of urea to ammonia. In addition a whole soybean extract (1% of urea/water solution) was added to the urea solution as a source of urease. The straw was baled immediately after the urea treatment was applied. The bales were picked up within 30 minutes after baling and placed in a tight, uncovered stack. They were stored in a stack for two months, and then chopped in a forage tub grinder and mixed with corn juice to make UFCJ.

Corn juice is a waste by-product of the sweet corn canning industry. It consists of the juice of husk and broken corn kernels. After the kernels are removed from the cobs, the cobs, husk, corn cobs and broken kernels are pressed. The solids fraction is used for silage making, while the juice is currently either disposed of by conventional waste water treatment/sewage or sprayed on fields.

Animals And Feeding Management

Experiment 1

Thirty-six HerefordxAngus beef heifers (263 kg) were used in this trial to compare basal feeds which consisted of 1) GH used as control; 2) FCJ; 3) UFCJ; and 4) RCJ. Basal feeds, water and mineral mixtures were available free choice. Heifers on all treatments were fed the same concentrate supplement (1.36 kg per head per day). Ingredient composition (percent) of the concentrate was: barley grain (rolled) 77.5, soybean meal 18.75 and molasses 3.75. Chemical composition of roughages and supplements used is given in Table 1.1. A macro-mineral mixture (P > 18.5%; Ca <26 and > 19% ; Fl < .185 %) and trace-mineral mixture (not less than) (Zn 0.35%, Mn 0.3%, Fe 0.23%, Cu 0.23%, I 0.012%, Co 0.06%, Se 0.009% and common salt 96%) after mixing in 1:2 ratio (1 part macro-mineral mixture and 2 parts trace-mineral mixture) were fed free choice. Heifers were stratified by weight and within stratum allotted randomly to four diets (9 heifers per treatment). Out of 9 heifers allotted per treatment, four were individually-fed using electronic head gates, while the remaining five were fed in one group. A 7-day adjustment period was used to let heifers get trained to use individual electronic feeding gates with one feeder allotted to each heifer. Weighed feed was offered to each individually-fed heifer and groups twice daily. Orts were removed and weighed at 2 day intervals to calculate feed intake. Each

morning the concentrate was offered and heifers normally consumed the whole supplement in less than 10 minutes. Roughages were then offered after supplement was finished. All animals were weighed every two weeks to determine weight gain (ADG) and feed efficiency (FE).

Chemical Analysis

Feed samples were taken weekly for chemical analysis. These samples were dried at 55^{0}C for 48 h for DM determinations, which were then used to calculate roughage and total DM intake. The dried samples were then ground to pass through a 1 mm screen and saved for laboratory analysis. Dry matter, ash and CP were determined by standard procedures (AOAC, 1990). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined as described by Goering and Van Soest (1970) but modified by a micro method as described by Waldern (1971). The pH of silages was determined once a month by mixing distilled water with silages and reading on the pH meter. In vitro dry matter digestibility (IVDMD) of all four basal feeds was determined as described by Tilley and Terry (1963). The first experiment lasted for 70 days i.e. December 1990 to Feb 1991.

Statistical Analysis

Feed intake, weight gain and feed efficiency (kg of feed consumed per kg of weight gain) data were analysed as a completely randomized design using the general linear model (GLM) procedure of SAS (1987) and means were separated by the least significant difference (LSD) procedure.

Experiment 2

In this experiment the roughages and animals were same as in the experiment 1, but the supplementation was changed. Heifers fed GH received 1.36 kg per head per day of

concentrate, while in the 3 silage groups the concentrate was reduced to 0.68 kg per head per day. The concentrate was the same as used in experiment 1. The 3 silage-fed groups were also offered chaffed alfalfa hay (1.36 kg per head per day), while the UFCJ group received in addition 125 g of fishmeal per head per day. Allotment of animals to different feeds, feed intake recording, weighing of animals, feed sampling for chemical analysis and statistical analysis were the same as described in experiment 1. Basal feeds, water, and minerals were available free choice. This experiment 2 lasted for 54 days i.e. Feb 91 to April 1991.

Experiment 3

Twelve mature SuffolkxHampshire ewes were used to measure the digestibility of the four basal feeds that were used in the first two experiments i.e. GH , UFCJ , FCJ , and RCJ. There was no supplement offered. The ewes were kept in wooden metabolism cages and were used in a switch over design. There were three switch over periods each consisting of a 10 day adjustment period followed by 7 days of fecal collection. Feeds and water were available free choice. Before the start of experiment the sheep were fed these silages in group pens, to ensure that they would all consume the feed. Feed was offered twice daily (0830 and 1730 hours). During the 7 d collection period, all feces voided from each sheep were collected and recorded, and feed intake of each sheep was recorded. Composite samples of feed, orts and feces from each sheep were collected each day and dried at 55^{0}C for 72 h. At the end of each collection period, dried feed, orts and fecal samples of each sheep were mixed and a composite sample was taken, which was then ground to pass through a 1 mm screen. Chemical and statistical analysis methods were same as used in first experiment. Gross energy was determined using Parr adiabatic bomb calorimeter.

Results and Discussion

Chemical Composition

The chemical composition of different feeds (mean of 3 experiments) is given in Table 1.1. Urea treatment of tall fescue straw resulted in 113% increase in the CP content (7.99% to 16.99%) compared to non-treated tall fescue straw. Dry matter (49% to 51%), NDF (70% to 72%) and hemicellulose (HC) (29% to 32%) were decreased in urea treated compared to untreated fescue straw, whereas ash content (5.81% to 5.30%) and pH (3.82 to 3.60) were slightly higher in urea treated vs untreated fescue straw. The IVDMD was numerically higher in UFCJ vs FCJ (56% vs 54%). Saenger et al. (1983) found an increase in CP and decrease in HC content, when they treated wheat straw with anhydrous ammonia (3% of DM). DelCurto et al. (1991) found an increase in CP (5.75 to 14.82%) and decrease in NDF content (71.2 to 69.8 %) in tall fescue straw treated with 3% urea. Similar results were found by Nelson et al. (1985), Chestnut et al. (1987), and Hunt et al. (1990). Llamas-Lamas and Comb (1990) found that ammoniation of wheat straw (3.5% DM) decreased NDF concentration from 86.9% to 80.6% and increased CP content from 3.6 to 11.1 %. Buettner et al.(1982) demonstrated solubilization of HC when fescue hay was treated with ammonia. Dryden and Leng (1988), and Van Soest et al. (1984) also reported decreases in HC as a result of ammoniation. Chestnut et al. (1988) found that the pH of ensiled forage treated with ammonia or urea was higher than control. Brown (1988) reported that ammoniation with anhydrous ammonia increased total N and IVOMD and reduced NDF concentrations of stargrass hay. Kunkle et al.(1980) reported that the DM digestibility of chopped corn plant residue was increased by 5 percentage units by ammoniation before ensiling at 3.5% of DM. Paterson et al. (1979) reported that the DM digestibility of corn plant residue ammoniated at

3% of DM before ensiling was increased 13.9 percentage units and weight gain was improved. In our experiment, increased CP content and improved digestibility as a result of ammoniation probably accounts for better growth and FE in UFCJ group compared to FCJ treatment.

The mode of action of alkali substances such as anhydrous ammonia in improving digestion is still not completely understood. Some authors (eg. Mason et al., 1990) suggest that the increase in cell wall digestibility could result from the breakage of ester linkages between cell wall carbohydrates and phenolic acids, while others (Chesson and Orskov, 1984) suggest that lignin itself could be fragmented. Hvelplund (1989) suggested that chemical treatments release cell wall bound N, which is normally unavailable to ruminants in straws. Theander (1981) suggests that alkali treatment may cleave the linkages between lignin and other cell wall carbohydrates and cause partial solubilization of HC and lignin. Ammonia treatment may improve nutritional value of straws by swelling the cellulose moiety, thus improving DMD (Saenger et al., 1982). Furthermore, the N that is added to the forage as a result of treatment is used by the increased ruminal microbial population when more energy becomes available (Waagepetersen and Thomsen, 1977). In any case the result is an increase in accessibility of rumen microbes to cell wall constituents as observed by Spencer and Akin (1980) and Grenet and Barry (1990).

Waiss et al. (1972) reported that the effect of ammonia was more pronounced for plant materials with an initially low digestibility. Kernan et al. (1979) found that with ammonia treatment the increases in CP were 8.1, 4.7 and 5.7 percentage units for wheat, oats and barley straws, respectively. The corresponding improvements in DOM were 8.6, 6.1 and 6.6 percentage units. Horton and Steacy (1979) and Horton (1979) also found greater improvements in the digestibility of wheat straw than in barley and oat straw. They concluded

that digestibility after ammoniation was highly dependent on the quality of the starting material. Because the nutritive value of cool season grass straws is better than the cereal straws, there may be less effect of ammoniation.

Experiment 1

Feed intake, weight gain, feed efficiency and IVDMD data of the individually-fed heifers are given in Table 1.2. In the individually-fed animals forage DM intake was highest (4.21 kg) with FCJ followed by GH (3.98 kg), UFCJ (3.65 kg) and RCJ (3.36 kg), however, none differed significantly ($P > .05$). Weight gain was highest (0.67 kg) with GH followed by UFCJ (0.58 kg), FCJ (0.56 kg) and RCJ (0.52 kg) treatments. Heifers on UFCJ treatment needed 1.59 kg less feed per kg of weight gain compared to FCJ treatment. In all the three parameters of feed intake, weight gain and FE, no statistical differences ($P > .05$) were found among the four treatments.

Feed intake(FI), average daily gain (ADG) and FE data of group-fed heifers are given in Table 1.4. In group-fed heifers FI was highest with GH followed by RCJ, FCJ and UFCJ groups. However, FE was best in UFCJ (9.52 kg) followed by FCJ (9.83 kg), GH (11.75 kg) and RCJ (15.52 kg). The ADG was highest in GH (0.71 kg) group followed by UFCJ (0.57 kg), FCJ (0.56 kg) and RCJ (0.38 kg). The ADG of animals on GH treatment was higher ($P < .05$) than for animals on RCJ. The minor differences between individually-fed versus group-fed may be due to competition for feeding space, dominance of some animals over the others, and differences in the type of housing of group-fed vs individually-fed. The FI for the UFCJ group was numerically lower than for FCJ in both individually-fed and group-fed heifers. Nelson et al. (1985) reported that ammoniation or protein supplementation of ammoniated low-quality roughages (LQR) had no effect on DMI. DelCurto et al. (1991)

observed similar results in terms of DMI when they compared the FI of meadow hay, urea treated and untreated fescue straw. Hunt et al. (1990) reported that DMI was numerically greater for beef steers consuming untreated vs urea treated hay. Results of our study (UFCJ vs FCJ) are similar to the results described in previous studies. Naseeven and Kincaid (1992) found that ammoniation (3% of DM) of wheat straw did not significantly increase DMI compared to untreated straw but improved ADG. Horton (1979) reported that ammoniation of wheat straw (3.5% DM) had no effect on straw consumption when fed with high proportions of concentrate. The decreased consumption of urea treated straws may be because of some palatability problem, because urea is not palatable, and some residual urea may depress feed intake. However many workers have reported increase in FI as a result of ammoniation (Brown, 1988; Chesson and Orskov, 1984; Saadullah, 1986; Llamas-Lamas and Comb, 1990).

Brown (1988) found that cattle fed less mature hay ate more feed ($P < .05$), gained more ($P < .05$) weight and had improved FE ($P < .05$) compared with cattle fed more mature hay. Similar results were reported by Lipple (1980) with bermudagrass hay. This could explain the results of our study where FI and ADG was better in GH groups ($P > .05$), although there was lack of statistical differences, which may be due to small sample size.

One heifer (group-fed) on UFCJ treatment showed symptoms of either ammonia toxicity or ammoniated hay toxicosis (21 d after start of experiment). The animal went off feed, but appeared depressed rather than hyperexcited. The other symptoms included involuntary ear twitching, loss of balance, rapid respiration and some frothing at the mouth. These symptoms continued for 2 to 3 days. Perdok and Leng (1987) reported that roughages with a high content of soluble carbohydrates prior to ammoniation, appeared to be particularly liable to cause hyperexcitability when fed after ammoniation. Toxins such as imidazole appear

to be formed by chemical reactions involving ammonia, reducing sugars and heat. However, hyperexcitability was not seen when straw temperatures remained below 70°C during treatment, and also no such problems occurred when they ensiled straw with urea as a source of ammonia. In our experiment, conditions were favorable for imidazole formation. The corn juice contained soluble sugars, ammonia was present, and the silage bags were exposed to high temperatures when silage was prepared in late summer.

Experiment 2

Feed intake (FI), weight gain (WG) and feed efficiency (FE) data of individually-fed heifers are presented in Table 1.3. Roughage intake and total FI were highest in the FCJ (8.89 kg) treatment and lowest in UFCJ (7.60 kg). The FI was not different ($P < .05$) among treatments. The WG was highest in UFCJ (0.97 kg) and lowest in RCJ (0.76 kg); and FE was also best in UFCJ (7.87 kg). Heifers in UFCJ group consumed 3.46 kg less feed compared to FCJ for each kg of WG. The WG of heifers on UFCJ was higher ($P < .05$) than heifers on RCJ while differences with other treatments were non-significant ($P > .05$). The FE of animals on UFCJ (7.87 kg) was better ($P < .05$) from animals on FCJ (11.33 kg). Differences with other treatments were not significant ($P > .05$). Supplementation with alfalfa hay in all the three silage fed-groups resulted in improvements in terms of all the performance parameters compared to performance relative to GH in experiment 1. Supplementation of UFCJ group with additional fishmeal (FM) (125 gram per head per day) further improved the WG and FE. In the UFCJ group WG was 20 percentage units (158 g) better than FCJ, and FE was 44 percentage units better.

The FI, WG and FE data of group-fed animals is given in Table 1.5. Roughage and total FI was highest in GH and lowest in RCJ, while FE was best for UFCJ group. The minor differences between individually-fed and group-fed animals can be due to differences in initial

body weight, type of housing, dominance factor and competition for feeder space, especially when supplements were fed.

For higher levels of production, the supply of amino acids from ruminally-synthesized microbial protein is inadequate for optimal productivity. Therefore, supplementary sources of escape protein often increase animal growth rate and forage DM digestion (Mc Collum and Galyean, 1985; DelCurto et al., 1990a, 1990c). Because of its high protein content, excellent amino acid balance and low degradability in the rumen, FM is a very effective source of by-pass protein (ARC, 1980; NRC, 1985; Newbold et al., 1987). Growing cattle usually need more metabolizable protein than they obtain from microbial protein (NRC, 1985). Anderson et al. (1988) reported that gain was increased by 0.13 kg per day when FM was fed to steers grazing smooth bromegrass. Rusche et al. (1993) found that increased CP and use of a CP source with higher potential for ruminal escape increased WG in calves. DeGarcia and Ward (1991) also reported increased WG when dietary CP was increased in isoenergetic diets fed to mature beef cows. Nicholson et al. (1992) found that DM intake was similar with all supplements while cattle fed the FM supplement tended to gain faster and were more efficient in feed conversion. This is consistent with other reports in the literature (Veira et al., 1985; Steen, 1989) and suggests that provision of a by-pass protein was alleviating an imbalance in absorbed nutrients (Gill et al., 1987). MacRae et al. (1985) reported that abomasal infusion of casein increased the efficiency of ME utilization in sheep, possibly by supplying more glucogenic precursors. Glucose entry rate also has been shown to be increased by greater quantities of protein presented to the small intestine (Teleni et al., 1989). In a study by Gill et al. (1987), young growing steers offered high quality silage (14% CP) on ad libitum basis had increased WG in response to 150 g FM per kg DM with no increase in FI. Gill and Beever (1982) previously reported similar responses when 100 g FM per kg silage DM was fed to

young calves but no improvements occurred with a lower level of supplementation (50 g FM/kg silage DM). Gibb and Baker (1987) when supplementing either grass silage or ammoniated grass hay diets for steers with 0.75 g FM/kg LW, found improved WG by 148 and 88 g for the silage and hay diets, respectively, compared to controls. Similarly Smith et al. (1985) reported that WG was increased by 12% in yearling dairy heifers by changing the forage part of FM supplemented diets from barley straw to corn silage. Several studies have shown a growth advantage in young cattle fed straw-based diets supplemented with FM (Smith et al., 1980; Hovell et al., 1983). Large responses in WG to small supplements of by-pass protein were also reported by Holzer et al. (1986) and Lee et al. (1987). Saadullah (1986) reported an additional WG of 62 g per day for a supplement of 15 g FM in calves given urea-ensiled rice straw, but was unable to explain this large response. Steen (1992) reported that the response in WG to the inclusion of FM in a supplement was 580 g per kg FM. Similar responses were obtained in some other experiments (Steen, 1988). However, much larger responses in WG (1150 to 2000 g per kg FM) were obtained when FM was given as the only supplement to poorly preserved and/or low digestibility silages (Garstang et al., 1979; Garstang, 1980; England and Gill, 1985). McAllister et al. (1992) reported that lambs supplemented with FM showed increased WG (5.3%) and NDF digestion (7.3%). Singh and Mehra (1990) found that urea ensiled straw and mixed with molasses when supplemented with FM (25 to 200 g per day) improved WG in buffalo calves. Veira et al. (1988) noted that supplementation of grass silage with FM improved WG and FE of beef calves.

Nitrogen retention in cattle given grass silage is often low in animals given fresh or dried forage (Thomas, 1982). Forage proteins are extensively degraded in the rumen (NRC, 1985) and thus FM supplementation results in an increased dietary amino acid flow to the duodenum and/or improved ruminal fiber fermentation through a continuous release of

nitrogenous substances to the rumen microbes (Hussein and Jordon, 1991). The additional protein fed may have overcome an amino acid deficiency per se (Whitelaw et al., 1985) or may have improved the efficiency of ME utilization.

Feeding value of crop residues is limited by deficiencies of CP, ME, minerals and vitamins (Owen, 1985). Another way of improving the utilization of such crop residues is by proper supplementation with leguminous forages (Mosi and Butterworth, 1985). Owens et al. (1991) reported that adequate rumen ammonia is critical for the metabolic activity of cellulolytic bacteria which populate the floating fiber mat in the rumen. However, because much of the free ammonia is found in the liquid fraction, not in the fiber mat, there may be advantages to feeding proteinaceous forages rather than concentrates as supplements. Supplemental forages will join the fiber of the basal forage in the fiber mat, bringing their additional N with them, thereby providing a ready supply for local microbes. DelCurto et al. (1991) reported that supplementation of urea treated tall fescue straw with alfalfa pellets (0.45% of BW) decreased DMI, but increased WG and FE. They also found that DMI of meadow hay was greater than for ammoniated or untreated fescue straw. Ndlovu and Buchanan Smith (1985) reported that alfalfa supplementation (30% of total feed) increased in sacco rate of fiber digestion. Klopfenstein and Owen (1981) reported positive associative effects in terms of ADG and FE when both treated and untreated crop residues were supplemented with alfalfa hay.

Slow rate of rumen fiber digestion and slow rate of evacuation of indigestible material from the rumen are major constraints to voluntary intake of LQR (Van Soest, 1982). Ndlovu and Buchanan Smith (1985) reported that rate of passage was increased by alfalfa supplementation of corn cobs but did not affect barley straw passage rate. Isobutyric and valeric acids, essential nutrients for some cellulolytic microbes (Bryant, 1973) were increased

by alfalfa supplementation of barley straw and corn cobs presumably through supplying amino acids which were deaminated to provide branched-chain carbon skeletons for these VFAs (El Shazly, 1952). In sheep given ammoniated wheat straw, Romulo (1986) measured an increase in WG of 40 g (from 19 to 59 g) in response to a supplement of 150 g alfalfa chaff.

Adding a by-pass protein to a diet of low digestibility depresses metabolic heat production or heat increment of feeding (Blaxter, 1962), which may improve the overall efficiency of the animal (Meang et al., 1989). Supplementing high silage diets with preformed proteins frequently increases animal performance, often without increasing daily intake of silage DM (Nicholson and Macleod, 1966; Wilkins, 1974b; Veira et al., 1985; Gill et al., 1987; Steen, 1989). These results suggest that the improved performance is the result of alleviating amino acid (AA) deficiency, however, as described by Gill et al.(1987) it may be a result of providing a more balanced nutrient supply rather than alleviating a specific AA deficiency. Many researchers (Tiwari et al., 1990; DelCurto et al., 1990c; Klopfenstein and Owen, 1981), however, reported increased FI as a result of by-pass protein supplementation of LQR. In our study FM supplementation resulted in decreased FI. The FI of ammoniated silage was also less compared to untreated silage of fescue straw. Provision of extra NPN as urea decreased intake by animals fed high-silage rations (Steen, 1985; Choung et al., 1990). Bailey (1989) reported that steers on forage diets when supplemented with undegradable protein showed high rate of gain and were more efficient.

Soluble carbohydrates given at moderate levels increase the amount of energy in the diet, improve the utilization of N in the rumen and may increase ruminal outflow rate (Stern and Hoover, 1979; Huhtanen, 1987; Rooke et al., 1987; Khalili and Huhtanen, 1991a). Khalili (1993) reported positive effects of molasses supplementation on N utilization, gluconeogenesis and on the supply of glucose precursors, which could improve the utilization

of forage-based diets. Similar results were reported by Ahmad and Kay (1975) and England and Gill (1985) with molasses or sucrose supplementation. Low levels of molasses supplements (100, 200, 300 g d^{-1}) have been found to have little effect on DM digestibility (Iwuanyunwu et al., 1990). Results of molasses supplementation of LQR are relevant because corn juice and molasses are similar in being sources of readily available carbohydrates. Similarly, carrots have approximately 12% DM, 9.9% CP and 9.7% fiber on DM basis (NRC, 1984), which resembles the composition of corn juice except that corn juice has higher CP and lower fiber. Laflamme (1992) made a silage of 3:1 carrots:mature marsh hay (as is basis) and compared it with bromegrass/alfalfa silage in weaned cattle and found similar growth performance on both silages. Results of our experiment are in agreement with these findings.

Experiment 3

In the sheep experiment the apparent digestibility data of four basal feeds is presented in Table 1.6. The dry matter (DM) digestibility was highest in GH (60%) and lowest in FCJ (55%) and RCJ (55%). The DM digestibility in GH and UFCJ (59%) was higher ($P < .05$) than FCJ and RCJ and it was 7% higher in UFCJ vs FCJ treatment. The percent in vivo dry matter digestibility of these feeds in sheep were: 57, 54, 56 and 54 for GH, FCJ, UFCJ and RCJ, respectively. Apparent digestibility of gross energy (GE) was highest in UFCJ (60%) and lowest in FCJ (56%) and RCJ (56%), however, differences among the four treatments were non-significant ($P > .05$). Digestibility of CP was also highest in UFCJ (74%) group and lowest in RCJ. The CP digestibility in UFCJ was higher ($P < .05$) than all other treatments and it was lower ($P < .05$) in RCJ compared to other three treatments. The ADF digestibility was also highest in UFCJ (57%) followed by GH (56%), RCJ (50%) and FCJ (49%),

respectively. This ADF digestibility for GH and UFCJ groups was higher ($P < .05$) than for FCJ and RCJ. Neutral detergent fiber digestibility was highest in GH (52%) and lowest in RCJ (43%). The NDF digestibility for GH (52%) and UFCJ (51%) groups was higher ($P < .05$) than for FCJ (46%) and RCJ (43%) groups. Average daily roughage intake (ADRI) was highest in GH (1.18 kg) and lowest in RCJ (0.97 kg), however, differences among 4 treatments were not significant ($P > .05$). DelCurto et al. (1991) found that in cattle, forage DMI of meadow hay was numerically greater than urea-treated or untreated tall fescue straw. A similar trend can be seen between RCJ and FCJ fed groups of our experiments. Ammoniation of LQR has been shown to increase their nutritive value and digestibility (Ward and Ward, 1987; Chestnut et al., 1988). Urea has also been used as a source of ammoniation with similar improvements in digestibility (Craig et al., 1988; Hunt et al., 1990). Moore et al. (1985) reported that ammoniation (anhydrous) of grass legume silage increased digestibility of DM, NDF, ADF, HC and cellulose by 13.4, 16.8, 17.9, 15.5 and 17.8 percentage units, respectively. In our study, we observed 7, 11, and 16 percentage units improvement in the digestibility of DM, NDF, and ADF, respectively. Llamas-Lamas and Comb (1990) reported that wheat straw ammoniation increased DM digestibility from 55.5 to 58.2 % with ad libitum intake and from 58.8 to 61.4 % at restricted intake. We also observed similar increases in DM digestibility. Buettner et al. (1982) reported increased NDF and IVDMD in wheat straw after ammoniation. Brown (1988) reported improved DM and fiber digestibilities and Dias-Da-Silva and Sundstol (1986) reported increased cell wall digestibility as a result of ammoniation, where urea treatment of stacked straw was less effective than urea treatment of ensiled straw, and availability of N retained by ammoniated straw was high. Lalonde et al. (1975) found that ammoniation of corn silage (2% of DM) increased in vivo NDF digestibility in sheep by 7.1 percentage units. In our study we found 11 percentage units improved

digestibility of NDF in UFCJ vs FCJ. Naseeven and Kincaid (1992) also reported that ammoniation improved NDF, ADF and CP digestibilities. Males and Gaskins (1982) reported an increase in N retention by sheep fed diets of ammoniated wheat straw (3% of DM). Chiquette et al. (1992) reported that ammoniation of timothy improved the apparent digestibility of DM and CP compared to untreated hay. McCollum and Galyean (1985) and DelCurto et al. (1990a, 1990c) have reported increases in forage DM digestibility as a result of protein supplementation. Caton et al. (1988) found increased in situ NDF disappearance by protein supplementation. Tiwari et al. (1990) reported that the digestibilities of ADF, NDF and CP were higher in animals supplemented with urea-molasses blocks. Sharma and Jahanwar (1973) reported increased CP digestibility with an increase in the intake of protein. These results are probably a result of associative effects of dietary nutrients which might have resulted owing to an increase in the growth of rumen microflora (Leng, 1984). Cottyn and DeBoever (1988) reported that wheat straw treatment with urea-N increased apparent CP digestibility by 25-35 percentage units. The increased CP digestibility is largely due to the high absorbability of ammonia from the rumen.

In our experiment, the digestibility of most of the parameters was numerically higher in GH group compared to plain straw:corn juice silage groups. This is due to the plant high cell wall and lignin contents of straw. The lignin is bound to the cellulose-HC fraction of the cell wall and acts as a barrier for the enzymatic degradation by rumen microorganisms. Microbes can only ferment the cell walls if they come into direct contact with them (Engels, 1987). Therefore, the degradation rate of the cell wall fraction decreases with maturity. During maturation of grasses there is also an increase in the stem-to-leaf ratio and a secondary thickening and lignification of cell walls. This results in higher contents of structural polysaccharides (mainly cellulose and xylans) and lignin and lower contents of extractives,

soluble carbohydrates and CP. These factors result in overall lower digestibility of LQR like straws compared to hays. A similar pattern has been observed in our study, where grass hay digestibility was higher than for the straw treatments. However, UFCJ treatment was equal to or even better in most parameters compared to GH group. Chiquette et al. (1992) reported that ammoniation of mature timothy increased energy released from structural carbohydrates which resulted in improved overall DM digestibility. Thus ammoniation compensated for deterioration caused by late harvest. Results of our study are in line with the above mentioned studies.

In conclusion, grass straw:corn juice silages were similar in feeding value to medium quality grass hay and ammoniation resulted in even better performance than GH. Supplementation with FM and alfalfa hay further improved performance. However, ensiling ammoniated straw with corn juice, may cause ammoniated hay toxicosis. because of likelihood of exposure of the ensiled material to sufficient heat to promote imidazole formation, ensiling ammoniated straw with corn juice is potentially hazardous.

TABLE 1.1
Chemical composition (D.M. basis) of feeds used in three experiments.

Feed Type[1]	Composition (%)							
	DM	CP	NDF	ADF	HC[2]	ASH	pH	IVDMD%[3]
GH	88.00	6.92	73.27	40.72	32.55	6.04	5.94	57.00
FCJ	51.00	7.99	71.89	40.23	31.66	5.30	3.60	54.00
UFCJ	49.00	16.99	69.83	40.51	29.32	5.81	3.82	56.00
RCJ	62.00	6.70	69.75	40.17	29.58	6.02	3.64	54.00
Alfalfa hay	89.00	18.59	42.70	29.84	12.86	9.12	-	-
Fishmeal	91.00	60.91	-	-	-	0.06	-	-
Concentrate	87.00	14.32	25.83	9.51	16.32	3.86	-	-
Corn juice	15.00	14.46	7.53	3.19	4.34	4.34	-	-

[1] GH, Grass hay; FCJ, Tall fescue straw:Corn juice silage ;UFCJ, Ammoniated tall fescue straw:Corn juice silage; RCJ, Annual ryegrass straw:corn juice silage.
[2] HC = Hemicellulose; [3] IVDMD = Percent in vitro dry matter digestibility.

TABLE 1.2
Performance data for beef heifers in experiment 1 (Individually-fed)

Item	Treatments[1]				
	GH	FCJ	UFCJ	RCJ	SEM[2]
Dry matter Intake					
(Kg per head per day)					
Forage	3.98	4.21	3.65	3.36	0.32
Total	5.16	5.40	4.84	4.54	0.32
Average daily gain (kg)	0.67	0.56	0.58	0.52	0.05
Gain as % of control	100.00	83.00	86.40	77.90	-
Feed/gain (kg)	7.97	10.00	8.41	8.92	0.86

[1] GH, Grass hay; FCJ, Tall fescue straw:Corn juice silage ;UFCJ, Ammoniated tall fescue straw:Corn juice silage; RCJ, Annual ryegrass straw:corn juice silage.

[2] SEM, Standard error of the mean.

TABLE 1.3
Performance data for beef heifers in experiment 2 (Individually-fed)

Item	Treatments[1]				
	GH	FCJ	UFCJ+FM	RCJ	SEM[2]
Dry matter Intake					
(Kg per head per day)					
Forage	6.81	7.08	5.68	6.02	0.44
Total	7.99	8.89	7.60	7.83	0.44
Average daily gain (kg)	0.91[ab]	0.81[ab]	0.97[a]	0.76[b]	0.05
Gain as % of control	100.00	89.00	106.40	83.80	-
Feed/gain (kg)	8.80[ab]	11.33[a]	7.87[b]	10.37[ab]	0.77

[1] GH, Grass hay; FCJ, Tall fescue straw:Corn juice silage ;UFCJ+FM, Ammoniated tall fescue straw:Corn juice silage; RCJ plus FM, Annual ryegrass straw:corn juice silage.

[2] SEM, Standard error of the mean .
[ab] Row means without common superscripts differ ($P < .05$).

TABLE 1.4

Performance data for beef heifers in experiment 1 (Group-fed)

Item	Treatments[1]			
	GH	FCJ	UFCJ	RCJ
Dry matter Intake (Kg per head per day)				
Forage	7.14	4.35	4.22	4.74
Total	8.33	5.54	5.41	5.92
Average daily gain (kg)	0.71[a]	0.56[ab]	0.57[ab]	0.38[b]
Gain as % of control	100.00	79.40	80.00	53.50
Feed/gain (kg)	11.75	9.83	9.52	15.52

[1] GH, Grass hay; FCJ, Tall fescue straw:Corn juice silage ;UFCJ, Ammoniated tall fescue straw:Corn juice silage; RCJ, Annual ryegrass straw:corn juice silage.

[ab] Row means without common superscripts differ ($P < .05$).

TABLE 1.5

Performance data for beef heifers in experiment 2 (*Group-fed*)

Item	Treatments[1]			
	GH	FCJ	UFCJ+FM	RCJ
Dry matter Intake				
(Kg per head per day)				
Forage	7.24	5.38	4.86	5.32
Total	8.43	7.19	6.79	7.13
Average daily gain (kg)	0.76[a]	0.67[ab]	0.70[ab]	0.55[b]
Gain as % of control	100.00	88.00	91.70	72.90
Feed/gain (kg)	11.11	10.77	9.75	12.90

[1] GH, Grass hay; FCJ, Tall fescue straw:Corn juice silage ;UFCJ+FM, Ammoniated tall fescue straw:Corn juice silage plus FM; RCJ, Annual ryegrass straw:corn juice silage.

[ab] Row means without common superscripts differ ($P < .05$).

TABLE 1.6
Percent digestibility of different feeds in sheep (Experiment 3)

	Treatments[1]				
Item	GH	FCJ	UFCJ	RCJ	SEM[2]
Dry matter	60.00[a]	55.00[b]	59.00[a]	55.00[b]	1.27
Gross energy	59.00	56.00	60.00	56.00	1.24
Crude protein	46.00[a]	51.00[a]	74.00[b]	30.00[c]	1.61
Neutral detergent fiber	52.00[a]	46.00[b]	51.00[a]	43.00[b]	1.19
Acid detergent fiber	56.00[a]	49.00[b]	57.00[a]	50.00[b]	1.49
Feed intake (Kg $h^{-1}d^{-1}$)	1.18[a]	1.11[a]	1.10[a]	0.97[a]	0.03
Digestible energy (kcal kg^{-1})	2316	2287	2409	2275	-

[1] GH, Grass hay; FCJ, Tall fescue straw:Corn juice silage ;UFCJ, Ammoniated tall fescue straw:Corn juice silage; RCJ, Annual ryegrass straw:corn juice silage.

[2] SEM, Standard error of the mean.

[abc] Row means without common superscripts differ ($P < .05$).

REFERENCES

Agricultural Research Council. 1980. The nutrient requirements of ruminant livestock. Commonwealth Agricultural Bureaux, Slough, UK.

Ahmad, F.A. and Kay, M., 1975. A note on the value of molasses and tapioca as energy supplements to forage for grazing steers. Anim. Prod., 21: 191-194.

Aitchison, E.M., Gill, M., Dhanoa, M.S. and Osbourn, D.F., 1986. The effect of digestibility and forage species on the removal of digesta from the rumen and the voluntary intake of hay by sheep. Br. J. Nutr., 56: 463-476.

Anderson, S.J., Klopfenstein, T.J. and Wilkinson, V.A., 1988. Escape protein supplementation of yearling steers grazing smooth brome pastures. J. Anim. Sci., 66: 237-242.

Association of Official Analytical Chemists. 1990. Official Methods of Analysis 15th ed. AOAC. Inc. Arlington, VA.

Bailey, C.B., 1989. Rate and efficiency of gain from weaning to slaughter of steers given hay supplemented with ruminal undegradable protein, or concentrate. Can. J. Anim. Sci., 69: 691-706.

Blaxter, K.L., 1962. The Energy Metabolism of Ruminants. Hutchinson, London.

Brown, W.F., 1988. Maturity and ammoniation effects on the feeding value of tropical grass hay. J. Anim. Sci., 66: 2224-2232.

Bryant, M.P., 1973. Nutritional requirements of the predominant rumen cellulolytic bacteria. Federation Proc., 32: 1809-1813.

Buettner, M.R., Lechtenberg, V.L., Hendrix, K.S. and Hertel, J.M., 1982. Composition and digestion of ammoniated tall fescue (*Festuca arundinaces Schreb.*) hay. J. Anim. Sci., 54: 173-178.

Campling, R.C., 1966. The effect of concentrates on the rate of disappearance of digesta from the alimentary tract of cows given hay. J. Dairy Res., 33: 13-23.

Caton, J.S., Freeman, A.S. and Galyean, M.L., 1988. Influence of protein supplementation on forage intake, in situ forage disappearance, ruminal fermentation and digesta passage rate in steers grazing dormant blue gama rangeland. J. Anim. Sci., 66: 2262-2271.

CH_2M Hill and Oregon State Univ., 1991. Opportunities in grass straw utilization, Corvallis, OR. USA.

Chesson, A. and Orskov, E.R., 1984. Microbial degradation in the digestive tract. In: F. Sundstol and E. Owen (Editors), Straw and Other Fibrous By-products as Feed.

Developments in Animal and Veterinary Sciences, Elsevier, Amsterdom, pp 305-339.

Chestnut, A.B., Berger, L.L. and Fahey,Jr. G.C., 1988. Effects of conservation methods and anhydrous ammonia or urea treatment on composition and digestion of tall fescue. J. Anim. Sci., 66: 2044-2056.

Chestnut, A.B., Berger, L.L. and Fahey,Jr. G.C., 1987. Effects of ammoniation of tall fescue on phenolic composition, feed intake, site and extent of nutrient digestion and ruminal dilution rates of steers. J. Anim. Sci., 64: 842-854.

Chiquette, J., Flipot, P.M. and Vinet, C.M., 1992. Effects of ammoniation and urea addition on chemical composition and digestibility of mature timothy hay, and rumen fluid characteristics of growing steers. Can. J.Anim. Sci., 72: 299-308.

Choung, J.J., Chamberlain, D.G., Thomas, P.C. and Bradbury, I., 1990. The effects of intraruminal infusions of urea on the voluntary intake and milk production of cows receiving grass silage diets. J. Dairy Res., 57: 455-464.

Cottyn, B.G. and DeBoever, J.L., 1988. Upgrading of straw by ammoniation. Anim. Feed Sci. Technol., 21: 287-294.

Craig, W.M., Ulloa, J.A., Watkins, K.L. and Nelson, B.D., 1988. Effects of level, form and time of urea application on the nutritive value of Alicia bermuda grass. J. Anim. Sci., 66: 185-193.

Cronje, P.B., Nolan, J.V. and Leng, R.A., 1991. Acetate clearance rate as a potential index of the availability of glucogenic precursors in ruminants fed on roughage-based diets. Br. J. Nutr., 66: 301-312.

DeGarcia, M. and Ward, J.K., 1991. Escape protein for beef cows: 2. Source and level of ammoniated wheat straw-corn silage diets. J. Anim. Sci., 69: 2289-2293.

DelCurto, T., Barton, R.K., Cheeke, P.R. and Turner, H.A., 1991. Urea-ammoniation and (or) supplementation strategies to improve the nutritive value of tall fescue straw for beef cattle production. Proc. West. Sec. Am. Soc. Anim. Sci., 42: 241-244.

DelCurto, T., Cochran, R.C., Harmon, D.L., Beharka, A.A., Jacqes, K.A., Towne, G. and Vanzant, E.S., 1990a. Supplementation of dormant tallgrass-prairie forage: 1. Influence of varying supplemental protein and (or) energy levels on forage utilization characteristics of beef steers in confinement. J. Anim. Sci., 68: 515-531.

DelCurto, T., Cochran, R.C., Nagaraja, T.G., Corah, L.R., Beharka, A.A. and Vanzant, E.S., 1990c. Comparison of soybean meal/sorghum grain, alfalfa hay and dehydrated alfalfa pellets as supplemental protein sources for beef cattle consuming dormant tallgrass-prairie forage. J. Anim. Sci., 68: 2901-2915.

Dias-Da-Silva, A.A. and Sundstol, F., 1986. Urea as a source of ammonia for improving the nutritive value of wheat straw. Anim. Feed Sci. Technol., 14: 67-79.

Dryden, G.McL. and Leng, R.A., 1988. Effects of ammonia and sulphur dioxide gases on the composition and digestion of barley straw. Anim. Feed Sci. Technol., 19: 121-133.

El-Shazly, K., 1952. Degradation of protein in the rumen of sheep. 2. The action of rumen microorganisms on amino acids. Biochem. J. 51: 647-653.

Engels, F.M., 1987. Changes in the physical/chemical structures of cell walls during growth and degradation. In: J.M. van der Meer, B.A. Rajkens and M.P. Ferranti (Editors), Degradation of lignocellulosics in ruminants and in industrial processes. Elsevier, London, pp 13-20.

England, P. and Gill, M., 1985. The effect of fishmeal and sucrose supplementation on the voluntary intake of grass silage and liveweight gain of young cattle. Anim. Prod., 40: 259-265.

Garstang, J.R., 1980. Silage supplements for calves. Anim. Prod., 32: 355(Abstr).

Garstang, J.R., Thomas, C. and Gill, M., 1979. The effect of supplementation of grass silage with fishmeal on intake and performance of British Friesien calves. Anim. Prod., 28: 423 (Abstr.).

Gibb, M.J. and Baker, R.D., 1987. Performance of young steers offered silage or thermo-ammoniated hay with or without fishmeal supplement. Anim.Prod. 45: 371-381.

Gill, M. and Beever, D.E., 1982. The effect of protein supplementation on digestion and glucose metabolism in young cattle fed on silage. Br. J. Nutr., 48: 37-47.

Gill, M., Beever, D.E., Buttery, P.J., England, P., Gibb, M.J. and Baker, R.D., 1987. the effect of oestradiol-17b implantation on the response in voluntary intake, liveweight gain and body composition, to fishmeal supplementation of silage offered to growing calves. J. Agric. Sci. (Camb.)., 108: 9-16.

Goering, H.K. and Van Soest, P.J., 1970. Forage Fiber Analysis (Apparatus, Reagents, Procedures and some applications). USDA-ARS Agri. Handbook No. 379.

Grenet, E. and Barry, P., 1990. Microbial degradation in the rumen of wheat straw and anhydrous ammonia treated wheat straw observed by electron microscopy. Reprod. Nutr. Devel., 30: 533-540.

Holzer, Z., Levy, D., Samuel, V. and Bruckenthal, I., 1986. Interactions between supplementary N source and ration energy density on performance and N utilization in growing and fattening male cattle. Anim. Prod., 42: 19-28.

Horton, G.M.J., 1979. Feeding value of rations containing nonprotein N or natural protein and of ammoniated straw for beef cattle. J. Anim. Sci., 48: 38-44.

Horton, G.M.J. and Nicholson, H.H., 1981. Nitrogen sources for growing cattle fed barley and either wheat straw or dehydrated alfalfa. J. Anim. Sci., 52: 1143-1149.

Horton, G.M.J., Steacy, G.M., 1979. Effect of anhydrous ammonia treatment on the intake and digestibility of cereal straws by steers. J. Anim. Sci., 48: 1239-1249.

Hovell, F.D.DeB., Orskov, E.R., Grubb, D.A. and Macleod, N.A., 1983. Basal urinary nitrogen excretion and growth response to supplemental protein by lambs close to energy equilibrium. Br. J. Nutr., 50: 173-178.

Huhtanen, P., 1987. The effect of intraruminal infusions of sucrose and xylose on the N and fiber digestion in cattle receiving diets of grass silage and barley. J. Agri. Sci. Finl., 59: 405-424.

Hunt, C.W., Loeseke, J.A., Kivioja, D.A. and Haenny, S.C., 1990. Efficiency of urea application as a means of ammoniation of cool season forage. Proc. West Sec. Am. Soc. Anim. Sci., 41: 304-306.

Hussein, S.A. and Bryant, M.J., 1986. The response of store lambs to dietary supplements of fishmeal. 1. Effects of forage-to-concentrate ratio. Anim. Prod., 42: 223-232.

Hussein, H.S. and Jordan, R.M., 1991. Fishmeal as a protein supplement in ruminant diets: a review. J. Anim. Sci., 69: 2147-2156.

Hvelplund, T., 1989. Digestibility of rumen microbial protein and undegraded dietary protein estimated in the small intestine of sheep and by in sacco procedure. Acta Agric. Scavd., 25(suppl.): 133-134.

Iwuanyanwu, I.E.J., Umuuna, N.N. and Din, N.I., 1990. Effects of urea supplement with or without molasses on the intake, digestibility and liveweight changes of beef heifers fed native hay. Anim. Feed Sci. Technol., 31: 277-284.

Kernan, J.A., Crowle, W.L., Spurr, D.T. and Coxworth, E.C., 1979. Straw quality of cereal cultivation before and after treatment with anhydrous ammonia. Can. J. Anim. Sci., 59: 511-518.

Khalili, H. and Huhtanen, P., 1991a. Sucrose supplements in cattle given grass silage-based diets. 1. Digestion of organic matter and nitrogen. Anim. Feed Sci. Technol., 33: 247-261.

Khalili, H., 1993. Supplementation of grass hay with molasses in crossbred (Bos taurus * Bos indicus) non-lactating cows: effect of level of molasses on feed intake, digestion, rumen fermentation and rumen digesta pool size. Anim. Feed Sci. Technol., 41: 23-38.

Klopfenstein, T. and Owen, F.G., 1981. Value and potential use of crop residues and by-products in dairy rations. J. Dairy Sci., 64: 1250-1268.

Kunkle, W.E., Leffel, E.C., Escobar, E.N. and Smith, L.W., 1980. Effect of method of harvest, anhydrous ammonia treatment and supplemental protein on the feeding value

of corn residue. J. Anim. Sci., 52(Suppl.1): 241.

Laflamme, L.F., 1992. Carrot / grass silage as cattle feed. Can. J. Anim. Sci., 72: 441-443.

Lalonde, C.M., Long, T.A., Harpster, H.W. and Saylor, W.W., 1975. Evaluation of cold flow ammonia treated corn silage and high moisture corn. J. Dairy Sci., 58: 1243 (Abstr.).

Lee, G.J., Hennessy, D.W., Nolan, J.V. and Leng, R.A., 1987. Responses to nitrogen and maize supplements by young cattle offerer a low quality pasture hay. Aust. J. Agric. Res., 38: 195-207.

Leng, R.A., 1984. Supplementation of tropical and subtropical pastures for ruminant production. In: F.M.C. Gilchrist and R.I. Mackie (Editors), Herbivore Nutrition in the Tropics and Subtropics. Science Press, Pretoria, pp 129-144.

Lipple, H., 1980. Forage characteristics related to intake, digestibility and gain by ruminants. J. Anim. Sci., 50: 952-961.

Llamas-Lamas, G. and Combs, D.K., 1990. Effects of environmental temperature and ammoniation on utilization of straw by sheep. J. Anim. Sci., 68: 1719-1725.

MacRae, J.C., Smith, J.S., Dewey, P.J.S., Brewer, A.C., Brown, D.S. and Walker,A., 1985. The efficiency of utilization of metabolizable energy and apparent absorption of amino acids in sheep given spring and autumn harvested dried grass. Br. J. Nutr., 54: 197-202.

Males, J.R. and Gaskins, C.T., 1982. Growth, nitrogen retention, dry matter digestibility and ruminal characteristics associated with ammoniated wheat straw diets. J. Anim. Sci., 55: 505-515.

Mason, V.C., Cook, J.E., Dhanoa, M.S., Keene, A.S., Hoadley, C.J. and Hartley, R.D., 1990. Chemical composition, digestibility, in-vitro biodegradability of grass hays oven treated with different amounts of ammonia. Anim. Feed Sci. Technol., 29: 237-249.

McAllister, T.A., Beauchemin, K.A., McClelland, L.A. and Cheng, K.A., 1992. Effect of formaldehyde-treated barley or escape protein on nutrient digestibility, growth and carcass traits of feedlot lambs. Can. J. Anim. Sci., 72: 309-316.

McCollum, F.T., and Galyean, M.L., 1985. Influence of cotton seed meal supplementation on voluntary intake, rumen fermentation and rate of passage of prairie hay in beef steers. J. Anim. Sci., 60: 570-577.

Meang, W.J., Cheng, M.B., Yun, H.S. and Choi, I., 1989. Dilution rate effect on the efficiency of rumen microbial growth in continuous culture. Asian-Australasion J. Anim.Sci., 2(3): 477-480.

Moore, K.J., Lechtenberg, V.L. and Hendrix, K.S., 1985. Quality of orchardgrass hay

ammoniated at different rates, moisture concentrations and treatment durations. Agron. J., 77: 67-71.

Mosi, A.K. and Butterworth, M.H., 1985. The voluntary intake and digestibility of cereal crop residues and legume hay for sheep. Anim. Feed Sci. Technol., 12: 241-251.

Naseeven, M.R. and Kincaid, R.L., 1992. Ammonia and sulfur dioxide treated wheat straw as a feedstuff for cattle. Anim. Feed Sci. Technol., 37: 111-128.

National Research Council., 1985. Ruminant nitrogen usage. National Academy Press, Washington, D.C.

National Research Council., 1984. Nutrient requirements of beef cattle. 6th ed. NAS-NRC, Washington, D.C.

Ndlovu, L.R. and Buchanan-Smith, J.G., 1985. Utilization of poor quality roughages by sheep: effects of alfalfa supplementation on ruminal parameters, fiber digestion and rate of passage from the rumen. Can. J. Anim. Sci., 65: 693-703.

Nelson, M.L., Klopfenstein, T.J., Britton, R.A. and Lowery, S.R., 1985. Protein supplementation of ammoniated roughages. III. Corncobs supplemented with a blood-meal-corn gluten meal mixture in steer studies. J. Anim. Sci., 61: 1567-1575.

Newbold, J.R., Garnsworthy, P.C., Buttery, P.J., Cole, D.J.A. and Haresign, w., 1987. Protein nutrition of growing cattle: Food intake and growth responses to rumen degradable protein and undegradable protein. Anim. Prod., 45: 383-394.

Nicholson, J.W.G., Charmley, E. and Bush, R.S., 1992. The effect of supplemental protein source on ammonia level in rumen fluid and blood and intake of alfalfa silage by beef cattle. Can. J. Anim. Sci., 72: 853-862.

Nicholson, J.W.G. and MacLeod, A.B., 1966. Effects of form of nitrogen fertilizer, a preservative, and a supplement on the value of high-moisture grass silage. Can. J. Anim. Sci., 46: 71-82.

Owen, E., 1985. Crop residues as animal feeds in developing countries, use and potential use. p.25-42. In: Wanapat, M. and Devendra, C. (eds.). Relevance of crop residues as animal feeds in developing countries. Proc. Int. Workshop, Thailand.

Owens, F.N., Garza, J. and Dubeski. P., 1991. Advances in amino acid and N nutrition in grazing ruminants. Proc.Graging Livestock Conference.

Paterson, J.A., Klopfenstein, T.J., and Britton, R.A., 1979. Ammonia treatment of corn residues. J. Anim. Sci., 49: 270 (Abstr.)

Perdok, H.B. and Leng, R.A., 1987. Hyperexcitability in cattle fed ammoniated roughages. Anim. Feed Sci. Technol., 17: 121-143.

Romulo, B., 1986. Studies on the role of supplementation and of manipulation of protozoal population in the rumen on productivity of sheep given straw based diets. Ph.D. Thesis, Univ. of New England, Armidale.

Rooke, J.A., Lee, N.H. and Armstrong, D.G., 1987. The effects of intraruminal infusions in cattle receiving grass silage diets. Br. J. Nutr., 57: 89-98.

Rusche, W.C., Cochran, R.C., Corah, L.R., Stevenson, J.S., Harmon, D.L., Brandt. R.T.Jr., and Minton, J.E., 1993. Influence of source and amount of dietary protein on performance, blood metabolites, and reproductive function of primiparous beef cows. J. Anim. Sci., 71: 557-563.

Saadullah, M., 1986. Supplementing urea treated rice with fishmeal and its effects on the gut contents and dressed carcass weight. In: M.N.M.Ibrahim and J.B.Schiere (eds.). Rice straw and related feeds in ruminant rations. pp. 248-254., Agri. Univ. Wageningen.

Saenger, P.F., Lemenager, R.P. and Hendrix, K.S., 1983. Effects of anhydrous ammonia treatment of wheat straw upon its in vitro digestion, performance and intake by beef cattle. J. Anim. Sci., 56: 15-20.

Saenger, P.F., Lemenager, R.P. and Hendrix, K.S., 1982. Anhydrous ammonia treatment of corn stover and its effects on digestibility, intake and performance of beef cattle. J. Anim. Sci., 54: 419-425.

Sharma, V.V. and Jhanwar, B.M., 1973. Effect of supplementation of wheat straw with concentrate on voluntary intake, digestibility and growth in cattle. Indian J. Anim. Sci., 43: 688-693.

Singh, U.B. and Mehra, V.R., 1990. Utilization of wheat straw given in a feed block and supplemented with varying quantities of fishmeal and oil-extracted rice bran. Anim. Feed Sci. Technol., 28: 129-134.

Smith, T., Broster, V.J. and Hill, R.E., 1980. A comparison of supplementary nitrogen for young cattle receiving fiber-rich diets. J.Agric. Sci. (Camb.)., 95: 687-695.

Smith, T., Siviter, J.W. and Merry, R.J., 1985. Further comparison of energy and protein sources for growing cattle. J. Agric. Sci. (Camb)., 104: 485-491.

Spencer, R.R. and Akin, D.E., 1980. Rumen microbial degradation of potassium hydroxide-treated coastal bermudagrass leaf blades examined by electron microscopy. J. Anim. Sci., 51: 1189-1196.

Statistical Analysis Systems., 1987. SAS- Institute, Cary, NC, USA.

Steen, R.W.J., 1992. A comparison of soya-bean meal, fishmeal and maize gluten feed as protein sources for calves offered grass silage ad libitum. Anim. Prod., 54: 333-339.

Steen, R.W.J., 1989. A comparison of soya-bean, sunflower and fishmeal as protein

supplements for yearling cattle offered grass silage-based diets. Anim. Prod., 48: 81-89.

Steen, R.W.J., 1988. The effect of supplementing silage-based diets with soybean and fishmeals for finishing beef cattle. Anim. Prod., 46: 43-51.

Steen, R.W.J., 1985. Protein supplementation of silage-based diets for calves. Anim. Prod., 41: 293-300.

Stern, M.D. and Hoover, W.H., 1979. Methods of determining and factors affecting rumen microbial protein synthesis: a review. J. Anim. Sci., 49: 1590-1603.

Sundstol, F., 1984. Ammonia treatment of straw: Methods for treatment and feeding experience in Norway. Anim. Feed Sci. Technol., 10: 173-187.

Sundstol, F. and Coxworth, E.M., 1984. Ammonia Treatment. In: F. Sundstol and E.Owen (Eds), Straw and Other Fibrous By-Products as Feed. Elsevier, Amsterdam / Oxford / New York / Tokyo, pp 196-247.

Sutton, J.D., 1968. The fermentation of soluble carbohydrates in rumen contents of cows fed diets containing a large proportion of hay. Br. J. Nutr., 22: 689-712.

Teleni, E., King, W.R., Rowe, J.B. and McDowell, G.H., 1989. Lupins and energy yielding nutrients in ewes. 1. Glucose and acetate biokinetics and metabolic hormones in sheep fed a supplement of lupin grain. Aust. J. Agric. Res., 40: 913-924.

Theander, O., 1981. Chemical composition of low quality roughages as related to alkali treatment. In: J.A. Kategile, A.N., A.N. Said, and F. Sundstol (Editors). Utilization of low quality roughages in Africa. Rep.1, AUN-Agri. Development, Aas, Norway, 1-106.

Thomas, P.C., 1982. Utilization of conserved forages. In: Forage protein in ruminant animal production. (Eds. D.J. Thomson, D.E. Beever and R.G.Gunn), occasional publication, Br. Society Anim. Prod., no.6, pp 67-76.

Tilley, J. M. A. and Terry, R. A., 1963. A two-stage technique for the in vitro digestion of forage crops. J. Brit. Grassl. Soc. 18: 104-111.

Tiwari, S.P., Singh, U.B. and Mehra, U.R., 1990. Urea molasses mineral blocks as a feed supplement: Effect on growth and nutrient utilization in buffalo calves. Anim. Feed Sci. Technol., 29: 333-341.

Van Soest, P.J., 1982. Nutritional Ecology of The Ruminant. O & B Books, Corvallis, OR.

Van Soest, P.J., Mascarenhas, F.A. and Hartley, R.D., 1984. Chemical properties of fiber in relation to nutritive quality of ammoniated forages. Anim. Feed Sci. Technol., 10: 155-164.

Veira, D.M., Butler, G., Ivan, M. and Proulx, J.G., 1985. Utilization of grass silage by cattle: effect of barley and fishmeal supplements. Can.J.Anim.Sci., 65: 897-903.

Veira, D.M., Proulx, J.G., Butler, G. and Fortin, A., 1988. Utilization of grass silage by cattle: further observations on effect of fishmeal. Can. J. Anim. Sci., 68: 1225-1235.

Waagepetersen, J. and Thomsen, K.V., 1977. Effect on digestibility and nitrogen content of barley straw of different ammonia treatments. Anim. Feed Sci. Technol., 2: 131-136.

Waiss, A.C.Jr., Guggolz, J., Kohler, G.O., Waller Jr. H.G. and Garrett, W.N., 1972. Improving digestibility of straws for ruminant feed by aqueous ammonia. J. Anim. Sci., 35: 109-112.

Waldern, D.E., 1971. A rapid micro-digestion procedure for neutral and acid detergent fiber. Can. J. Anim. Sci., 51: 67-69.

Ward, M.G. and Ward, J.K., 1987. Ammoniation of warm-season grass hay for gestating beef cows. J. Anim. Sci., 65: 359-365.

Whitelaw, F.G., Milne, J.S., Orskov, E.R. and Smith, J.S., 1985. The effect of casein supplements given by abomasal infusion on the nitrogen and energy metabolism of lactating cows. Proc. Nutr. Soc., 44.

Wilkins, R.J., 1974b. The effects of partial neutralization with sodium bicarbonate or ammonia and the feeding of blood meal on the voluntary intake of whole crop barley silage by sheep. Anim. Prod., 19: 87-91.

Williams, P.E.V., Innes, G.M. and Brewer, A., 1984. Ammonia treatment of straw via the hydrolysis of urea. II Additions of soybean (urease), sodium hydroxide and molasses; effects on digestibility of urea treated straw. Anim. Feed Sci. Technol., 11: 115-119.

CHAPTER 3

EVALUATION OF ANNUAL RYEGRASS STRAW:CORN JUICE SILAGE WITH CATTLE AND WATER BUFFALO: DIGESTIBILITY IN CATTLE VS BUFFALO, AND GROWTH PERFORMANCE AND SUBSEQUENT LACTATIONAL PERFORMANCE OF HOLSTEIN HEIFERS.

I. Hussain and P.R. Cheeke

Animal Sciences Department

Oregon State University, Corvallis, OR 97331

Abstract

Two experiments were undertaken to evaluate ryegrass straw:corn juice silage (35:65, wt/wt), as a basal feed for Holstein heifers and to determine digestibility in water buffaloes and Hereford cows. In experiment 1 (143 d) 48 pregnant heifers (16 animals, and 3 pens per treatment) were fed: 1) Mixed cool season grass hay (GH); 2) Straw:corn juice silage (S); and 3) S + 125 g fishmeal h^{-1} d^{-1} (SF). Average daily gain (kg h^{-1}) was 1.00, 0.82 and 1.02 for GH, S and SF groups, respectively. The ADG in SF group was higher ($P < .05$) than S group. Roughage DM intake was: 7.77, 6.45 and 6.02 (kg h^{-1} d^{-1}) for GH, S and SF treatments, respectively. Total feed intake was: 12.33, 11.01 and 10.70 for GH, S and SF groups, respectively. Feed intake differed ($P < .05$) among 3 treatments. Feed efficiency was: 12.91, 14.31 and 10.96 for H, S and SF, respectively. Feed efficiency was significantly better ($P < .05$) in SF vs S. Milk, milk fat and SNF yield (kg h^{-1} d^{-1}) were: 30.91, 1.13, 1.03; 31.5, 1.19, 1.05; 32.06, 1.19 and 1.07 for H, S, and SF, respectively. None of the milk production

parameters differed ($P > .05$) among 3 treatments. In experiment 2, six water buffaloes and 6 Hereford cows were fed the same silage as fed to experiment 1 animals. Silage was mixed with chromic oxide and fed for 15 days. Fecal grab samples were obtained over several days. Digestibility (percent) of DM, CP, NDF and ADF was calculated by the determination of chromic oxide concentration in feed and feces. Respective apparent digestibility values for buffaloes and cows were: dry matter, 47 and 40%; crude protein, 47 and 34%; neutral detergent fiber, 47 and 41%; acid detergent fiber, 43 and 35%. All the digestibility parameters were significantly higher ($P < .05$) in buffaloes than in cows. In conclusion, straw:corn juice silage, was equivalent to grass hay in supporting weight gain and feed efficiency and FM supplementation of UFCJ significantly improved the FE compared to plain fescue straw:corn juice silage. There was no long term effect of nutrition on milk production and composition of Holstein heifers.Corn juice-straw silage digestibility was significantly higher in buffaloes than cows.

Introduction

At present, about 1.0 to 1.2 million tons of straw are generated in Oregon by the grass seed industry (980 thousand to 1.1 million tons in the Willamette Valley) (Conklin et al., 1991). After harvest of the seed crop, most of straw residue is disposed of by open field burning, which helps in controlling diseases, recycling nutrients, maintaining genetic purity, and facilitating next crop establishment and weed control, and increasing seed yields. However, open field burning has been under increasing public criticism, and may be totally banned in the future. Therefore, alternatives for straw disposal need to be found.

Another agricultural by-product produced in large quantity is corn juice, a waste product of corn canneries. Over six million gallons of waste corn juice are produced by Oregon canneries (A. Wakefield, Agripac Inc., Personal Communication, 1989). Disposal of corn juice by the traditional means of application to fields or in sewage treatment facilities has water pollution concerns. Therefore, disposal of both seed straw and corn juice is a problem to agriculture. Grass straws and corn juice have opposite but complementary properties, such as high vs low water content, high vs low fermentable sugars, high vs low fiber, etc. When mixed, these two by-products can be ensiled. Ensiling of straws helps to improve their palatability and digestibility (Lal and Mudgal, 1967., Narang and Pradhan, 1974). Ensiling these two waste products (straws and corn juice) would reduce environmental pollution, as well as producing a feed for livestock production. For making silage from straw, it is necessary to add a minimum of 30% water, a source of fermentable carbohydrate and nitrogen. Corn juice is a good source of all these nutrients.

An alternate approach to achieve increased utilization of poor quality roughages (PQR) like straws is through N supplementation. Feeding small quantities of fishmeal (FM) as a supplement to grass silage can improve liveweight gain (WG) in young cattle (Sanderson et

al., 1992). Many other researchers (Veira et al., 1985; Steen, 1989; Nicholson et al., 1992) have reported that cattle fed FM supplements tended to gain more and have more efficient feed conversion. Usmani et al. (1989) reported higher yields of milk and milk fat for the first 75 d of lactation in buffaloes on higher prepartum feeding levels. Wiley et al. (1991) reported that prepartum nutrition had no effect on post-partum milk production.

The present experiments were undertaken to determine if these two products can be ensiled; if FM supplementation is beneficial; if this silage can replace traditional grass hay; and if there are any effects of pre-partum feeding of straw silage on post-partum milk yield and milk composition. We also determined the digestibility of straw:corn juice silage in water buffaloes versus Hereford cows. Many researchers (Singh and Mudgal, 1967; Poonappa et al., 1971; Razdan et al., 1971; Katiyar and Bisth, 1989) have reported higher digestibility of fibrous feeds in water buffalo versus cattle, while others (Naga and Al-Shazly, 1969; Cheturvedi et al., 1973) reported no digestibility differences between the two species.

Materials And Methods

Experiment 1

Silage Preparation

Silage was prepared by mixing chaffed annual ryegrass straw with corn juice in a mixer wagon. The straw was chopped in a forage tub grinder, before mixing it with corn juice. The ratio of straw:corn juice was 35:65 (wt/wt). After mixing, the material was packed into a large plastic bag (Ag Bag) and allowed to ferment for about two months, which resulted in good quality silage. The color and aroma of the silage was good and pH was 3.88.

Corn juice is a waste by-product of the sweet corn canning industry. After kernels are separated from cobs, the cobs, husk and broken kernels are pressed to squeeze out corn juice. It also contains the broken corn kernels. The corn juice used contained 15% DM, 14.5% CP, 7.5% NDF and 3.20% ADF. The dry matter of corn juice mainly comes from broken corn kernels, therefore, it is good source of energy.

Animals And Feeding Management

Forty-eight pregnant Holstein dairy heifers were used in experiment 1 which lasted for 143 days (January to June 1992). Heifers were stratified by the stage of gestation and then within each stratum were randomly allotted to 3 treatments (16 heifers and 3 replicates per treatment). Average gestation length $\pm$ SD at the start of experiment was:123 $\pm$ 67; 118 $\pm$ 68; and 121 $\pm$ 69 days for control (GH); silage (S) and silage+fishmeal (SF) treatments, respectively. The 3 treatments were: 1) Mixed cool-season grass hay (GH) which was used as a control; 2) annual ryegrass straw:corn juice silage (S); and 3) S + 125 g FM/h/d (SF). All animals were also fed dairy concentrate at 5 lbs/h/d. All the roughages were offered free choice. Each animal also received 56 g of vitamin/mineral mixture (Ca 14-16%; P 8%; NaCl

4-5%; Mg 6%; K 3%; S 2%; Mn 0.44%; Zn 0.57%; Cu 0.1%; Fe 0.1%; I 0.006%; Co 0.003%; Se 0.005%; Vitamin A 250,000 units/lb; Vitamin D_3 70,000 units/lb; Vitamin E 200 units/lb) daily. Trace mineral blocks (Zn 0.35%; Mn 0.2%; Fe 0.2%; Mg 0.15%; Cu 0.33%; I 0.007%; Co 0.005%) and water were available free choice. Animals were fed in a semi-covered barn with 3 pens per treatment. After feeding the roughage, the concentrate, vitamin/mineral mixture and fishmeal were offered each morning. All these supplements were consumed in a few minutes. Mangers were cleaned three times a week. Out of 143 days of total experimental period, roughage intake was accurately recorded for 60 days by feeding the weighed quantity of roughage every day, and then weighing the orts three times a week. Animals were transferred back to the Dairy Center approximately one week before the expected date of calving. Cows were weighed every 15 days and at the beginning and end of the feeding period for calculating weight gain.

Milk yield and milk composition data (Table 2.3) were collected from the Dairy Center upto July 1993 for all the cows used in the three treatments, and were statistically analysed to see if there were any long term effects of these pre-partum feeding treatments on post-partum milk production and composition.

Chemical Analysis

Chemical composition of roughages and supplements is given in Table 2.1. Feed samples were collected weekly for chemical analysis. These samples were dried at 55^{0}C for 48 h for DM determinations, which were then used to calculate roughage and total DM intake. The dried samples were ground to pass through a 1 mm screen and stored for further laboratory analysis. The DM, ash and CP were determined by the standard procedures (AOAC, 1990). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were

determined as described by Goering and Van Soest (1970) but modified by a micromethod as described by Waldern (1971). Silage pH was determined once a month by mixing distilled water with silages and reading on a pH meter.

Statistical Analysis

Feed intake, weight gain, feed efficiency, lactation length, milk, fat and solids not fat (SNF) production data were analysed as a completely randomized design using the GLM procedure of SAS (1987) and means were assayed by the LSD procedure (Steel and Torrie, 1980). The same statistical procedures were used in the buffalo versus cattle digestibility experiment (Expt 2).

Experiment 2

In this experiment 6 water buffaloes and 6 Hereford cows were used to evaluate the comparative digestibility of the silage used in experiment 1. Chromic oxide was mixed in the silage at 2.5 kg chromic oxide per 636 kg of silage, using a mixer wagon. Silage without chromic oxide was fed to buffaloes and cows in the first week. During the second week chromic oxide mixed silage was fed ad libitum to both cows and buffaloes. Fecal samples from all the animals were collected for the last five days, three times a day.Water was available free choice. Fecal samples of each animal were composited, dried at 50^{0}C for 72 h, and ground to pass through 1 mm screen. Silage samples were collected every day, dried and ground and stored for further analysis. Feed and fecal samples were analysed for chromic oxide by the method of Suzuki and Early (1991). Other chemical analysis procedures were same as described in expt.1.

The nutrient digestibility (percent) was calculated using this formula:

Digestibility of nutrient (%) =

= 100 -(100 x % marker in feed/ % marker in feces x % nutrient in feces/ % nutrient in feed).

Results and Discussion

Chemical composition of feeds used in the dairy heifer experiment (Expt.1) is shown in Table 2.1. Feed intake (FI) and weight gain (WG) data are given in Table 2.2. The WG for the silage plus FM group (SF) was significantly higher ($P < .05$) than for the unsupplemented silage-fed group (S). However, differences between hay (GH) and S and GH and SF were not significant ($P > .05$). Roughage and total feed intake were different ($P < .05$) among the three treatments. The FE (F/G ratio) was significantly ($P < .05$) lower in SF compared to S, while differences between GH vs S and GH vs SF were not significant ($P > .05$). Milk production and milk composition data are shown in Table 2.3. No differences ($P > .05$) in lactation length, milk yield, milk fat and SNF yield were found among three treatments. Numerically milk and SNF yield was slightly higher in SF vs S and GH treatments. Fat yield was lowest in GH and similar in S and SF groups.

Comparative digestibility data of annual ryegrass straw:corn juice silage (same silage as used in experiment 1) in water buffaloes versus Hereford cows is given in Table 2.4. Digestibility of DM, CP, NDF, and ADF was significantly higher ($P < .05$) in water buffaloes than in Hereford cows.

Discussion

In the dairy heifer experiment (Expt.1), supplementation of S with 125 g FM improved weight gain and feed efficiency, compared to the non-supplemented S treatment. Numerically FI in FM supplemented animals was lower than for those fed silage alone. For higher levels of production, the supply of amino acids (AA) from microbial protein is often inadequate for optimal productivity, therefore supplementary sources of escape protein often

increase animal production and forage digestion (McCollum and Galyean, 1985; DelCurto et al., 1990c). Fishmeal is considered to be a high ruminal escape protein source (ARC, 1980; NRC, 1985). Anderson et al.(1988) reported that gain was increased by 0.13 kg d^{-1} when escape protein (FM) was fed to steers grazing smooth bromegrass. Many researchers (Veira et al., 1985; Steen, 1989; Nicholson et al., 1992) have reported that cattle fed FM supplements tended to gain more and showed efficient FE. Gill et al. (1987) found that when steers were offered silage ad libitum and supplemented with 150 g FM/kg DM, WG was increased without an increase in FI. When grass silage or ammoniated grass hay were supplemented with 0.75 g FM/kg liveweight, Gibb and Baker (1987) found improved WG by 148 and 88 g for silage and hay diets, respectively. Steen (1992) reported that inclusion of FM in a supplement gave a WG response of 580 g per kg FM. Similar responses were obtained in some other experiments (Steen, 1988). However, much larger responses in WG (1150 to 2000 g per kg FM) were obtained when FM was given as a supplement to low digestibility silages (Garstang et al., 1979; Garstang, 1980; England and Gill, 1985). In our experiment the WG response to FM supplement was 1568 g per kg FM. McAllister et al. (1992) reported that lambs supplemented with FM showed increased WG (5.3%) and NDF digestion (7.3%). In our study WG was improved by 24%. Seoane et al. (1993) found that protein supplementation (95 g per 100 kg BW) with FM increased hay DM intake but not silage DM intake. Singh and Mehra (1990) found that urea-ensiled straw and mixed with molasses when supplemented with FM (25 to 200 g per day) improved WG in buffalo calves. Veira et al. (1988) noted that supplementation of grass silage with FM improved WG and FE of beef calves. It has been found that animals on diets based on sugarcane chaff, straw or dry pasture have a much larger response to supplementation with small amounts of by-pass protein than animals on a diet based on cereal grains (Bird et al., 1979; Orskov, 1982). Bailey (1989) compared steers

consuming a predominantly forage diet to steers given a similar diet plus undegradable protein. It was concluded that steers fed the undegradable protein had a higher rate of gain and were energetically more efficient. Addition of FM improved WG and N digestibility in lambs (Yilala and Bryant, 1985; Hussein et al., 1991). Improvements in fiber digestion have been reported in sheep supplemented with escape protein (Lindberg, 1984; Hussein et al., 1991).

Combellas et al. (1993) found that when cattle diets were supplemented with FM at 300 g per day, the WG increments were 50 and 108 g per 100 g FM with forage and low quality silage, which indicates that WG response to FM is very large with low quality tropical forages, and as its quality improves this response is apparently reduced. In a Canadian study (Erfle et al., 1983) cows fed 15.4% CP diet (containing 3.2% CP as FM) produced more milk than those fed a 16.2% CP diet (containing 6.9% CP as FM). Thus a proper proportion of FM protein and CP to be supplied by other dietary components for maximizing milk production may vary, and needs to be established. In studies with cows producing less than 27 kg per day of milk, feeding of FM failed to increase milk production (Sloan et al., 1988). Erfle et al. (1983) and Sloan et al. (1988) found that dairy cows receiving FM supplements tended to gain more weight. Atwal and Erfle (1992) reported that FM supplementation (4.1% CP as FM) decreased FI but increased milk yield and fat content. In our experiment FI was reduced and milk yield increased as a result of FM supplementation. Hussein and Jordan (1991) reported that FM was more effective in improving WG in young than in finishing ruminants. Daily WG and FE were higher with FM supplemented medium or poor-quality silages than when it was added to high-quality silages. Chalupa (1975) suggested that the potential for ruminally undegraded protein sources to improve rate and efficiency of gain and N balance may be greatest in young growing ruminants in which the ruminal microbial AA

supply may be insufficient to meet metabolic AA requirements for maintenance and rapid growth.

Usmani and Inskeep (1989) reported that yields of milk and milk fat for the first 75 days of lactation were greater for buffaloes on higher prepartum energy levels. Wiley et al. (1991) reported that prepartum nutrition have no effect on postpartum milk production. Davies (1992) reported that when cows were subsequently turned out to pasture, milk yields of cows from different protein treatments gradually converged and by week 7, no significant residual effects were observed on milk quality or cow liveweight change. Blauwiekel et al. (1990) reported that sources of undegradable protein did not affect total milk or fat corrected milk yields, DM intake or milk protein percentages. Sutton (1989) reported that increasing the amount of dietary protein within a constant amount of dietary energy has little or no effect on milk protein concentration.

Factors that could contribute to the higher response to bypass protein are an improvement in the efficiency of feed utilization through a reduction in waste energy generated in fermentative digestion (Leng, 1990) or a more balanced supply of nutrients (Gill et al., 1987). Forage proteins are extensively degraded in the rumen (NRC, 1985) and FM supplementation then results in an increased dietary AA flow to the duodenum and/or improved fiber fermentation through a continuous release of nitrogenous substances to the rumen microbes (Hussein and Jordan, 1991). The additional proteins fed may have overcome an AA deficiency per se (Whitelaw et al., 1985) or may have improved the efficiency of ME utilization.

In our experiment, roughage DM intake was higher in the hay treatment compared to silage treatments. Kellems et al. (1991) reported that consumption of DM tended to decline as DM content of the ration decreased. Similar results were found by Lehr et al. (1983). At least

three potential factors are associated with increasing moisture content of ration that could result in depressed DM intake. The first factor is not related to the moisture content but rather to increasing concentrations of fermentation end products in feeds with increasing moisture content. These soluble components can restrict DM intake (Phillip et al., 1981). The second factor is the increased bulk of feedstuffs caused by intracellular, or non-expressible water. This could limit intake due to rumen fill until cellular structures are destroyed through mastication or fermentation, to release contained water. This factor becomes more important as the diet forage proportion increases. The third factor related to increasing moisture content that could reduce intake is the increased intake of water. This could limit intake by exceeding the capacity to transport water from the rumen, thereby, restricting intake due to rumen fill.

In experiment 2, the comparative digestibilities of silage DM, CP, NDF, and ADF in water buffaloes versus Hereford cows were significantly ($P < .05$) higher in buffaloes. Contradictory observations regarding superiority of buffaloes over that of cattle in the efficiency of feed utilization are available in literature. Wahid (1973) reported that buffaloes are excellent scavengers and can utilize coarse forages more efficiently than cattle. He also noted that buffalo calves have higher birth weight, grow at a faster rate and can utilize coarse feeds more efficiently than cattle, thus they can produce beef more economically. Cockrill (1980) reported that because buffalo can better utilize roughage, meat can be produced at lower cost than in the case of cattle. Katiyar and Bisth (1989) found that the digestibility of the fibrous fraction of lucerne-hay based rations was significantly higher in buffaloes than in cattle. They also reported that when buffaloes and cattle were fed ad libitum lucerne hay plus 0.3 kg of concentrate per kg of milk produced, the ADF digestibility was 45.6 and 50.1 for cattle and buffaloes, respectively. However, when concentrate was fed at 0.6 kg per kg of milk produced, the ADF digestibility was 37.9 and 45.0 for cattle and buffalo, respectively.

In our experiment, the ADF digestibility of silage was 35 and 43 percent for cattle and buffaloes, respectively. Katiyar and Bisth (1989) fed oat-hay based rations to buffaloes and cattle and found significantly higher digestibility of fibrous matter by buffaloes. Ranjhan (1991) in most of the experiments he reviewed found that buffaloes are superior to cattle in their ability to digest the organic matter and VFA production in the rumen. Pradhan et al. (1991) also reported that buffaloes digest more feed nutrients than cattle when fed poor quality roughages. Katiyar and Bisth (1989) reported comparatively higher rumen ammonia-N concentration in buffaloes than cattle, but the pattern of attaining peak ammonia concentration and its decline was similar in both species. Total VFA concentration increased more sharply after feeding in buffaloes than in cattle and the peak concentration was higher in buffaloes. Many other workers (Singh and Mudgal, 1967; Poonappa et al., 1971; Razdan et al., 1971) reported significantly better nutrient utilization in buffaloes than in cattle. However, there are many other researchers (Jain and Majumdar, 1962; Naga and El-Shazly, 1969; Cheturvedi et al., 1973) who did not find significant differences between buffaloes and cattle in this respect.

Differences in diet digestibility exist among various other species of domestic ruminants. Many comparative studies have been done between cattle and sheep and goats vs sheep. Colucci et al. (1989) reported that at high feed intake, digestion values in cows were less than those in sheep for all diets. An increase in intake depressed the digestion of cell wall fractions and cell solubles including starch in cows, whereas in sheep, an increase in intake reduced cell wall digestibility and to a lesser extent cell solubles, without affecting starch digestion. Blaxter and Wainman (1961) also showed a lower digestive capacity in cattle than in sheep fed a diet made up of 2 parts of hay and 1 part of rolled oats at 2 times maintenance. A poorer digestion of energy by cattle than sheep fed all grain rations (sorghum and barley) was also observed by Keating et al. (1965). However, there are many studies where

digestibility is greater in cattle than in sheep. The results of a detailed analysis of 1912 trials involving 27 feeds (Cipolloni et al., 1951) indicated that cattle tended to digest dry roughages and silages better than sheep but sheep tended to digest concentrates better than cattle. Greater digestibility values have been reported for cattle than for sheep fed low and medium quality roughages (Blaxter et al., 1966; Leaver et al., 1969). This difference in digestive efficiency (with high fiber diets) appears to become large as roughage quality decreases (Rees and Little, 1980). Several other workers (Siebert and Kennedy, 1972; Bird, 1974; Plyne, 1978) have also shown that FI and digestibility is more in cattle than sheep, when they are offered same feed. Rees and Little (1980) found that feed is retained longer in the cattle rumen than in sheep and that may result in higher digestion in cattle. Reid et al. (1988) reported that where the same forages were fed, mean DMD and FI were lower ($P < .05$) for sheep than for cattle. Poppi et al. (1980) and Prigge et al. (1984) attributed the greater digestibility of high-fiber forage by cattle to increased rumen retention time. Demment and Van Soest (1985) suggest that a higher digestibility of forage by cattle should result from increased body size because of longer retention in the reticulo-rumen.

There are claims of superiority of goats over sheep in regard to roughage intake and digestion (El Hag, 1976; Gihad, 1976). Wahed and Owen (1986) found that ammonia-treated barley straw consumption was higher for goats compared to sheep, however, they failed to detect differences between sheep and goats in their ability to digest grass hays. Mohammad and Owen (1982) found greater intake in goats and reflected it as their greater maintenance energy requirements compared with sheep. Domingue et al. (1991) reported that when goats and sheep are fed prairie grass straw, goats had greater voluntary FI, greater apparent DM digestibility (36.8 vs 32.6) and a larger rumen pool of DM and liquid than sheep. Goats also had greater apparent digestibility of fiber. Goats had a higher rumen ammonia concentration

(115 vs 80 mg N per liter), lower rumen pH (6.73 vs 6.90), and a smaller proportion of large particles and greater proportion of small particles in rumen contents than sheep. Reid et al. (1990) found that for nine types of hay, DM and NDF digestibility by cattle and goats was higher ($P < .05$) than by sheep.

In conclusion, the straw:CJ silage was equal to cool-season grass hay in terms of FI, WG, FE. When supplemented with FM it gave better dairy heifer performance than did hay alone. There were no long term effects of these feeds on milk production and composition. Digestibility (DM, CP, NDF and ADF) of this silage was significantly higher in water buffaloes than in Hereford cows.

Table 2.1

Chemical composition (Percent-DM basis) of feeds used in dairy heifer experiment

Feed type	Composition				
	DM	CP	NDF	ADF	ASH
Silage	37.85	6.39	74.21	49.62	6.79
Grass hay	89.92	6.93	71.49	41.42	7.90
Fishmeal[1]	91.71	57.4	-	2.10	4.81
Dairy Concentrate[2]	89.15	15.19	31.02	15.40	7.35

[1] Fishmeal was provided by Advanced Hydrolyzing Systems, Astoria, OR.

[2] Dairy concentrate ingredient composition (percent) = wheat mill run, 7.5; corn, 25; oats, 10; wheat, 7.5; canola fines, 4.4; SLS40[a], 26.25; mixed screenings, 15; salt, 0.5; molasses, 2.5; trace minerals/vitamins, 1.35.

[a] SLS40 is a propriety mix having soy, linseed and sunflower meals with 40% CP, 2.75% fat and 9.5% fiber.

Table 2.2

Feed intake (DM basis) and performance data of dairy heifers

Parameter	Feed Types[1]			
	GH	S	SF	SE
Weight gain (kg h^{-1} d^{-1})	0.998^{ab}	0.824^{a}	1.02^{b}	0.05
FI (kg h^{-1} d^{-1}) Roughage	7.77^{a}	6.45^{b}	6.02^{c}	0.09
Total FI	9.84^{a}	8.52^{b}	8.15^{c}	0.10
FE[2]	10.42^{ab}	11.82^{a}	8.41^{b}	0.80

[1] GH= Grass hay; S= Ryegrass straw:corn juice silage; SF= S plus 125 g fishmeal per head per day.

[abc] Values in the same row with different superscripts differ ($P < .05$).

[2] FE= Kilograms of feed consumed per kg of weight gain.

SE= Pooled standard error.

Table 2.3

Milk production and composition data (kg per head per day).

Parameter	Feed Types[1]			
	GH	S	SF	SE
Lactation length (days)	309	307	331	16
Milk yield	30.91	31.50	32.06	1.43
Milk fat yield	1.13	1.19	1.19	0.05
SNF yield	1.03	1.05	1.07	0.04

[1] GH= Grass hay; S= Ryegrass straw:corn juice silage; SF= S plus 125 g fishmeal per head per day.

SE= Pooled standard error.

Table 2.4

Comparative digestibility of ryegrass straw:corn juice silage in water buffaloes versus Hereford cows

Variable	Digestibility (percent)		
	Buffaloes	Cows	SE
Dry matter	47[a]	40[b]	1.09
Crude protein	47[a]	34[b]	1.74
NDF	47[a]	41[b]	1.56
ADF	43[a]	35[b]	1.55

[ab] Values in the same row with different superscripts differ ($P < .05$).

SE= Pooled standard error.

REFERENCES

Agricultural Research Council. 1980. The nutrient requirements of ruminant livestock. Commonwealth Agricultural Bureaux, Slough, UK.

Anderson, S.J., Klopfenstein, T.J. and Wilkerson, V.A., 1988. Escape protein supplementation of yearling steers grazing smooth brome pastures. J. Anim. Sci., 66: 237-242.

Association of Official Analytical Chemists. 1990. Official methods of analysis 15th ed. AOAC. Inc. Arlington, VA.

Atwal, A.S. and Erfle, J.D., 1992. Effect of feeding fishmeal to cows on digestibility, milk production and milk composition. J. Dairy Sci., 75: 502-507.

Bailey, C.B., 1989. Rate and efficiency of gain from weaning to slaughter of steers given hay supplemented with ruminal undegradable protein, or concentrate. Can. J. Anim. Sci., 69: 691-706.

Bird, P.R., 1974. Sulphur metabolism and excretion studies in ruminants. XIII. Intake and utilization of wheat straw by sheep and cattle. Australian J. Agric. Res., 25: 631-642.

Bird, S.H., Hill, M.K. and Leng, R.A., 1979. The effect of defaunation of the rumen on the growth of lambs on low-protein-high-energy diets. Br. J. Nutr., 42: 81-87.

Blauwiekel, R., Hoover, W.H., Slider, S.D. and Miller, T.K., 1990. Effect of fishmeal protein supplementation on milk yield and composition and blood constituents of dairy cows. J. Dairy Sci., 73: 3217-3221.

Blaxter, K.L. and Wainman, F.W., 1961. The utilization of food by sheep and cattle. J. Agri. Sci. (Camb.)., 57: 419-426.

Blaxter, K.L., Wainman, F.W. and Davidson, J.L., 1966. The voluntary intake of food by sheep and cattle in relation to their energy requirements for maintenance. Anim. Prod., 8: 75-86.

Chalupa, W., 1975. Rumen by-pass and protection of proteins and amino acids. J. Dairy Sci., 68: 1198-1205.

Chaturvedi, M.L., Singh, U.B. and Ranjhan, S.K., 1973. Effect of feeding chopped and ground wheat straw on the utilization of nutrients and VFA production in growing cow calves and buffalo calves. Indian J. Anim. Sci., 43: 382-385.

Cipolloni, M.A., Schneider, B.H., Lucas, H.L. and Pavlech, H.M., 1951. Significance of the differences in digestibility of feeds by cattle and sheep. J. Anim. Sci., 10: 337-342.

Cockrill, W.R., 1980. The ascendant water buffalo - key domestic animal. World Anim. Rev., 33: 2-12.

Colucci, P.E., Macleod, G.K., Grovum, W.L., Cahill, L.W. and McMillan, I., 1989. Comparative digestion in sheep and cattle fed different forage to concentrate ratios at high and low intakes. J. Dairy Sci., 72: 1774-1785.

Combellas, J., Priore, F., Paralta, J. and Zavarce, O., 1993. Influence of the addition of fishmeal to diets of roughage or roughage and concentrate on the composition and liveweight gain of growing cattle. Anim. Feed Sci. Technol., 42: 319-331.

Conklin, F.S., Taylor, M.L., Miles,Sr. T.R., Miles,Jr. T.R., Davis, E.F. and McHugh, E.J., 1991. Opportunities in grass straw utilization: an alternate viewpoint. Special report 881, Agric. Expt. Stat., Oregon State University.

Davies, O.D., 1992. The effects of protein and energy content of compound supplements offered at low levels to October-calving dairy cows given grass silage ad libitum. Anim.Prod., 55: 169-175.

DelCurto, T., Cochran, R.C., Nagaraja, T.G., Corah, L.R., Beharka, A.A. and Vanzant, E.S., 1990c. Comparison of soybean meal/sorghum grain, alfalfa hay and pellets as supplemental protein sources for beef cattle consuming dormant tallgrass-prairie forage. J. Anim. Sci., 68: 2901-2915.

Demment, M.W. and Van Soest, P.J., 1985. A nutritional explanation for body-size patterns of ruminants and non-ruminant herbivores. Am. Nat., 125: 641-646.

Domingue, B.M.F., Delloe, D.W. and Barry, T.N., 1991. Voluntary intake and rumen digestion of a low-quality roughage by goats and sheep. J. Agric. Sci. (Camb.)., 117: 111-120.

El Hag, G.A., 1976. A comparative study between desert goats and sheep. Efficiency of feed utilization. Wld. Rev. Anim. Prod., 12(3): 43-48.

England, P. and Gill, M., 1985. The effect of fishmeal and sucrose supplementation on the voluntary intake of grass silage and liveweight gain of young cattle. Anim. Prod., 40: 259-265.

Erfle, J.D., Mahadevan, S., Teather, R.M. and Sauer, F.D., 1983. The performance of lactating cows fed corn silage in combination with soybean or fishmeal containing concentrates. Can. J. Anim. Sci., 63: 191-196.

Garstang, J.R., 1980. Silage supplements for calves. Anim. Prod., 32: 355 (Abstr.).

Garstang, J.R., Thomas, C. and Gill, M., 1979. The effect of supplementation of grass silage with fishmeal on intake and performance of British Friesien calves. Anim. Prod., 28: 423 (Abstr.).

Gibb, M.J. and Baker, R.D., 1987. Performance of young steers offered silage or thermo-ammoniated hay with or without fishmeal supplement. Anim. Prod., 45: 371-381.

Gihad, E.A., 1976. Intake, digestibility and nitrogen utilization of tropical natural grass hay by goats and sheep. J. Anim. Sci., 43: 879-883.

Gill, M., Beever, D.E., Buttery, P.J., England, P., Gibb, M.J. and Baker, R.D., 1987. the effect of oestradiol-17b implantation on the response in voluntary intake, liveweight gain and body composition, to fishmeal supplementation of silage offered to growing calves. J. Agric. Sci. (Camb.)., 108: 9-16.

Goering, H.K. and Van Soest, P.J., 1970. Forage Fiber Analysis (Apparatus, Reagents, Procedures and some applications). USDA-ARS Agri. Handbook No. 379.

Hussein, H.S. and Jordan, R.M., 1991. Fishmeal as a protein supplement in ruminant diets: a review. J. Anim. Sci., 69: 2147-2156.

Hussein, H.S., Jordan, R.M. and Stern, M.D., 1991. Ruminal protein metabolism and internal amino acid utilization as affected by dietary protein and carbohydrate sources in sheep. J. Anim. Sci., 69: 2134-2146.

Jain, S. and Majumdar, B.N., 1962. A study on comparative digestibility in different species of farm ruminants. Biochem. Exp. Med., 22: 303-309.

Katiyar, R.C. and Bisth, G.S., 1989. Nutrient utilization in Murrah buffalo and Hariana cattle - A comparative study with lucerne-hay-based rations. Proc. World Buffalo Congress., II: 194-198.

Katiyar, R.C. and Bisth, G.S., 1989. Nutrient utilization in Murrah buffalo and Hariana cattle - A comparative study with oat-hay based rations. Proc. World Buffalo Congress., II: 189-193.

Keating, E.K., Saba, W.J., Hale, W.H. and Taylor, B., 1965. Further observations on the digestion of milo and barley by steers and lambs. J. Anim. Sci., 24: 1080-1089.

Kellems, R.O., Jones, R., Andrus, D. and Wallentine, M.V., 1991. Effect of moisture in total mixed ration on feed consumption and milk production and composition in Holstein cows. J. Dairy Sci., 74: 929-932.

Lal, G.M. and Mudgal, V.D., 1967. Studies on the utilization of paddy straw (*Oryza sativa*) and berseem (*Trifolium alexandrinium*) as silage. Indian J. Dairy Sci., 20: 103-107.

Leaver, J.D., Campling, R.C. and Holmes, W., 1969. The effect of level of feeding on the digestibility of diets for sheep and cattle. Anim. Prod., 11: 11-17.

Lehr, D.A., Otterby, D.E., Johnson, D.G., Laz, J.G. and Landquist, R.G., 1983. Effect of moisture content of complete diets on feed intake and milk production by cows. J. Dairy Sci., 66: 1891-1898.

Leng, R.A., 1990. Some theoretical considerations on drought feeding recommendations. In: D.J.Ferrell (Editor), Recent Advances in Animal Nutrition in Australia, The Univ. of

New England, Armidale, N.S.W., pp 104-111.

Lindberg, J.E., 1984. Nitrogen metabolism in sheep. I. Rumen fermentation and microbial synthesis in sheep fed with hay, barley and various protein supplements. Swed. J. Agric. Res., 43: 37-43.

McAllister, T.A., Beauchemin, K.A., McClelland, L.A. and Cheng, K.A., 1992. Effect of formaldehyde-treated barley or escape protein on nutrient digestibility, growth and carcass traits of feedlot lambs. Can. J. Anim. Sci., 72: 309-316.

McCollum, F.T., and Galyean, M.L., 1985. Influence of cotton seed meal supplementation on voluntary intake, rumen fermentation and rate of passage of prairie hay in beef steers. J. Anim. Sci., 60: 570-577.

Mohammad, H.H. and Owen, E., 1982. Goats versus sheep: effects of coat thickness and body composition on maintenance energy requirements. Anim. Prod., 34: 391 (Abstr.).

Naga, N.A. and El-Shazly, K., 1969. Activities of rumen microorganisms in water buffalo (Bos bubalis) and in zebu cattle. J. Dairy Res., 36: 1-8.

Narang, M.P. and Pradhan, K., 1974. Studies on improving the utilization of poor quality roughages: Ensiling wheat straw with cowpea (Vigna linensis). Indian J. Anim. Sci., 44: 14-17.

National Research Council., 1985. Ruminant Nitrogen Usage. National Academy Press, Washington, D.C.

Nicholson, J.W.G., Charmley, E. and Bush, R.S., 1992. The effect of supplemental protein source on ammonia level in rumen fluid and blood and intake of alfalfa silage by beef cattle. Can. J. Anim. Sci., 72: 853-862.

Orskov, E.R., 1982. Protein Nutrition in Ruminants. Academic Press, London.

Phillip, L.E., Buchanan-Smith, J.G. and Grovum, W.L., 1981. Food intake and rumen osmolality in sheep. Differentiation of the effect of osmolality from that of the products of maize silage fermentation. J. Agric. Sci. (Camb.)., 96: 439-446.

Plyne, M.J., 1978. Differences between cattle and sheep in their digestion and relative intake of mature tropical grass hay. Anim. Feed Sci. Technol., 3: 41-49.

Poonappa, C.G., Nooruddin, M.D. and Raghavan, G.V. 1971. Rate of passage of food and its relation to digestibility of nutrients in Murrah buffaloes and Hariana cattle. Indian J. Anim. Sci., 41: 1026-1031.

Poppi, D.P., Minson, D.J. and Ternouth, J.H., 1980. Studies of cattle and sheep eating leaf and stem fractions of grasses. 1. The voluntary intake, digestibility and retention time in the reticulo-rumen. Aust. J. Agric. Res., 32: 99-108.

Pradhan, K., Bhatia, S.K. and Sangwan, D.C., 1991. Feed consumption pattern, nutrient digestibility and related physiological reactions in buffalo and cattle on high fibrous diets. Proc. Third World Buffalo Congress., I: 175.

Prigge, E.C., Baker, M.J. and Verga, G.A., 1984. Comparative digestion, rumen fermentation and kinetics of forage diets by steers and wethers. J. Anim. Sci., 59: 237-245.

Ranjhan, S.K., 1991. Comparative efficiency of utilization of feeds and forages in Indian cattle and buffaloes. Proc. Third World Buffalo Congress. I: 160.

Razdan, M.N., Sharma, D.D., Bhargava, P.K. and Chawala, M.S. 1971. Utilization of urea and water metabolism by zebu cattle and buffalo under tropical conditions. J. Dairy Sci., 54: 1200-1207.

Rees, M.C. and Little, D.A., 1980. Differences between sheep and cattle in digestibility, voluntary intake and retention time in the rumen of three tropical grasses. J. Agric. Sci. (Camb.)., 94: 483-488.

Reid, R.L., Jung, G.A., Cox-Ganser, J.M., Rybeck, B.F. and Townsend, E.C., 1990. Comparative utilization of warm and cool season forages by cattle, sheep and goats. J. Anim. Sci., 68: 2986-2994.

Reid, R.L., Jung, G.A. and Thayne, W.V., 1988. Relationship between nutritive quality and fiber components of cool season and warm season forages: A retrospective study. J. Anim. Sci., 66: 1275-1291.

Sanderson, R., Thomas, C. and McAllan, A.B., 1992. Fish-meal supplementation of grass silage given to young growing steers: effects on intake, apparent digestibility and live-weight gains. Anim. Prod., 55: 389-396.

Seoane, J.R., Amyot, A.M., Christen, A.M. and Petit, H.V., 1993. Performance of growing steers fed either hay or silage supplemented with canola or fishmeal. Can. J. Anim. Sci., 73: 57-65.

Siebert, B.D. and Kennedy, P.M., 1972. The utilization of spear grass. 1. Factors limiting intake and utilization by cattle and sheep. Australian J. Agric. Res., 23: 35-44.

Singh, U.B. and Mehra, V.R., 1990. Utilization of wheat straw given in a feed block and supplemented with varying quantities of fishmeal and oil-extracted rice bran. Anim. Feed Sci. Technol., 28: 129-134.

Singh, B.K.and Mudgal, V.D., 1967. The comparative utilization of feed nutrients from lucerne hay in buffalo and crossbred zebu heifers. Indian J. Dairy Sci., 20: 142-148.

Sloan, B.K., Rowlison, P. and Armstrong, D.G., 1988. The influence of a formulated excess of rumen degradable protein or undegradable protein on milk production in dairy cows in early lactation. Anim. Prod., 46: 13-19.

Statistical Analysis Systems., 1987. SAS- Institute, Cary, NC, USA.

Steel, R.G.D. and Torrie, J.H., 1980. Principles and Procedures of Statistics. 2nd. ed. Mc Graw Hill, New York.

Steen, R.W.J., 1992. A comparison of soya-bean meal, fishmeal and maize gluten feed as protein sources for calves offered grass silage ad libitum. Anim. Prod., 54: 333-339.

Steen, R.W.J., 1989. A comparison of soya-bean, sunflower and fishmeal as protein supplements for yearling cattle offered grass silage-based diets. Anim. Prod., 48: 81-89.

Steen, R.W.J., 1988. The effect of supplementing silage-based diets with soybean and fishmeals for finishing beef cattle. Anim. Prod., 46: 43-51.

Sutton, J.D., 1989. Altering milk composition by feeding. J. Dairy Sci., 72: 2801-2814.

Suzuki, E.Y. and Early, R.J., 1991. Analysis of chromic oxide in small samples of feeds and feces using chlorine bleach. Can. J. Anim. Sci., 71: 931-934.

Usmani, R.H. and Inskeep, E.K., 1989. Effect of prepartum feeding on milk yield and calf growth rate in limited-suckled and non-suckled buffaloes. J. Dairy Sci., 72: 2087-2094.

Veira, D.M., Butler, G., Ivan, M. and Proulx, J.G., 1985. Utilization of grass silage by cattle: effect of barley and fishmeal supplements. Can. J. Anim.Sci., 65: 897-903.

Veira, D.M., Proulx, J.G., Butler, G. and Fortin, A., 1988. Utilization of grass silage by cattle: further observations on effect of fishmeal. Can. J. Anim. Sci., 68: 1225-1235.

Wahed, R.A. and Owen, E., 1986. Comparison of sheep and goats under stall-feeding conditions: Roughage intake and selection. Anim. Prod., 42: 89-95.

Wahid, A., 1973. Pakistani buffaloes. World Anim. Rev., 7: 22-28.

Waldern, D.E., 1971. A rapid micro-digestion procedure for neutral and acid detergent fiber. Can. J. Anim. Sci., 51: 67-69.

Whitelaw, F.G., Milne, J.S., Orskov, E.R. and Smith, J.S., 1985. The effect of casein supplements given by abomasal infusion on the nitrogen and energy metabolism of lactating cows. Proc. Nutr. Soc. 44.

Wiley, J.S., Peterson, M.K., Ansotegni, R.P. and Bellows, R.A., 1991. Production from first-calf heifers fed a maintenance or low level of prepartum nutrition and ruminally undegradable or degradable protein postpartum. J. Anim. Sci., 69: 4279-4293.

Yilala, k. and Bryant, M.J., 1985. The effects upon the intake and performance of store lambs of supplementing grass silage with barley, fishmeal and rapeseed meal. Anim. Prod., 40: 111-121.

CHAPTER 4

FIELD APPLICATION OF CORN JUICE TO GRASS STRAW AND CULL ONION-STRAW ENSILING FOR UTILIZATION OF AGRICULTURAL BY-PRODUCTS AS LIVESTOCK FEEDS.

I. Hussain and P.R. Cheeke

Animal Sciences Department

Oregon State University, Corvallis, OR 97331

Abstract

Three in vitro and one in vivo experiments were conducted to investigate the preparation of grass straw:cull onion silages. In experiment 1, ryegrass straw:cull onions and tall fescue straw:cull onions laboratory-scale silages with 3% urea with and without 0.1% raw soybean (RSB) as a source of urease were prepared in the ratios of straw:onion: 30:70; 40:60; 50:50; 60:40; 70:30 (wt/wt). Addition of RSB significantly increased CP and OM with both types of straw, while it significantly reduced NDF, ADF and ash in ryegrass:onion silage (ROS) and NDF, ASH and hemicellulose (HC) in tall fescue straw:onion silage (FOS). In vitro dry matter digestibility (IVDMD) was similar in both groups. In experiment 2, where onions and ryegrass straw ratios ranged from 0 to 100 percent, and urea was applied at 0, 3 and 5 percent level, the CP concentration was significantly lower in silage with no urea treatment (U0), compared to silage with 3% urea (U3) and silage with 5% urea (U5) treatments, and CP in U3 was lower ($P<.05$) than U5 treatment (9.96, 13.81, 18.50 % CP) for U0, U3 and U5 respectively. The IVDMD in U0 was significantly lower than U3 and U5 treatments (63.45, 69.40 and 69.60) for U0, U3 and U5, respectively. Ash concentration was

significantly higher ($P < .05$) in U0 vs U3 and U5, respectively. The reverse pattern was observed for OM (93.10, 94.31, 94.67) for U0, U3 and U5, respectively. In experiment 2, onions were non-pungent type while in experiment 3, yellow, pungent type onions were used. In experiment 3, similar patterns were observed as in experiment 2, except that CP, IVDMD and OM contents were slightly higher and ash content lower in experiment 3 vs experiment 2. In experiment 4, silage DMI by sheep was higher ($P < .05$) in the non-supplemented onion:straw silage group (S) vs alfalfa pellets (75 g h^{-1} d^{-1}) supplemented group (SA) (1000 vs 919 g h^{-1} d^{-1}). However, total feed intake and weight loss were similar between S vs SA. Packed cell volume (PCV) at the start of experiment was significantly higher (39.8%) than after 30 days when it averaged 34.35%, suggesting an effect of hemolytic agents in onions. In experiment 5, corn juice with or without 3% urea and 0.1% raw soybean (RSB) was sprayed on (5 pounds each) annual ryegrass straw, perennial ryegrass straw and tall fescue straw. The ratios of corn juice:straw were: 30:100; 40:100; 50:100; 60:100; 70:100; 80:100; 90:100; 100:100; 200:100; and 300:100 (wt/wt). By spraying the corn-juice-3% urea-0.1% RSB mixture, the CP content in all straws was significantly increased compared to corn juice spray with no urea; however, there were no differences in the ADF concentration between the two treatments with all the three silages. In conclusion, urea treatment and addition of raw soybean as a source of urease are effective in improving the nutritive value of straws:onion silages. Onion:straw silage feeding resulted in weight loss in sheep, and alfalfa pellets supplementation showed very little benefit. The silage was very high in ash, probably because of soil contamination of onions and straw in the field. Spraying of straws with CJ with urea plus RSB did improve the CP content, but ADF contents remained unchanged.

Introduction

Depending on fluctuations in market price and produce quality, considerable quantities of onions are either discarded in disposal areas or fed to livestock, mainly sheep, which will eat them both fresh and spoiled. Disposal of cull onions, particularly those infected with the disease white rot, is a problem in many onion-producing areas including the Willamette Valley of Oregon. The principal disposal method is a costly one whereby the cull onions are macerated, returned to the fields and plowed under. This procedure is important in increasing the dispersal of white rot disease. Since landfills will no longer accept cull onions, some value added methods of their disposal are needed. Nutritionally, onions have approximately the same nutritional value as barley grain on a DM basis (NRC, 1984). The main difference between the two feeds is in the moisture content. Onions have about 85% moisture vs 12% for barley.

In addition to cull onions, there are other agricultural by-products that are waste disposal problems in western Oregon. For example, about two-thirds of the U.S. production of grass seed takes place in the Willamette Valley of western Oregon (Conklin et al., 1989). Large quantities of crop residues such as straw are produced, which traditionally has been disposed of by open-field burning. The disposal of straws through open field burning is becoming difficult because of environmental pollution concerns and regulations. Another agricultural by-product produced in large quantity is corn juice (CJ). Over six million gallons of CJ are produced annually by the Oregon corn canneries (A.Wakefield, Agripac Inc., Personal Communication, 1989). Its disposal has water pollution concerns. Therefore, cull onions, CJ and seed straws are considered wastes. These grass straws are low in CP, DE and many minerals. On the other hand cull onions and CJ have reasonable contents of CP and soluble carbohydrates and are high in moisture. For making silage from straw, it is necessary

to add a minimum of 30% water, a source of fermentable carbohydrates and nitrogen. Cull onions and CJ could serve as a source of these nutrients. Therefore, if straw and onions are mixed in the right proportions, a good quality silage may be formed. The objective of this study was to make lab silages with different combinations of straws and onions, with or without urea treatments, and with and without urease source to find the most suitable proportions.The effect of feeding straw:onion silage with alfalfa pellets supplementation to sheep on intake, weight gain and blood packed cell volume (PCV), was also investigated. The PCV was measured because onions contain a hemolytic agent, n-propyldisulfide. The final experiment involved the field application of corn juice with or without urea and raw soybean (RSB) to straw windrows, followed by sun drying, as a means of increasing the nutritional content of straw and providing a means of disposal of corn juice.

Materials and Methods

Experiment 1

Five laboratory silages were prepared in sealed plastic bags using annual ryegrass straw:cull onions in the ratio of 30:70; 40:60; 50:50; 60:40; 70:30. Cull onions were chopped before mixing with chopped straw. Each silage bag weighed 1 kg, i.e. a 30:70 straw:onions silage contained 300 g straw mixed with 700 g of fresh chopped onions. Urea was mixed in all silages at the rate of 3% (as is basis). No water was added. After mixing the straw, onions and urea, the mixture was sealed in plastic bags, and bags were pressed well before sealing to exclude all the air. Five exactly similar silages were prepared as mentioned above except that in addition ground raw soybean (RSB) was added (0.1%) as a source of urease. Another 10 silages were prepared exactly as mentioned above, except that tall fescue straw was used, instead of annual ryegrass straw. After 6 weeks in the sealed plastic bags, the bags were opened, and silages dried at 50°C for 72 h for DM determinations. The dried samples were then ground to pass through a 1 mm screen and saved for laboratory analysis. The DM, ash and CP were determined by standard procedures (AOAC, 1990). The NDF and ADF were determined as described by Goering and Van Soest (1970) but modified by a micromethod as described by Waldern (1971). The in vitro dry matter digestibility (IVDMD) was determined as described by Tilley and Terry (1963). Organic matter (OM) was determined by difference (DM-Ash) and HC was also determined by difference (NDF%-ADF%). The methods used for chemical analysis and IVDMD were the same in all the five experiments. In the statistical analysis of the data, the overall mean of silages with urea was compared with overall mean of silages with urea plus RSB, using the GLM procedure of the SAS (SAS, 1987) and means were compared using LSD procedure.

Experiment 2

In this experiment 33 silages were prepared by using annual ryegrass straw and cull onions with 0, 3 and 5 percent urea (wet weight basis). All the silages with urea also contained 0.1% of raw soybean as a source of urease. The silages with urea but no onions were made by mixing with 15% water. The mixtures of straw:onions (1 kg each) were sealed in plastic bags and kept at room temperature for 60 days, after which the bags were opened and the silages dried and analysed for CP, ash and IVDMD. The ratios of straws:onions (wt/wt) were: 0:100; 10:90; 20:80; 30:70; 40:60; 50:50; 60:40; 70:30; 80:20; 90:10; 100:0. Separate silages were prepared for each straw:onion level with 0, 3% and 5% urea (wet weight basis). In this experiment the cull onions used were a red, non-pungent type.

Experiment 3

In this experiment 33 silages were prepared, having exactly the same combinations as described in experiment 2. The only difference was that pungent, yellow cull onions were used in this experiment. In the statistical analysis of experiment 2 and 3, the mean values for silages with 0, 3 and 5 percent urea were compared using the GLM procedure of the SAS (SAS, 1987). Means were separated by LSD procedure.

Experiment 4

Twenty mature Hampshire ewes of about 4 years of age and 77 kg body weight were used in this experiment with 10 sheep and 2 pens per treatment. All the animals were weighed at the start and then at the end of experiment which lasted for one month. Blood samples were taken from all animals at the start and end of the experiment by jugular vein puncture, using vacutainer tubes and 20-gauge needles for the determination of packed cell volume (PCV).

The PCV was determined by a micro-hematocrit method. The control sheep were fed ad-libitum ryegrass straw:cull onions (30:70) silage, while the treatment groups were fed ad-lib silage plus 75 g alfalfa pellets per head per day. Daily feed intake was recorded for 30 days. The data was statistically analysed using GLM procedure of SAS (SAS, 1987) and means were separated by GLM procedure (Steel and Torrie, 1980).

Experiment 5

In this experiment we used unchaffed straws of annual ryegrass straw, perennial ryegrass straw and tall fescue straw (5 lbs for each treatment), put the straw in the field in the form of windrows, and then sprayed it with CJ mixed with or without 3% urea and 0.1% RSB as a source of urease. The ratios of CJ:straws were: 30:100; 40:100; 50:100; 60:100; 70:100; 80:100; 90:100; 100:100; 200:100; and 300:100 (wt/wt). Urea (3 lbs of urea per 100 lbs of straw) and ground RSB (0.1 lbs of RSB per 100 lbs of straw) were mixed with CJ, and that mixture was sprayed on 5 lbs of straw. The straws were air dried, chaffed, ground to pass through a 1 mm screen and analysed for CP and ADF. For statistical analysis, data for each straw treated with different concentrations of CJ were averaged and analysed using GLM procedure of SAS (SAS, 1987). Means were compared using LSD procedure, and differences were seen at 95% level of probability.

Results and Discussion

In experiment 1 most of the parameters studied showed positive effects of using 0.1% raw soybean (RSB) as a source of urease when treating annual ryegrass straw or tall fescue straw and cull onions with urea before ensiling (Table 3.1). The CP content was significantly higher in samples having urease source compared to the one having no urease source in both straws. The NDF concentration was significantly lower ($P < .05$) in samples treated with urea and urease source vs just urea treatment. This difference was observed in both types of straws. In ryegrass straw:onions silages (ROS) ADF was also significantly lower ($P < .05$) in urea plus urease vs simple urea treatments, however, in tall fescue straw:onions silages (FOS) differences in ADF were not significant between urease and simple urea silages. Ash content was significantly lower ($P < .05$) in ROS and FOS treated with urea and RSB compared to simple urea treatment. The opposite trend was observed for organic matter, as would be expected because organic matter is dry matter content minus ash. Concentration of HC was not different in ROS, however, it was lower ($P < .05$) in FOS treated with urea-RSB vs urea alone. However, there was no difference ($P > .05$) in IVDMD with or without urease source in both types of straws. Data on different combinations of tall fescue straw:onions and ryegrass straw:onions is given in Tables 3.6 and 3.7, respectively.

In experiment 2 (Table 3.2), there was a significant difference ($P < .05$) in CP content among 0% urea control (U0), 3% urea (U3) and 5% urea (U5) treatments. The CP content in U0 was lower ($P < .05$) than U3 and U5 treatments, and it was lower ($P < .05$) in U3 vs U5 treated silages. In vitro dry matter digestibility (IVDMD) in U0 was lower ($P < .05$) than U3 and U5 silages. The ash and OM content differed ($P < .05$) among three treatments. Ash content in U0 was higher ($P < .05$) than the U3 and U5, and it was higher in U3 vs U5.

Reverse trend was observed for OM content, that is, it was lower ($P < .05$) in U0 vs U3 and U5, and it was higher in U5 vs U3.

In experiment 3 (Table 3.3), similar trends were observed for CP, IVDMD, ash and OM concentrations as seen in experiment 2. However, the IVDMD and level of CP were higher in experiment 3 vs expt.2, which was probably due to different types of onions used in the two experiments.

In experiment 4 (Table 3.5), the sheep fed onions-straw silage (S) ate 1 kg of DM per head daily. The sheep fed S plus 75 g of alfalfa pellets (SA), ate 0.92 kg of silage DM per head daily and their total FI was 0.99 kg. Silage DM intake was higher ($P < .05$) in S vs SA but total feed intake did not differ ($P > .05$) between treatments. Sheep in S group lost 30 g per head per day and the SA groups lost 25 g per head per day and the difference between the two groups was not significant. The packed cell volume (PCV) at the start of experiment was 39.8% and at the end of experiment was 34.35%, and difference was significant. Chemical composition of feeds offered to sheep is given in Table 3.4.

In experiment 5, spraying of annual ryegrass straw with urea-mixed CJ improved ($P < .05$) CP content (3.75% vs 9.29%) compared to simple CJ spray (Table 3.10). In perennial ryegrass straw sprayed with CJ:urea solution the CP content increased from 5.77% to 10.06%, while in tall fescue straw the CP increased from 6.35% to 9.99%. The ADF content of straws sprayed with corn juice, with or without urea and RSB did not differ in any treatment. This indicates that little of the CJ solids remained on the straw after spraying. Data on all combinations of straws:corn juice is presented in Table 3.11.

Discussion

In experiment 1 the addition of raw soybean (RSB) at 0.1% as a source of urease significantly increased the CP content and significantly decreased NDF concentration

compared to simple urea treatments. There was no difference ($P > .05$) in IVDMD with or without urease source in both types of straws. Joy et al. (1992) reported improved N content and IVDMD when they added urease in straw treated with urea. Dias-Da-Silva et al.(1988) reported that the degree of urea hydrolysis was significantly increased by RSB addition, but it had no effect on digestibility. Jayasuriya and Pearce (1983) reported that addition of urease to urea treated straw reduced the treatment time to 2-4 days, to achieve a given level of digestibility. Insufficient urease activity can be compensated for by the addition of supplementary urease sources in the form of soybean or jackbean meal (Sundstol and Coxworth, 1984). Joy et al. (1992) found that addition of RSB as a source of urease improved the degree of ureolysis in treatment up to 20% moisture content. Williams et al. (1984) did not observe any additional improvement when RSB was added in treatment undertaken at 25-50% moisture contents. In experiment 1 ash content was significantly lower in ROS and FOS treated with urea and RSB compared to simple urea treatment. Joy et al. (1992) reported decrease in ash content in urea-treated maize stover when urease was added.

In experiment 2, CP content was higher ($P < .05$) in urea-treated straw: cull onion silage (3% of fresh weight) compared to no urea treatment, and CP was higher ($P < .05$) in silage treated with 5% urea compared to 3% urea-treated straw. The IVDMD was higher ($P < .05$) in 3 and 5 percent urea treated silages compared to non-treated silages. Dias-Da-Silva et al. (1988) reported that urea treatment of straw significantly ($P < .001$) improved IVOMD and a 3-fold increase in total nitrogen. They reported that urea hydrolysis was more pronounced when the moisture content rose from 400 to 600 g per kg. Similar effects were seen by Williams et al. (1984b) when they treated barley straw. Jayasuriya and Pearce (1983) reported that urea treatments of wheat and rice straw significantly ($P < .05$) increased IVOMD and N content. Zorrilla-Rios et al. (1991) reported that percentage of N and IVDMD values

were increased in wheat straw by the ammoniation from 0.42 to 1.82 and 34.8 to 54.3, respectively. Craig et al. (1988) reported that bermudagrass treated with 3% urea ammonia had higher ($P < .05$) CP and IVOMD than did 1.5% urea ammonia treated forage. Kraiem et al. (1991) reported that urea treatment improved total N content of the wheat straw (2.8-6.6%) and OM digestibility (51 to 55.3%). Several other researchers (Saadullah et al., 1981; Hadjipanayiotou, 1982; Williams and Innes, 1982; Ibbotson, 1983) reported increased digestibility in vivo and in vitro for urea-treated straws. DelCurto et al. (1991) treated tall fescue straw with 3% urea solution and found an increase in CP (5.75% to 14.8%). Similar results were reported by others (Nelson et al., 1985; Chestnut et al., 1987; Hunt et al., 1990). In our experiment 2 and 3 we added 15% water in straw silages where we did not use onions, and we observed increased IVDMD compared to 10:90 ratio of onion:straw silages, which may be due to higher water content in silages where we used water. Mandell et al. (1988) reported that when wheat straw was treated with urea at different moisture levels (15%, 20%, 25% and 30% moisture) it increased ($P < .05$) the CP content from 3.5 to 6.6% at 15% moisture; 6.7% at 20% moisture; 6.3% at 25% moisture and 8.6% at 30% moisture level. The ammoniation process can be enhanced by the addition of water before treatment. Waiss et al. (1972) recommended adding 30% water, while Sundstol et al. (1979) reported 25-30% water and Streeter and Horn (1984) reported increases in digestibility at 35% water for ammoniation. When we increased the level of onions in the silages, there was a trend of increased IVDMD (Table 3.8 and 3.9), which may be due to increased ureolysis because of increased water content, or due to increased digestibility of onions themselves. However, level of increase was more in ammoniated silages vs non-ammoniated silages, which indicates that increased water content is probably responsible for increased IVDMD. Saenger et al. (1983) found an increase in CP (3.6 to 11.2 %) when they treated wheat straw with 3%

anhydrous ammonia. Brown (1988) reported increased ($P < .05$) total N and IVOMD of stargrass hay through anhydrous ammoniation. Kunkle et al. (1980) reported increased DM digestibility of chopped corn plant residue by 5 percentage units by ammoniation at 3.5% of DM before ensiling. Paterson et al. (1979) reported that the DM and fiber digestibility of corn plant residue ammoniated at 3% of DM before ensiling were increased 13.9 and 14.5 percentage units, respectively. Cottyn and DeBoever (1988) reported that wheat straw treatment with 3% ammonia improved digestibility and energy values by an average of 11.2 percentage units and 0.75 MJ. Treatment also improved CP and digestible CP from 3.4 to 8.5% and from 0.1 to 2.3% in the DM, respectively. Moore et al. (1985) reported that ammoniation of grass legume silage increased digestibility of DM by 13.4 percentage units. Buettner et al. (1982) reported increased IVDMD in wheat straw after ammoniation. Dias-Da-Silva (1986) reported increased cell wall digestibility as a result of ammoniation. Chiquette et al. (1992) reported improved apparent digestibility of DM (68 vs 62) as a result of ammoniation of timothy.

Waiss et al. (1972) indicated that the effect of ammonia was more pronounced for plant materials with an initially low digestibility. Kernan et al. (1979) found that due to ammonia treatment the improvement in CP were 8.1, 4.7 and 5.7 percentage units for wheat, oats and barley straw, respectively. The corresponding increases in DOM were 8.6, 6.1 and 6.6 percentage units. Hortan and Steacy (1979) also found greater improvements in the digestibility of wheat straw than in barley and oat straw. They concluded that digestibility after ammoniation was highly dependent on the quality of the starting material. Because the quality of cool season grass straws is better than the cereal straws, and because cull onions are also of good nutritive value, there may be less effect of ammoniation.

In our experiment 2 and 3, the ash content in U0 was higher ($P < .05$) than the U3 and U5, and it was higher in U3 vs U5. Joy et al. (1992) reported that urea treatment of barley straw caused a decrease in ash content (4.8 - 5.6), while in wheat straw the ash content was 7.2% at 3% urea; 8.1% at 5% urea; 7.9% at 6% urea and 8.9% in control. How ammoniation could reduce ash content is not known. Possibly it is a dilution effect from the added urea.

Of the laboratory methods available, the in vitro DM digestibility system is most highly correlated with in vivo digestibility (Marten and Barnes, 1980). Many factors can influence the IVDMD, including source and activity of inoculum. Several studies have indicated that IVDMD of a given forage was not affected by source of ruminal inocula (Marinucci et al., 1992), whereas other studies have reported significant effects (Church and Paterson, 1960; Nelson et al., 1972; Grant et al., 1974). Cherney et al. (1993) reported that IVDMD differed with different sources of ruminal inocula and different filtration methods.

In the sheep feeding trial (experiment 4), two pens that were supplemented with 75 g alfalfa pellets per head per day (SA), ate less ($P < .05$) silage DM compared to the non supplemented sheep (S), however, total FI was similar in both treatments. Weight loss was less ($P > .05$) in SA vs S treatment. Owen (1985) reported that feeding value of crop residues is limited by deficiencies of CP, ME, minerals and vitamins. One way of improving the utilization of such crop residues is by proper supplementation with leguminous forages (Mosi and Butterworth, 1985). DelCurto et al. (1991) reported that supplementation of urea-treated tall fescue straw with alfalfa pellets (0.45% of BW) decreased DMI, but increased WG and FE. In our study the level of alfalfa pellets supplementation was 0.1% of the body weight. Probably one reason for not finding a difference in terms of WG compared to the control was lower level of supplementation. Ndlovu and Buchanan-Smith (1985) reported that rate of

passage was increased by alfalfa supplementation (30% of DM) of corn cobs but did not affect passage rate for barley straw. Klopfenstein and Owen (1981) reported positive associative effects in terms of WG and FE when both treated and untreated crop residues were supplemented with alfalfa hay. In sheep given ammoniated wheat straw, Romulo (1985) measured an increase in WG of 40 g to a supplement of 150 g lucerne chaff. Adding a by-pass protein to a diet of low digestibility depresses metabolic heat production (Blaxter, 1962), which may improve efficiency of the animal (Meang et al., 1989). Supplementing high-silage diets with preformed proteins often improves animal performance without increasing FI (Wilkins, 1974b; Veira et al., 1985; Steen, 1989). In our study, although supplementation reduced weight loss compared to non-supplemented group, there was no weight gain. The ash content of the silage was extremely high (40-42%). This could be due to soil contamination of the onion waste and the straw. This higher ash content resulted in lower silage consumption (1.30 percent of BW), which ultimately resulted in body weight loss.

The packed cell volume (PCV) on day 1 of the experiment was 39.8% and at the end of experiment (day 30) it decreased to 34.3%. John and Marie (1979) observed decrease in PCV as a result of feeding cull onions to sheep. Studies by James and Binns (1966) and Van Kampen et al. (1970) on ewes fed wild onions demonstrated decreases in PCV, hemoglobin and RBC. Toxic effects of feeding onions have been reported in cattle, horses and dogs (Gruhzit, 1931; Throp, 1939; Koger, 1956). Onions contain hemolytic agents such as n-propyldisulfide which may cause red blood cell hemolysis and reduce PCV (Cheeke and Shull, 1985). The toxin is a membrane oxidant which increases the requirement for reducing agent (hydrogen) generated by the enzyme glucose-6-phosphate-dehydrogenase in the metabolic chain within the erythrocytes. The erythrocytes containing Heinz bodies are

removed from the circulation by the reticuloendothelial system of the spleen. If large numbers of erythrocytes are removed, a hemolytic anemia will develop.

In experiment 5, the spraying of annual and perennial ryegrass straws and tall fescue straw with CJ mixed with 3% urea and 0.1% RSB, compared to spraying these straws with only CJ, resulted in higher ($P < .05$) CP in straws sprayed with CJ mixed with urea and RSB compared to just plain spray of CJ (Table 3.5). The ADF concentration, however, did not differ between treatments for any type of straw:CJ combinations. No consistent changes in composition were noted with the various application rates of CJ. There was a slight tendency for ADF level to decrease (Table 3.6) as the amount of CJ increased. However, this was not of sufficient magnitude to significantly affect the feeding value of straw. Similarly, there were no discernable changes in the CP level with application of the simple CJ. The CP content of urea-treated straws declined as the level of added CJ increased. This indicates that the higher moisture levels enhanced the conversion of urea to ammonia, which presumably was lost by volatilization. Dias-Da-Silva et al. (1988) reported that urea treatment of straw resulted a in 3-fold increase in straw N. Zorrilla-Rios et al. (1991) reported that percentage of N was increased in wheat straw by ammoniation from 0.42% to 1.82%. Kraiem et al. (1991) reported that urea treatment improved total N content of wheat straw from 2.8% to 6.6%. DelCurto et al. (1991) by treating tall fescue straw with 3% urea, found increase in CP from 5.75% to 14.8%. Nelson et al. (1985), Chestnut et al. (1987) and Hunt et al. (1990) found similar results. Jayasuriya and Pearce (1983) when treating wheat and rice straw with urea, found significant improvements in N content. In this experiment, the improvements in CP (percentage units) as a result of spraying of straws with CJ mixed with urea and RSB were: 148, 74 and 57, for annual ryegrass straw, perennial ryegrass straw and tall fescue straw, respectively. Waiss et al. (1972) indicated that effect of ammoniation was greater for materials

with initially low digestibility. Kernan et al. (1979) found that improvements in CP due to ammoniation were 4.7, 5.7 and 8.1 percentage units for oats, barley and wheat. Horton and Steacy (1979) found more improvements in the digestibility of wheat straw compared to oat and barley straw and concluded that the effect of ammoniation on digestibility was highly dependent on the quality of the starting material. Because the quality of tall fescue straw and perennial ryegrass straw is better than annual ryegrass straw, improvement in CP content was more in annual ryegrass straw.

In conclusion, treatment of straw:cull onion silages with urea and urease (RSB) compared to simple urea treatment improved CP content and decreased NDF and ADF concentrations. The treatment of straw:onions silage with urea at the 3% and 5% levels improved CP content and IVDMD, compared to non treated silage. Although poor results were obtained with feeding onion:straw silage to sheep, effects of feeding ammoniated straw:onion silages to sheep and cattle need to be investigated, because ammoniation might inactivate the toxic components of onions and thus prove to be a good feed for sheep and cattle and alfalfa supplementation at higher levels may prove more useful. Field application of CJ to straws did not significantly enhance its nutritional value. Apparently the solids of CJ were not sufficiently retained on the straw to change its composition. Therefore, direct ensiling of CJ with straw appears to be more effective way of improving straw utilization.

Table 3.1

Effect of raw soybean (RSB) addition on chemical composition (% DM) and in vitro dry matter digestibility (IVDMD%) of urea treated straw:onion silages in experiment 1.

Parameters	Silage Type					
	Ryegrass straw:onion silage			Fescue straw:onion silage		
	0% RSB	0.1% RSB	SE	0% RSB	0.1% RSB	SE
Crude Protein	6.74[a]	7.58[b]	0.23	11.65[a]	11.97[b]	0.24
NDF	73.23[a]	71.02[b]	0.49	65.31[a]	62.84[b]	1.09
ADF	49.58[a]	48.02[b]	0.45	39.64[a]	39.43[a]	0.32
Ash	6.65[a]	6.30[b]	0.08	8.51[a]	8.13[b]	0.16
Organic Matter	93.35[a]	93.70[b]	0.08	91.49[a]	91.87[b]	0.16
Hemicellulose	23.66[a]	23.01[a]	0.43	25.65[a]	23.87[b]	0.91
IVDMD %	62.42[a]	62.01[a]	0.52	64.12[a]	63.44[a]	1.09

[ab] Values in the same row for each silage with different superscripts differ ($P < .05$)

Table 3.2

Effect of different levels of urea on chemical composition (% DM) and in vitro dry matter digestibility of silages in experiment 2.

Parameters	Cull onions:Ryegrass straw silages			
	0% urea	3% urea	5% urea	SE
Crude Protein	6.96[a]	13.81[b]	18.50[c]	1.54
Ash	6.90[a]	5.69[b]	5.33[c]	0.27
Organic Matter	93.10[a]	94.31[b]	94.67[c]	0.27
IVDMD %	63.45[a]	69.40[b]	69.60[b]	1.13

[abc] Values in the same row with different superscripts differ ($P < .05$).

Table 3.3

Effect of different levels of urea on chemical composition (% DM) and in vitro dry matter digestibility of silages in experiment 3.

Parameters	Cull onions:Ryegrass straw silages			
	0% urea	3% urea	5% urea	SE
Crude Protein	9.25[a]	19.67[b]	22.34[c]	2.25
Ash	6.96[a]	5.43[b]	5.20[c]	0.15
Organic Matter	93.04[a]	94.57[b]	94.80[c]	0.15
IVDMD %	67.13[a]	74.50[b]	74.92[b]	1.23

[abc] Values in the same row with different superscripts differ ($P < .05$).

Table 3.4

Chemical composition (% DM) of straw:onion silage and orts in sheep experiment (Experiment 4).

Items	Silage	Orts	Alfalfa Pellets
Crude Protein	7.17	6.40	15.8
NDF	57.71	63.36	43.91
ADF	53.88	55.81	29.12
Ash	39.66	41.91	13.00

Table 3.5

Performance of sheep fed ryegrass straw:onion silage (Experiment 4).

Parameters	Feed Type[1]		
	S	SA	SE
Silage intake (g h^{-1} d^{-1})	1000[a]	919[b]	39.01
Total feed intake (g h^{-1} d^{-1})	1000	987	39.01
Weight loss (g h^{-1} d^{-1})	30	26	2.45

[ab] Values in the same row with different superscripts differ ($P < .05$).

[1] S = Simple silage; SA = Silage plus 75 g alfalfa pellets h^{-1} d^{-1}.

Table 3.6

Influence of tall fescue straw:onion silage treatment with urea and raw soybean (RSB) on chemical composition and digestibility in experiment 1

Onion%	RSB%	Composition (percent) and IVDMD%						
		CP	NDF	ADF	ASH	OM	HC	IVDMD
70	0	11.61	73.45	39.60	8.03	91.98	33.86	62.33
60	0	11.24	62.43	40.74	8.11	91.89	21.69	65.30
50	0	12.16	62.82	38.66	7.96	92.05	24.17	62.62
40	0	11.44	62.72	38.67	8.12	91.89	24.06	62.31
30	0	11.82	65.13	39.52	8.46	91.55	25.61	68.01
70	0.1	13.8	58.98	37.77	9.89	90.11	21.21	63.25
60	0.1	11.99	61.99	39.16	8.56	91.45	22.82	61.50
50	0.1	11.96	62.81	39.98	8.05	91.96	22.83	57.87
40	0.1	10.79	65.50	41.04	8.56	91.45	24.46	63.97
30	0.1	11.29	64.94	40.24	7.52	92.48	24.71	70.53

Table 3.7

Influence of ryegrass straw:onion silage treatment with urea and raw soybean (RSB) on chemical composition and digestibility in experiment 1

Onion%	RSB%	Composition (percent) and IVDMD%						
		CP	NDF	ADF	ASH	OM	HC	IVDMD
70	0	7.81	70.49	47.88	6.91	93.10	22.61	62.36
60	0	6.20	74.34	51.62	6.95	93.06	22.73	61.75
50	0	7.50	73.62	48.78	6.28	93.72	24.85	59.07
40	0	6.13	73.85	48.39	6.49	93.51	25.46	64.55
30	0	6.10	73.87	51.23	6.63	93.37	22.64	63.23
70	0.1	8.25	69.64	46.97	6.62	93.38	22.67	59.24
60	0.1	7.55	71.74	47.76	6.25	93.76	23.99	62.46
50	0.1	8.03	69.63	47.12	6.44	93.57	22.51	62.97
40	0.1	7.74	72.52	48.14	5.94	94.07	24.38	64.24
30	0.1	6.36	71.61	50.13	6.28	93.72	21.48	61.97

Table 3.8
Influence of treating straw:onions with and without urea on chemical composition and digestibility (Experiment 2)

Onions%	Urea%	Composition (percent) and IVDMD%			
		CP	ASH	OM	IVDMD
0	3	8.10	4.77	95.23	68.84
10	3	9.56	4.89	95.12	60.39
20	3	8.83	4.92	95.08	67.05
30	3	9.13	5.06	94.95	71.43
40	3	9.20	5.05	94.96	73.12
50	3	11.04	5.19	94.81	73.32
60	3	12.31	5.53	94.47	72.58
70	3	15.18	5.62	94.39	68.19
80	3	17.78	6.25	93.76	68.87
90	3	20.75	7.11	92.89	64.59
100	3	30.00	8.19	91.82	75.03
0	5	11.95	4.89	95.12	67.72
10	5	13.90	4.75	95.26	57.91
20	5	13.38	4.83	95.18	62.87
30	5	11.75	4.86	95.15	71.87
40	5	12.13	4.86	95.14	74.19
50	5	12.12	5.03	94.97	69.03
60	5	13.69	5.29	94.72	69.18
70	5	16.05	5.33	94.67	71.31
80	5	23.47	5.68	94.33	68.14
90	5	31.00	6.27	93.73	70.80
100	5	44.09	6.83	93.17	82.61
0	0	2.99	5.18	94.82	60.36
10	0	3.26	5.46	94.54	60.75
20	0	3.79	5.52	94.48	60.94
30	0	4.63	5.54	94.46	62.10
40	0	4.67	5.99	94.02	61.88
50	0	5.21	6.14	93.87	59.91
60	0	6.07	6.00	94.01	62.99
70	0	7.25	7.31	92.70	63.44
80	0	7.57	7.55	92.46	59.62
90	0	11.04	8.64	91.36	66.95
100	0	20.13	12.63	87.37	79.07

Table 3.9
Influence of treating straw:onions with and without urea on chemical composition and digestibility (Experiment 3)

Onions%	Urea%	Composition (percent) and IVDMD%			
		CP	ASH	OM	IVDMD
0	3	8.81	4.84	95.16	73.80
10	3	10.94	4.83	95.17	70.71
20	3	9.92	4.77	95.23	71.26
30	3	10.60	4.94	95.06	78.31
40	3	11.35	5.07	94.93	76.84
50	3	14.28	4.93	95.07	77.33
60	3	17.56	5.14	94.86	71.15
70	3	20.15	5.29	94.71	69.15
80	3	25.25	5.65	94.35	70.77
90	3	30.10	6.25	93.75	72.42
100	3	57.42	5.52	94.48	87.84
0	5	16.92	4.71	95.29	73.00
10	5	15.09	4.78	95.22	70.55
20	5	15.77	4.68	95.32	76.42
30	5	15.07	4.81	95.19	72.61
40	5	14.19	5.03	94.97	74.03
50	5	14.59	5.76	94.24	74.18
60	5	18.32	5.76	94.24	76.35
70	5	20.19	6.25	93.75	68.73
80	5	27.83	5.96	94.04	75.99
90	5	33.23	5.60	94.40	77.02
100	5	54.55	6.39	93.61	85.22
0	0	5.09	6.01	93.99	65.25
10	0	6.34	6.29	93.71	63.26
20	0	5.56	6.48	93.52	63.58
30	0	6.27	6.47	93.53	63.31
40	0	6.27	6.68	93.32	62.98
50	0	6.57	6.72	93.28	65.84
60	0	7.96	6.47	93.53	65.06
70	0	8.82	6.87	93.13	67.64
80	0	10.08	7.18	92.82	65.25
90	0	13.37	7.56	92.44	66.52
100	0	25.50	9.83	90.17	89.76

Table 3.10

Effects of spraying corn juice (CJ) with or without urea and raw soybean on chemical composition of straws.

Straw type	Percent CP		Percent ADF	
	CJ±SE	CJ+urea±SE	CJ±SE	CJ+urea±SE
Annual ryegrass	3.75[a] ± 0.15	9.29[b] ± 0.43	49.03 ± 0.55	47.39 ± 0.58
Perennial ryegrass	5.77[a] ± 0.17	10.06[b] ± 0.46	40.78 ± 0.37	40.92 ± 0.43
Tall fescue	6.35[a] ± 0.16	9.99[b] ± 0.59	41.83 ± 0.43	41.98 ± 0.62

[ab] Values in the same row with different superscripts differ ($P < .05$)

Table 3.11

Effect of spraying of corn juice (CJ) and urea to straw on its composition.

Straw	Corn juice	Urea	% CP	% ADF
A. ryegrass				
100	30	-	3.5	51.9
100	40	-	4.0	51.2
100	50	-	3.6	49.1
100	60	-	3.3	47.1
100	70	-	4.5	48.1
100	80	-	3.4	48.7
100	90	-	3.5	49.4
100	100	-	3.2	50.0
100	200	-	4.4	48.6
100	300	-	4.1	46.2
100	30	+	11.4	46.9
100	40	+	9.6	48
100	50	+	10.9	49.1
100	60	+	9.4	49.7
100	70	+	10.5	49.0
100	80	+	9.4	45.3
100	90	+	9.2	47.5
100	100	+	8.3	48.7
100	200	+	7.6	44.8
100	300	+	6.9	44.9
100 Tall fescue	30	-	6.4	41.9
100	40	-	6.2	41.4
100	50	-	6.0	39.3
100	60	-	5.7	41.3
100	70	-	6.2	43.5
100	80	-	6.4	42.5
100	90	-	6.3	43.9
100	100	-	7.7	41.4
100	200	-	6.3	40.6

100 Table 3.11 continued	300	-	6.3	42.5
100	30	+	12.2	44.3
100	40	+	12.4	40.3
100	50	+	11.3	43.6
100	60	+	10.2	44.9
100	70	+	10.9	42.2
100	80	+	10.3	40.5
100	90	+	9.5	43.5
100	100	+	8.7	40.8
100	200	+	7.5	39.3
100	300	+	6.9	40.4
100 P. Ryegrass	30	-	5.9	40.3
100	40	-	5.7	40.5
100	50	-	4.3	41.2
100	60	-	5.9	38.9
100	70	-	5.8	40.4
100	80	-	6.0	41.9
100	90	-	6.0	42.6
100	100	-	5.9	41.6
100	200	-	6.0	39.2
100	300	-	6.2	41.2
100	30	+	11.5	43.0
100	40	+	11.4	40.6
100	50	+	11.6	41.6
100	60	+	11.0	41.6
100	70	+	9.4	42.6
100	80	+	11.1	40.8
100	90	+	9.9	38.6
100	100	+	8.9	40.3
100	200	+	7.8	39.3
100	300	+	8.0	40.8

REFERENCES

Association of Official Analytical Chemists., 1990. Official Methods of Analysis. 15th. ed. AOAC, Inc., Arlington, VA.

Blaxter, K.L., 1962. The Energy Metabolism of Ruminants. Hutchinson, London.

Brown, W.F., 1988. Maturity and ammoniation effects on the feeding value of tropical grass hay. J. Anim. Sci., 66: 2224-2232.

Buettner, M.R., Lechtenberg, V.L., Hendrix, K.S. and Hertel, J.M., 1982. Composition and digestion of ammoniated tall fescue (*Festuca arundinaces Schreb.*) hay. J. Anim. Sci., 54: 173-178.

Cheeke, P.R. and Shull, C.R., 1985. Natural Toxicants in Feeds and Poisonous Plants. Avi. Pub. Co. Inc., Westport, CT.

Cherney, D.J.R., 1993. In vitro digestion kinetics and quality of perennial grasses as influenced by forage maturity. J. Dairy Sci., 76: 790-797.

Chestnut, A.B., Berger, L.L. and Fahey,Jr. G.C., 1988. Effects of conservation methods and anhydrous ammonia or urea treatment on composition and digestion of tall fescue. J. Anim. Sci., 66: 2044-2056.

Chestnut, A.B., Berger, L.L. and Fahey,Jr. G.C., 1987. Effects of ammoniation of tall fescue on phenolic composition, feed intake, site and extent of nutrient digestion and ruminal dilution rates of steers. J. Anim. Sci., 64: 842-854.

Chiquette, J., Flipot, P.M. and Vinet, C.M., 1992. Effects of ammoniation and urea addition on chemical composition and digestibility of mature timothy hay, and rumen fluid characteristics of growing steers. Can. J.Anim. Sci., 72: 299-308.

Church, D.C. and Peterson, R.G., 1960. Effect of several variables on in vitro fermentation. J. Dairy Sci., 43:81-89.

Conklin, F.S., Young III, W.C. and Youngberg, H.W., 1989. Burning grass seed fields in Oregon's Willamette Valley: the search for solutions. O.S.U. Extension Service, OR. Agric. Expt. Stat. and USDA-ARS Cooperating Extension Miscellaneous 8397, Corvallis.

Cottyn, B.G. and DeBoever, J.L., 1988. Upgrading of straw by ammoniation. Anim. Feed Sci. Technol., 21: 287-294.

Craig, W.M., Ulloa, J.A., Watkins, K.L. and Nelson, B.D., 1988. Effects of level, form and time of urea application on the nutritive value of Alicia bermuda grass. J. Anim. Sci., 66: 185-193.

DelCurto, T., Barton, R.K., Cheeke, P.R. and Turner, H.A., 1991. Urea-ammoniation and

(or) supplementation strategies to improve the nutritive value of tall fescue straw for beef cattle production. Proc. West. Sec. Am. Soc. Anim. Sci., 42: 241-244.

Dias-Da-Silva, A.A., 1986. Urea as a source of ammonia for improving the nutritive value of wheat straw. Anim. Feed Sci. Technol., 14: 67-79.

Dias-Da-Silva, A.A., Mascarenhas, F.A. and Cristina, V.M.G., 1988. Effects of moisture level, treatment time and soybean addition on the nutritive value of urea-treated maize stover. Anim. Feed Sci. Technol., 19: 67-77.

Goering, H.K. and Van Soest, P.J., 1970. Forage Fiber Analysis (Apparatus, Reagents, Procedures and some applications). USDA-ARS Agri. Handbook No. 379.

Grant, R.G., Van Soest, P.J. and McDowell, R.E., 1974. Influence of rumen fluid source and fermentation time on in vitro true dry matter digestibility. J. Dairy Sci., 57:1201-1207.

Gruhzit, O.M., 1931. Anemia of dogs produced by feeding whole onions and onion fractions. Am. J. Med. Sci., 181: 812-814.

Hadjipanayiotou, M., 1982. The effect of ammoniation using urea on intake and nutritive value of chopped barley straw. Grass Forage Sci., 37: 89-93.

Horton, G.M.J., Steacy, G.M., 1979. Effect of anhydrous ammonia treatment on the intake and digestibility of cereal straws by steers. J. Anim. Sci., 48: 1239-1249.

Hunt, C.W., Loeseke, J.A., Kivioja, D.A. and Haenny, S.C., 1990. Efficiency of urea application as a means of ammoniation of cool season forage. Proc.West Sec. Am. Soc. Anim. Sci., 41: 304-306.

Ibbotson, C.F., 1983. The effectiveness of urea as a source of ammonia for increasing the digestibility of straw. Anim. Prod., 36: 358 (Abstract).

James, L.F. and Binns, W., 1966. Effects of feeding wild onions (Allium validum) to bred ewes. J. Am. Vet. Med. Assoc., 149: 512-514.

Jayasuriya, M.C.N. and Pearce, G.R., 1983. The effect of urease enzyme on treatment time and the nutritive value of straw treated with urea as ammonia. Anim. Feed Sci. Technol., 8: 271-281.

John, H.K. and Marie, S.B., 1979. Effects of feeding cull domestic onions (Allium cepa) to sheep. Am. J. Vet. Res., 40: 397-399.

Joy, M., Alibes, X. and Munoz, F., 1992. Chemical treatment of lignocellulosic residues with urea. Anim. Feed Sci. Technol., 38: 319-333.

Kernan, J.A., Crowle, W.L., Spurr, D.T. and Coxworth, E.C., 1979. Straw quality of cereal cultivation before and after treatment with anhydrous ammonia. Can. J. Anim. Sci.,

59: 511-518.

Klopfenstein, T. and Owen, F.G., 1981. Value and potential use of crop residues and by-products in dairy rations. J. Dairy Sci., 64: 1250-1268.

Koger, L.M., 1956. Onion poisoning in cattle. J. Am. Vet. Med. Assoc., 129: 75.

Kraiem, K., Abdouli, H. and Goodrich, R.D., 1991. Comparison of effects of urea and ammonia treatment of wheat straw on intake, digestibility and performance of sheep. Livestock Prod. Sci., 29: 311-321.

Kunkle, W.E., Leffel, E.C., Escobar, E.N. and Smith, L.W., 1980. Effect of method of harvest, anhydrous ammonia treatment and supplemental protein on the feeding value of corn residue. J. Anim. Sci., 52 (Suppl.1): 241.

Mandell, I.B., Christison, G.I., Nicholson, H.H. and Coxworth, E.C., 1988. The effect of variation in the water content of wheat straw before ammoniation on its nutritive value for beef cattle. Anim. Feed Sci. Technol., 20: 111-124.

Marinucci, M.T., Dehorty, B.A. and Loerch, S.C., 1992. In vitro and in vivo studies of digestion of feeds in synthetic fiber bags. J. Anim. Sci., 70: 296-302.

Marten, G.C. and Barnes, R.F., 1980. Prediction of energy digestibility of forages with an in vitro rumen fermentation and fungal enzyme system. Page 61 in Standardization of Analytical Methodology for Feeds. In: W.J.Pigden, C.C.Balch and M. Graham (eds.) Int. Dev. Res. Ctr., Ottawa, On, Canada.

Meang, W.J., Cheng, M.B., Yun, H.S. and Choi, I., 1989. Dilution rate effect on the efficiency of rumen microbial growth in continuous culture. Asian-Australasion J. Anim. Sci., 2(3): 477-480.

Moore, K.J., Lechtenberg, V.L. and Hendrix, K.S., 1985. Quality of orchardgrass hay ammoniated at different rates, moisture concentrations and treatment durations. Agron. J., 77: 67-71.

Mosi, A.K. and Butterworth, M.H., 1985. The voluntary intake and digestibility of cereal crop residues and legume hay for sheep. Anim. Feed Sci. Technol., 12: 241-251.

National Research Council., 1984. Nutrient requirements of beef cattle. 6th ed. NAS/NRC, Washington, D.C.

Ndlovu, L.R. and Buchanan-Smith, J.G., 1985. Utilization of poor quality roughages by sheep: effects of alfalfa supplementation on ruminal parameters, fiber digestion and rate of passage from the rumen. Can. J. Anim. Sci., 65: 693-703.

Nelson, B.D., Ellzey, H.D., Montgomery, C. and Morgan, E.B., 1972. Factors affecting the variability of an in vitro rumen fermentation technique for estimating forage quality. J. Dairy Sci., 55: 358-364.

Nelson, M.L., Klopfenstein, T.J., Britton, R.A. and Lowery, S.R., 1985. Protein supplementation of ammoniated roughages. III. Corncobs supplemented with a blood-meal-corn gluten meal mixture in steer studies. J. Anim. Sci., 61: 1567-1575.

Owen, E., 1985. Crop residues as animal feeds in developing countries, use and potential use. p.25-42. In: Wanapat, M. and Devendra, C. (eds.). Relevance of crop residues as animal feeds in developing countries. Proc. Int. Workshop, Thailand.

Paterson, J.A., Klopfenstein, T.J., and Britton, R.A., 1979. Ammonia treatment of corn residues. J. Anim. Sci., 49: 270(Abstr.)

Romulo, B., 1986. Studies on the role of supplementation and of manipulation of protozoal population in the rumen on productivity of sheep given straw based diets. Ph.D. Thesis, Univ. of New England, Armidale.

Saadullah, M., Haque, M. and Dolberg, F., 1981. Effectiveness of ammoniation through urea in improving the feeding value of rice straw in ruminants. Trop. Anim. Prod., 6: 30-36.

Saenger, P.F., Lemenager, R.P. and Hendrix, K.S., 1983. Effects of anhydrous ammonia treatment of wheat straw upon its in vitro digestion, performance and intake by beef cattle. J. Anim. Sci., 56: 15-20.

Statistical Analysis Systems., 1987. SAS- Institute, Cary, NC, USA.

Steel, R.G.D. and Torrie, J.H., 1980. Principles and Procedures of Statistics. 2nd. ed. Mc Graw Hill, New York, 633 pp.

Steen, R.W.J., 1989. A comparison of soya-bean, sunflower and fishmeal as protein supplements for yearling cattle offered grass silage-based diets. Anim. Prod., 48: 81-89.

Streeter, C.L. and Horn, G.W., 1984. Effect of high moisture and dry ammoniation of wheat straw on its feeding value for lambs. J. Anim. Sci., 59: 559-566.

Sundstol, F. and Coxworth, E.M., 1984. Ammonia Treatment. In: F. Sundstol and E.Owen (Eds), Straw and Other Fibrous By-Products as Feed. Elsevier, Amsterdam/ Oxford/ New York/ Tokyo, pp 196-247.

Sundstol, F., Said, A.N. and Arnason, J., 1979. Factors influencing the effect of chemical treatment on the nutritive value of straw. Acta. Agr. Scand., 29: 179-190.

Throp, F. and Harshfield, G.S., 1939. Onion poisoning in horses. J. Am. Vet. Med. Assoc., 94: 52-53.

Tilley, J.M. and Terry, R.A., 1963. A two stage technique for the in vitro digestion of forage crops. J. Br. Grassl. Soc., 18: 104-111.

Van Kampen, K.R., James, L.F. and Johnson, A.E., 1970. Hemolytic anemia in sheep fed wild onions (Allium validum). J. Am. Vet. Med. Assoc., 156: 328-332.

Veira, D.M., Butler, G., Ivan, M. and Proulx, J.G., 1985. Utilization of grass silage by cattle: effect of barley and fishmeal supplements. Can. J. Anim. Sci., 65: 897-903.

Waiss, A.C.Jr., Guggolz, J., Kohler, G.O., Waller Jr. H.G. and Garrett, W.N., 1972. Improving digestibility of straws for ruminant feed by aqueous ammonia. J. Anim. Sci., 35: 109-112.

Waldern, D.E., 1971. A rapid micro-digestion procedure for neutral and acid detergent fiber. Can. J. Anim. Sci., 51: 67-69.

Ward, M.G. and Ward, J.K., 1987. Ammoniation of warm-season grass hay for gestating beef cows. J. Anim. Sci., 65: 359-365.

Wilkins, R.J., 1974b. The effects of partial neutralization with sodium bicarbonate or ammonia and the feeding of blood meal on the voluntary intake of whole crop barley silage by sheep. Anim. Prod., 19: 87-91.

Williams, P.E.V., Innes, G.M. and Brewer, A., 1984. Ammonia treatment of straw via the hydrolysis of urea. II Additions of soybean (urease), sodium hydroxide and molasses; effects on digestibility of urea treated straw. Anim.Feed Sci.Technol., 11: 115-119.

Williams, P.E.V., Innes, G.M. and Brewer, A., 1984b. Ammonia treatment of straw via the hydrolysis of urea. I. Effects of dry matter and urea concentrations on the rate of hydrolysis of urea. Anim. Feed Sci. Technol., 11: 103-113.

Williams, P.E.V. and Innes, G.M., 1982. Effects of ammonia from urea hydrolysis on the dry matter loss from decaron bags of barley straw. Anim. Prod., 34: 385 (Abstr.).

Zorrilla-Rios, J., Horn, G.W. and McNew, R.W., 1991. Nutritive value of ammoniated wheat straw fed to cattle. J. Anim. Sci., 69: 283-294.

CHAPTER 5

EFFECT OF DIETARY *YUCCA SCHIDIGERA* EXTRACT ON RUMEN AND BLOOD PROFILES OF STEERS FED CONCENTRATE OR ROUGHAGE-BASED DIETS.

I. Hussain and P.R. Cheeke

Animal Sciences Department

Oregon State University, Corvallis, OR 97331

Abstract

In two experiments 4 rumen fistulated steers were used in a Latin square design arrangement with each rotation period of 15 days. *Yucca schidigera* extract (YE) was added at the rate of 250 mg per kg of mixed feed. In the first experiment, four isonitrogenous high-roughage (HR) feeds tested were: HR + SBM (R1); R1 + YE (R2); HR + urea (R3); R3 + YE (R4). Feed intake (FI) and weight gain (WG) (kg h^{-1} d^{-1}) were 11.4, 0.78; 11.2, 0.83; 11.3, 0.56; 11.0, 1.21 for R1, R2, R3 and R4, respectively. Ruminal pH and ammonia-N (mg/dl) for R1, R2, R3 and R4 (pooled values for 0, 3, 6, 9 HPF) were: 6.5, 11.5; 6.6, 10.2; 6.6, 15.1; 6.6, 12.9. Plasma ammonia-N (μg/ml) and plasma urea-N (mg/dl) were: 1.13, 13.64; 1.24, 14.79; 1.19, 16.11; and 1.04, 14.7 for R1, R2, R3 and R4, respectively. In trial 2, the four isonitrogenous, high-concentrate (HC) diets were: HC (barley) + SBM (C1); C1 + YE (C2); HC + urea (C3); and C3 + YE (C4). Average daily FI and WG (kg) were: 14.2, 1.29; 13.5, 1.10; 14.2, 1.47; and 13.7, 0.79 for C1, C2, C3 and C4, respectively. Ruminal pH and rumen ammonia-N (RAN) were: 5.81, 7.92; 5.82, 6.88; 6.09, 10.85; and 6.00, 10.50 for C1, C2, C3 and C4, respectively. The plasma ammonia-N (PAN)

and plasma urea-N (PUN) for C1, C2, C3 and C4 were: 1.17, 14.00; 0.89, 11.52; 1.15, 13.87; and 1.15, 13.76. In the HR trial the production of different volatile fatty acids (VFA) (averaged across time) was not different among the 4 treatments, except that isovalerate concentration in R1 was higher ($P < .05$) than R2. Numerically acetate production was lower in YE diets and propionate, isobutyrate and valerate concentrations were higher in R4 vs R3. There were less fluctuations in VFA production at different hours post-feeding (HPF) in R4 vs R3. Total VFA production was higher in R1 vs R2 and R4 vs R3. Acetate to propionate ratio was lower in R1 vs R2 and R4 vs R3. In HC trial, acetate, propionate, isobutyrate and valerate concentrations were lower in YE diets which may be due to better absorption of VFAs. Total VFA production and acetate to propionate ratios were lower in YE diets. The results showed a tendency for YE to reduce RAN, PAN and PUN, which could lead to more efficient utilization of dietary nitrogen, particularly when HR diets supplemented with urea were fed.

Introduction

Deodorase[1] contains glycosylated components which can bind ammonia (Headon, 1991). The yucca plant contains several steroid saponins known collectively as sarsaponins (S). Goodall and Matsushima (1978) found that S (40 ppm) can improve nutrient digestibility (6%) and reduce feed intake (7%) in yearling steers. Goodall et al. (1982) reported that with 66 ppm S in the diet the gains of cattle receiving high concentrate diets containing 10% CP were increased, but performance did not respond to S with a 17% CP diet. Goetsch and Owens (1985) fed dairy cows on sorghum silage (67% of diet DM) with 44 ppm S and noted increased digestion coefficients for OM, starch and N for S diet. In their second study, diets contained 50% concentrate (corn grain) either with or without S added at 44 ppm and ruminal pH for animals given S tended to be lower at 4, 8 and 12 hours post-feeding (HPF). Grobner et al. (1982) suggested that S at 30 and 60 ppm of diet DM increased microbial synthesis of protein in continuous fermentation cultures. No information exists about the effect of YE on FI, WG, rumen fermentation and blood nitrogen parameters when cattle are fed high-roughage (HR) as fescue grass hay and high-concentrate (HC) as rolled barley diets with or without urea. Our objective was to investigate if YE can bind ammonia in the rumen and act as a slow-release N source. With HR diets, a slow release N source might enhance fermentation by maintaining adequate rumen N for microbial growth throughout the post-feeding period. With urea-containing diets, rumen ammonia-N (RAN) levels peak rapidly post-feeding with the excess RAN being absorbed and excreted as urea.This results in inefficient use of the dietary-N and increases energy requirements for hepatic urea synthesis.

---

[1]Deodorase, is the extract of the *Yucca schidigera* plant, and is a commercial product of Alltech Biotechnology Inc; Nicholasville, KY. It has 30% active yucca extract, while remaining materials are: *Bacillus subtillus* fermentation extract, and calcium silicate.

Binding of excess RAN to YE when RAN levels are high, and slow N release as RAN levels decline post-feeding might enhance fermentation of HR and HC diets, with and without urea as a source of rapidly fermentable N. Rumen and blood samples were collected at 3 h interval post-feeding (PF) to determine if RAN was modulated by feeding YE.

Materials and Methods

Two trials were conducted, using either high roughage (HR) or high concentrate (HC) diets, each with either soybean meal (SBM) or urea as the source of supplementary nitrogen. Each of these combinations were compared with and without yucca extract (YE) at 250 mg per kg diet. For the HR trial, 4 rumen fistulated Hereford steers (mean wt. 574 kg) were used, while in the HC experiment, the mean weight of 4 rumen fistulated Hereford steers was 658 kg. In both experiments, arrangement of treatments was a 4x4 Latin square design, with each rotation period of 15 days. Ingredient composition of the experimental diets is given in Table 4.1. Feed samples of each treatment were collected twice a week, and dried at 50^0 C for 48 hours in a forced air oven for DM determination. All the dry samples were ground to pass through a 1 mm screen and analysed for DM and ash by standard procedures (AOAC, 1990). Feed samples were analysed for CP by the Kjeldahl method (AOAC, 1990). The NDF and ADF were analysed by the method of Goering and Van Soest (1970) as modified by a micro-method described by Waldern (1971). Hemicellulose (HC) was calculated as NDF-ADF, and organic matter (OM) was calculated as 100-%ash. Chemical composition of diets is given in Table 4.2.

The steers were kept in individual pens with free choice access to water. All animals were fed once daily at 0830 a.m. and feed was offered ad libitum. Orts were removed and weighed twice a week to calculate individual feed intake. At the start of each experiment, one week was given as adjustment period. Steers were weighed at the start of experiment and then on the morning of day 15 of each rotation period before feeding. After weighing, rumen liquor and jugular blood samples were collected in heparinized vacutainers at 0, 3, 6, and 9 hour-post-feeding (HPF).

Rumen fluid and blood samples were transported to the lab immediately after collection, where pH of the rumen fluid was determined using a pH meter. Blood samples were centrifuged at 3000 rpm for 15 minutes, plasma separated and stored at -20^{0}C for further analysis of plasma urea nitrogen (PUN). Plasma ammonia-N (PAN) was measured immediately using a Sigma kit (Sigma Chemical Co. St.Louis, MO). Rumen fluid was strained through four layers of cheese cloth and was frozen at -20^{0}C following mixing with 25% metaphosphoric acid in a 1:1 dilution for VFA analysis. For determination of rumen ammonia nitrogen (RAN) 5 ml of rumen liquor was mixed with 5 ml of 0.1N HCL, and 2 ml of this mixture was added to 28 ml distilled water and 0.6 ml of 32% N_aOH. The RAN concentration was measured using an ammonia ion electrode (Orion 9512) on an Orion 720A pH/ISE meter. The PAN and urea-N (PUN) were analysed using Sigma kits, using a narrow-band width UV spectrophotometer (Model UV 160 Shimadzu Corp, Kyoto, Japan). Ruminal VFA concentrations were determined by using a fused silica capillary column in a gas chromatograph (Hewlett Packard, HP 5890, Series II).

Data pertaining to weight gain were analysed as a Latin square design with effects for treatment, using the general linear model (GLM) procedure of statistical analysis system (SAS, 1987). Rumen fluid and plasma profiles were analysed as a Latin square design, split plot in time with respect to sampling time using the GLM procedure of SAS (SAS, 1987). Differences among treatments were noted by LSD test using 95% level of probability.

Results and Discussion

Trial 1 (High-Roughage Diets)

Ingredient and chemical composition of feeds is given in Table 4.1 and 4.2, respectively. Data (averaged across times) on weight gain (WG), feed intake (FI), rumen pH (pH), rumen ammonia nitrogen (RAN), plasma ammonia nitrogen (PAN) and plasma urea nitrogen (PUN) are presented in Table 4.3. The FI was numerically slightly lower in YE diets, and WG was higher ($P > .05$). The pH and RAN were not different between treatments, although RAN was 11% lower in R2 (YE-SBM diet) vs R1 and 15% lower in R4 (YE-urea diet) vs R3. The RAN in R2 was significantly lower than for the R3 treatment. Numerically pH was higher in R2 vs R1 and in R3 vs R4. The diets with urea (R3, R4) had slightly higher pH than diets with SBM (R1, R2). The PAN (μg/ml) was not different among the four treatments. The PUN concentrations were numerically lower in R4 vs R3 and R1 vs R2 and significantly lower in R1 vs R3. The data on pH, RAN, PAN, and PUN at different HPF are given in Table 4.11. The pH did not differ within each treatment at different time periods (0, 3, 6, 9 h post-feeding). There was a linear decrease in pH post-feeding from 0 to 9 hours in all treatments. The RAN in all the treatments peaked at 3 h post-feeding, and the peak was higher in R3 and R4 vs R1 and R2. However, the peak was less high in R4 compared to R3 and values remained low in R2 and R4 compared to R1 and R2 during all sampling times. In R1 RAN was lower ($P < .05$) at 9 h post feeding compared to 0 and 3 h post-feeding. In R2, R3 and R4, RAN was significantly higher at 3 h post-feeding compared to 0, 6 and 9 h post-feeding. The PAN concentration in each treatment at different times PF did not differ. The PUN peaked at 6 h post-feeding in R1, R3 and R4, while in R2 it peaked 3 h post-feeding. In R1 PUN at 9 h post-feeding was significantly lower than 0, 3 and 6 h post-feeding. In R2 PUN was higher ($P < .05$) at 3 h compared to 9 h post-feeding. In R4 PUN at 6 h was higher

($P < .05$) than 0 h post-feeding, while in R3 no differences among times were found. In the urea diets (R3, R4) PUN levels were lower in R4 vs R3. When the treatments were compared within each time (Table 12) no differences were observed among treatments at any HPF.

The data on VFA production (averaged across times) by animals on HR diets is presented in Table 4.5. No differences occurred in average VFA production among treatments for all VFA except isovalerate, which was higher ($P < .05$) in R1 compared to R2, R3 and R4. Total VFA production on R1 was higher than R2, but it was almost similar in R3 and R4. Acetate to propionate ratio was lower in R1, R2 and slightly higher in R3, R4 treatments. Data on VFA production at different times (0, 3, 6, 9 h post-feeding) within each treatment are given in Tables 4.6. There was lack of consistency in VFA production at different times post-feeding. There were no differences ($P > .05$) in most VFA production at different times except for isobutyrate and isovalerate, where isobutyrate in R1 at 0 h was higher ($P < .05$) than 6 and 9 h post-feeding. A similar pattern was observed in R2. Isovalerate production in R1 at 0 h was higher ($P < > 05$) compared to 6 and 9 h post-feeding. Its concentration at 3 h differed ($P < .05$) from 9 h post-feeding. In R2, isovalerate concentration at 0 and 3 h was higher than 6 and 9 h post-feeding. A similar trend was observed in R4, while in R3 at 0 h it was higher ($P < .05$) than 6 and 9 h post-feeding. However, in R4 diet, there were less fluctuations in VFA production compared to R3 diet. Comparison of VFA production among different treatments at each time is presented in Table 4.7. There were differences ($P < .05$) in propionate, isovalerate and valerate concentrations at 0 h and in isovalerate at 3 h post-feeding among four treatments. At 0 h post-feeding (0HPF) propionate in R1 was higher ($P < .05$) than R2 and isovalerate was higher in R1 vs R2 and R4; and valerate concentration at 0 HPF in R1 was higher than R2. At 3 h post-feeding (3HPF), isovalerate was higher ($P < .05$) in R1

vs R3 and R4. At 6 and 9 h post-feeding (6HPF, 9HPF), there were no differences among four treatments.

Trial 2 (High-Concentrate Diets)

The data (averaged across times) regarding feed intake (FI), weight gain (WG), ruminal pH (pH), ruminal ammonia-N (RAN), plasma ammonia-N (PAN) and plasma urea-N (PUN) are presented in Table 4.4. Average FI and WG among the four treatments were not different ($P > .05$). The FI and WG were numerically lower in animals on feeds having YE (C2, C4) vs animals on diets without YE (C1, C3). The ruminal pH of animals on the urea diet without YE (C3) was significantly higher than for animals on both SBM diets (C1, C2), while pH with C4 was higher ($P < .05$) than with C1. The RAN in animals on SBM diet with YE (C2) was significantly lower than for animals on both types of urea diets (C3, C4). Although the difference between two SBM diets was not significant, the RAN concentration was 13% lower on SBM diet with YE (C2) vs C1. Similarly it was 3% lower in animals on the diet with urea and YE (C4) vs diet with simple urea (C3). The PAN concentration was significantly lower in animals on SBM diet with YE (C2) compared with those on SBM diet without YE (C1), C3 and C4. Although the differences between the two urea diets were not significant, it was 3.5% lower in animals on diets with urea and YE (C4) vs urea alone diet (C3). The PUN was about 18% lower in animals on SBM plus YE (C2) diet compared with C1, C3 and C4, and the difference was significant. However, in the two urea diets, the difference in the concentration of PUN was not significant. At different times post-feeding (0, 3, 6, 9 h) there was a linear decrease in the pH from 0 to 9 h post-feeding (PF) in all treatments (Table 13). In C1 pH at 0 h was higher ($P < .05$) than at 6 and 9 HPF. A similar trend was observed in C2 and C3, but in C4 no differences were observed at different times

PF. The RAN decreased linearly from 3 to 9 HPF. The decrease in RAN PF was more steep compared to HR diets, and at 9 HPF in C1 and C2, it was below the optimum level. The RAN peak occurred 3 HPF and the peak was higher in urea diets (C3, C4) compared to SBM diets (C1, C2). However, RAN was lower in diets having YE (C2, C4) vs without YE (C1, C3). In C1 treatment, RAN at 9 HPF was lower ($P < .05$) than at 0 and 3 HPF, but in C2 no differences were seen among different times post-feeding. In C3, RAN was significantly higher at 3 h compared to 0, 6 and 9 HPF and a similar trend was observed in C4. Concentration of PAN at different times PF did not differ. It was lower in diets with YE (C2, C4) compared to C1, C3; and its peak mostly occurred at 9 HPF. The PUN peaked at 3 HPF in all treatments, and its concentration was lower in diets with YE. In C1, PUN concentration at 3 h was significantly higher compared to 9 HPF. In C4, PUN was higher at 3 h compared to 9 HPF. In C2 and C3, no differences were observed at different times PF. When treatments were compared within each time (Table 4.14) pH at 3 HPF was higher ($P < .05$) in C3 vs C2. The RAN at 6 HPF was lower ($P < .05$) in C2 compared to C4. The pH, RAN, PAN and PUN did not differ at other times among treatments.

The VFA production (averaged across times) by animals on HC diets is shown in Table 4.8. Total VFA production was higher in diets without YE. The acetate to propionate ratio was higher in urea diets (C3, C4) vs SBM diets (C1, C2), and it was slightly higher in diets with YE (C2, C4) compared to C1 and C3. Propionate was higher ($P < .05$) in C1 vs C4. Butyrate was higher in C1 vs C2, C3 and C4. Similar trend was seen for valerate. Isovalerate was higher in C1 vs C3 and C4 treatments. Data on VFA production at different times (0, 3, 6, 9 HPF) within each treatment is shown in Table 4.9. In C1 and C2, peak VFA production occurred at 3HPF, but in C3 and C4, in most of the cases VFA production peaked 6HPF. Acetate concentration in C2 was higher ($P < .05$) at 3 h compared to 0, 6 and 9 HPF.

A similar trend was observed for isobutyrate. Butyrate and valerate concentrations at 3 HPF were higher ($P < .05$) than 0 and 9 HPF. In C3, acetate and propionate concentrations at 6 h were higher than 0 and 3 HPF, while butyrate at 3 h was lower ($P < .05$) than 6 and 9 HPF. In C4, valerate at 6 h was higher ($P < .05$) than 0 and 3 HPF. Comparative data on VFA production among different treatments at one time is given in Table 4.10. At 0, 6 and 9 HPF no differences among treatments were observed, while at 3 HPF acetate concentration in C2 was higher ($P < .05$) than C3 and C4. Propionate and butyrate in C3 were lower ($P < .05$) than C1 and C2. Isovalerate concentration of C1 diet was higher ($P < .05$) than C3 diet. Valerate in C3 was lower ($P < .05$) than C1 and C2.

Discussion

In the high-roughage (HR) trial FI was 2 to 3 % lower in the two feeds with YE versus the ones without YE, but there was a big difference in WG with the two urea diets. Steers on R4 diet gained more ($P > .05$) than the ones on R3 diet. However, because of the small number of animals, short experimental duration and because of the effect of variable gut fill, the WG data lacks precision. It should be noted that the main objective was to study ruminal and blood N distribution; performance data was incidental to the main objective. A longer feeding period with a large number of animals per treatment would be necessary to adequately evaluate performance differences. A similar pattern in terms of FI was seen in the high-concentrate (HC) trial. Animals on the C3 diet gained much more than animals on C4 and animals on C1 gained 15% more than those on C2. In the HC trial YE did not show beneficial effects on performance, which might be due to the fact that two animals on the YE diet lost their fistulas during feeding and did not eat well which might have resulted in less weight gain. Goodall and Matsushima (1978) found that sarsaponin (40 ppm), the major steroid saponin of yucca extract, improved nutrient digestibility and reduced feed intake in

young steers. Johnston et al. (1981) reported that YE feeding (63 ppm) improved WG and FE in broilers and Al-Bar et al. (1993) found similar results in replacement pullet chicks and rabbits. Cromwell et al. (1985) reported improved WG after feeding YE to pigs. Mader and Brumm (1987) during the first 28 days of their four trials found that daily gains (0.74 kg) of steers fed urea plus YE were intermediate to and significantly higher than those fed the diet without YE (0.66 kg). The daily FI was similar among treatments. Goodall and Matsushima (1980) reported lower intakes but better digestibility and lower passage rates by feeding YE in both corn grain and corn silage diets. However, Goetsch and Owens (1985) did not observe a consistent intake or passage rate response to feeding YE and suggested that an interaction between YE and diet energy density or diet composition may exist. They reported that the lag time of digestion tended to be longer with the sarsaponin diets for corn, sorghum, soybean meal and corn gluten meal but shorter for alfalfa and prairie hay. Although YE may increase ruminal digestion of medium to low concentrates diets, in situ data indicates that effects may differ with type of feed. In some other studies improvements ($P < .05$) have been shown in ruminal DM (Goetsch and Owens, 1985) digestibilities by supplementing silage diets with YE. Headon (1991) reported that YE contains glycosylated components which bind ammonia. In non-ruminant studies, level of ammonia in poultry houses (Rowland et al., 1976; Al-Bar et al., 1993), rodent contact bedding (Russell, 1984) and rabbit houses (Al-Bar et al., 1993) were reduced by feeding YE. This reduced environmental ammonia may result in improved performance. Foster (1983b) found an interaction between YE and pig density, and concluded that the performance response from YE appears to be greater as floor space and feeder space per pig are reduced.

In our study rumen pH with the different treatments was similar. The pH was lower in the HC trial compared to HR trial. Ryan et al. (1993) reported that YE did not affect

rumen pH. Bosch et al. (1992) reported that rumen pH was negatively influenced by the amount of concentrates. Numerically, rumen pH in the HR trial was higher in R2 vs R1, but it was the same in R3 vs R4. In the HC trial pH was numerically slightly higher in C2 vs C1 (5.82 vs 5.81), while it was lower in C4 vs C3 (6.00 vs 6.09). In a study with dairy cows (Goetsch and Owens, 1985), when diets contained 50% concentrate either with or without YE added at 44 ppm, ruminal pH for animals given YE tended to be lower at 4, 8 and 12 HPF. Grobner et al. (1982) reported that 30 ppm YE increased pH and 60 ppm decreased pH in a continuous flow fermentor.

In our HR trial there was an 11% reduction in RAN in R2 diet vs R1, and a 15% reduction in R4 vs R3 diets. In the HC trial the reduction was 13% and 3% for C2 vs C1 and C4 vs C3, respectively. A reduction in urea hydrolysis and associated RAN levels would be beneficial by allowing greater quantities of urea to be utilized in high-roughage ruminant diets (Glimp and Tillman, 1965). Goetsch and Owens (1985) reported greater ($P < .13$) RAN concentration with the YE diet at 12 HPF, however, in this diet urea contributed only 0.06% of the diet. In contrast, Grobner et al. (1982) found lower RAN concentrations with YE supplementation. Gibson et al. (1985) found that RAN level was reduced by 27% when YE was fed to cattle in diets containing 0.87% urea, although DM digestibility was not influenced by YE supplementation. Ellenberger et al. (1985) noted a decrease in vitro ruminal urease activity with YE supplement. Ryan et al. (1993) and Wu et al. (1993) found that addition of YE had no effect on RAN. In the HC trial concentration of RAN was lower than in the HR trial. Haaland et al. (1982) reported that higher OM intakes result in higher VFA production, which may result in better utilization of ammonia by rumen microbes, which might cause lower RAN levels.

In our HR trial, PAN and PUN were lower in R4 vs R3, but higher in R2 vs R1 treatments. In the HC trial, concentration of PAN was lower in C2 vs C1. Preston et al. (1987) reported decreased PUN in rats supplemented with YE. Cai et al. (1993) reported that with increasing ME intake, there was a linear decrease in PUN. Tagari et al. (1964) reported that there is an inverse correlation between PUN and the amount of N retained in the body.

In our trials, total VFA production was higher in HC diets compared to HR diets, and acetate to propionate ratio was higher in HR diets compared to HC diets. Horton (1979) and Colucci et al. (1989) reported that total VFA concentrations were highest in high concentrate diets. Soluble carbohydrates have been found to increase molar proportions of propionate in rumen VFA (Sutton, 1968; Kellogg and Owen, 1969). Forage diets typically result in a high proportion of acetate relative to glucose precursors in the absorbed nutrients. It has been suggested that an inefficient supply of glucose relative to acetate may reduce the efficiency of acetate utilization (Preston and Leng, 1987). This was supported by the results of Cronje et al. (1991). Bosch et al. (1992) also reported that VFA concentrations were higher for the more digestible silages, and were higher when 7 kg concentrate was fed than with 1 kg concentrate. The ratio of non-glucogenic versus glucogenic fatty acids decreased with an increasing concentrate proportion in the diet. Rumsey et al. (1970) reported that total VFA increased as intake increased, probably as a result of higher rate of ruminal fermentation in the presence of increased fermentable carbohydrate. However, they also reported a decrease in pH and acetic acid and an increase in propionic acid as intake of concentrate increased. Similar results were found by Putnam et al. (1966). Wu et al. (1993) reported that addition of YE via the ruminal cannulae (0, 2, 4, 6, 8 g per day) had no effect on VFA and rumen pH. Ryan et al. (1993) reported that addition of YE decreased total VFA production compared to control. In our study also there was some reduction ($P > .05$) in total VFA concentration in

feeds having YE compared to control. Willms et al. (1991) reported that lambs when fed SBM had higher ($P < .05$) total VFA (106 mM) than when they were fed 33% supplemental CP from urea (95 mM). Increases in OM digestion increased total VFA concentration and lowered pH. We also observed similar trends in our study where total VFA concentrations were higher in C1 and C2 vs C3 and C4, and R1 vs R2, but concentration was higher in R4 vs R2.

In conclusion, in the HR trial, RAN was lower in YE diets vs control diets, and the RAN peak was less high in R4 vs R3. The trend for PUN concentration was lower in R4 vs R3, and there were less fluctuations in VFA productions at different times post-feeding in R4 vs R3, and acetate to propionate ratio was lower in R4 vs R3. In HC trial, RAN, PAN and PUN were numerically lower in YE diets; rumen pH was lower in C4 vs C3. These results give indications that YE supplementation favored rumen N metabolism, especially in HR trials and diets with urea.

Table 4.1. Ingredient composition of diets (percent) fed to steers (as fed basis).

Ingredient	High-roughage Diets				High-concentrate Diets			
	R1	R2	R3	R4	C1	C2	C3	C4
Grass hay (Fescue)	62.00	62.00	66.25	66.25	25.00	25.00	28.35	28.35
Alfalfa hay	30.00	30.00	30.00	30.00	20.00	20.00	20.00	20.00
Soybean meal	5.00	5.00	–	–	4.00	4.00	–	–
Molasses	2.00	2.00	2.00	2.00	–	–	–	–
TMS[1]	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Dical 0.5	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Urea	–	–	0.75	0.75	–	–	0.65	0.65
Deodorase[2]	–	+	–	+	–	+	–	+
Rolled barley	–	–	–	–	50.00	50.00	50.00	50.00

[1] TMS composition (percent): Common salt, 95-97; zinc, > 0.35; Mn, >0.3; Fe, >0.23; Cu, >0.023; I, > 0.012; Co, > 0.006; and Se, > 0.009.

[2] Deodorase was added @ 250 mg/kg of diet. Deodorase contains 30% *Yucca schidigera* plant extract; therefore, actual yucca extract was added @ 75 mg/kg of mixed diet.

Table 4.2. Chemical composition (%) of feeds fed to steers (DM basis).

Feed Type	DM	OM	CP	ADF	NDF	HC	Ash
R1	95.99	90.59	13.37	30.89	53.31	22.42	9.412
R2	96.04	90.82	13.32	31.51	53.90	22.39	9.178
R3	95.90	90.68	13.44	32.61	55.69	23.08	9.320
R4	95.95	90.74	13.02	33.19	57.35	24.16	9.257
C1	96.44	92.29	13.59	22.06	44.78	22.72	7.714
C2	96.79	93.23	12.79	21.49	44.21	22.72	6.768
C3	96.59	92.72	13.37	20.93	44.07	23.14	7.275
C4	96.64	92.98	13.25	21.4	44.22	22.82	7.017

Table 4.3. Feed intake (DM basis), weight gain, rumen and blood profiles of steers fed high-roughage diets.

Parameter	Diets[1]				
	R1	R2	R3	R4	SE
Feed intake (kg/h/d)	11.40	11.22	11.34	10.96	0.38
Weight gain (kg/h/d)	0.78	0.83	0.56	1.21	0.38
Rumen pH	6.48	6.58	6.59	6.59	0.17
Rumen ammonia-N (mg/dl)	11.50[ab]	10.16[b]	15.11[a]	12.88[ab]	2.53
Plasma NH_3N (μg/ml)	1.13	1.24	1.19	1.04	0.25
Plasma urea-N (mg/dl)	13.64[a]	14.79[ab]	16.11[b]	14.66[ab]	1.62

[1] R1 = soybean meal (SBM); R2 = SBM + Deodorase (YE); R3 = urea; R4 = urea + YE.

[ab] Values in the same row with different superscripts differ ($P < .05$).

SE = Pooled standard error.

Data presented above were averaged across time periods.

Table 4.4. Feed intake (DM basis), weight gain, rumen and blood profiles of steers fed high-concentrate diets.

Parameter	Diets[1]				
	C1	C2	C3	C4	SE
Feed intake (kg/h/d)	14.19	13.46	14.16	13.74	0.30
Weight gain (kg/h/d)	1.29	1.10	1.47	0.79	0.31
Rumen pH	5.81[a]	5.82[ac]	6.09[b]	6.00[bc]	0.07
Rumen ammonia-N (mg/dl)	7.92[ab]	6.88[b]	10.85[a]	10.50[a]	1.24
Plasma ammonia-N (μg/ml)	1.17[a]	0.89[b]	1.15[a]	1.15[a]	0.07
Plasma urea-N (mg/dl)	14.01[a]	11.52[b]	13.87[a]	13.76[a]	0.72

[1] C1 = soybean meal (SBM); C2 = SBM + Deodorase (YE); C3 = urea; C4 = urea + YE.

[ab] Values in the same row with different superscripts differ ($P < .05$).

SE = Pooled standard error.

Data presented above were averaged across time periods.

Table 4.5. Average volatile fatty acid production (millimoles/liter) by animals fed high-roughage diets.

	Diets[1]				
VFA	R1	R2	R3	R4	SE
Acetate	78.44	68.76	72.56	73.20	3.68
Propionate	21.42	17.97	18.11	19.02	1.21
Isobutyrate	1.03	0.83	0.81	0.86	0.08
Butyrate	10.61	9.04	9.87	9.81	0.69
Isovalerate	1.05[a]	0.79[b]	0.80[b]	0.72[b]	0.08
Valerate	1.03	0.87	0.86	0.88	0.09
Total	113.58	98.26	103.01	104.49	–
Acetate:Propionate ratio	3.66	3.83	4.01	3.85	–

[1] R1 = SBM; R2 = SBM + YE; R3 = urea; R4 = urea + YE.

[ab] Values in the same row with different superscripts differ ($P < .05$).

SE = Pooled standard error.

Data presented above were averaged across time periods.

Table 4.6. Volatile fatty acid production (millimoles/liter) within each time period for steers fed high-roughage diets.

Item	Time after feeding (h)	Diets[1] R1	R2	R3	R4	SE
Acetate	0	85.95	62.99	72.45	67.33	7.88
	3	79.50	75.26	76.13	73.35	7.88
	6	79.03	70.24	68.95	76.22	7.88
	9	69.27	66.57	72.72	75.90	7.88
Propionate	0	21.85	14.76	17.55	16.58	2.51
	3	22.31	20.20	19.56	19.41	2.51
	6	22.07	18.80	17.10	20.44	2.51
	9	19.45	18.12	18.29	19.63	2.51
Isobutyrate	0	1.37[a]	1.02[a]	0.99	1.08	0.14
	3	1.19[ac]	0.95[ac]	0.89	0.89	0.14
	6	0.87[bc]	0.70[bc]	0.69	0.75	0.14
	9	0.67[b]	0.64[b]	0.65	0.71	0.14
Butyrate	0	11.16	7.76	9.91	8.55	1.49
	3	11.24	9.80	10.10	9.63	1.49
	6	10.64	9.50	9.37	10.91	1.49
	9	9.40	9.11	10.10	10.15	1.49
Isovalerate	0	1.43[a]	1.05[a]	1.11[a]	0.91[a]	0.13
	3	1.25[ac]	0.95[a]	0.92[ab]	0.82[a]	0.13
	6	0.92[bc]	0.61[b]	0.63[b]	0.60[b]	0.13
	9	0.60[b]	0.57[b]	0.53[b]	0.55[b]	0.13
Valerate	0	1.07	0.65	0.78	0.68	0.19
	3	1.18	0.99	0.95	0.98	0.19
	6	0.85	0.93	0.82	1.00	0.19
	9	1.02	0.88	0.88	0.92	0.19

[1] R1 = SBM; R2 = SBM + YE; R3 = urea; R4 = urea + YE.

[abc] Values in columns for each VFA with different superscripts differ ($P < 0.05$).

SE = Pooled standard error.

Table 4.7. Volatile fatty acid production (millimoles/liter) by steers fed high-roughage diets.

Item	Time after feeding (h)	Diets[1] R1	R2	R3	R4	SE
Acetate	0	85.95	62.99	72.45	67.33	7.88
Propionate	0	21.85[a]	14.76[b]	17.55[ab]	16.59[ab]	2.51
Iosbutyate	0	1.37	1.02	0.99	1.08	0.14
Butyrate	0	11.16	7.76	9.91	8.55	1.49
Isovalerate	0	1.43[ac]	1.05[b]	1.11[abc]	0.92[b]	0.13
Valerate	0	1.07[a]	0.65[b]	0.78[ab]	0.68[ab]	0.19
Acetate	3	79.50	75.26	76.13	73.35	7.88
Propionate	3	22.31	20.20	19.56	19.41	2.51
Iosbutyrate	3	1.19	0.95	0.89	0.89	0.14
Butyrate	3	11.25	9.80	10.10	9.63	1.49
Isovalerate	3	1.25[a]	0.95[ab]	0.92[b]	0.82[b]	0.13
Valerate	3	1.18	0.99	0.95	0.90	0.19
Acetate	6	79.03	70.24	68.95	76.23	7.88
Propionate	6	22.07	18.80	17.02	20.44	2.51
Iosbutyrate	6	0.87	0.70	0.70	0.76	0.14
Butyrate	6	10.64	9.51	9.37	10.92	1.49
Isovalerate	6	0.92	0.61	0.63	0.60	0.13
Valerate	6	0.85	0.93	0.82	1.00	0.19
Acetate	9	69.27	66.57	72.72	75.90	7.88
Propionate	9	19.45	18.12	18.29	19.63	2.51
Iosbutyrate	9	0.68	0.64	0.65	0.71	0.14
Butyrate	9	9.40	9.11	10.10	10.15	1.49
Isovalerate	9	0.60	0.57	0.54	0.55	0.13
Valerate	9	1.02	0.89	0.88	0.92	0.99

[abc] Values in rows for each VFA with different superscripts differ ($P < .05$).

SE = Pooled standard error.

Table 4.8. Volatile fatty acid production (millimoles/liter) by steers fed high-concentrate diets (averaged across times).

	Diets[1]				
VFA	C1	C2	C3	C4	SE
Total	129.92	116.93	116.29	109.77	–
Acetate	85.94	78.65	80.01	74.46	4.16
Propionate	25.34[a]	22.47[ab]	22.56[ab]	20.75[b]	1.48
Isobutyrate	1.15	1.00	1.00	0.92	0.08
Butyrate	14.86[a]	12.59[b]	10.65[b]	11.62[b]	0.76
Isovalerate	1.23[a]	1.07[ab]	0.94[b]	0.94[b]	0.07
Valerate	1.40[a]	1.15[b]	1.13[b]	1.08[b]	0.08
Acetate:propionate ratio	3.39	3.50	3.55	3.59	–

[1] C1 = soybean meal (SBM); C2 = SBM + YE; C3 = urea; C4 = urea + YE.

[ab] Values in the same column with different superscripts differ ($P < .05$).

SE = Pooled standard error.

Data presented above were averaged across time periods.

Table 4.9. Volatile fatty acid production (millimoles/liter) by steers fed high-concentrate diets at different hours post-feeding.

Item	Time after feeding (h)	Diets[1] C1	C2	C3	C4	SE
Acetate	0	78.35	65.33[a]	72.43[a]	67.06	8.33
	3	92.46	94.33[b]	63.44[a]	69.37	8.33
	6	92.44	84.49[a]	101.40[b]	88.75	8.33
	9	80.49	70.45[a]	82.76[ab]	72.65	8.33
Propionate	0	22.03	17.62	19.85[a]	17.82	2.96
	3	27.45	27.28	17.94[a]	19.79	2.96
	6	26.80	24.67	28.39[b]	24.84	2.96
	9	25.10	20.31	24.07[ab]	20.56	2.96
Iosbutyrate	0	1.28	0.99[a]	1.25	1.01	0.17
	3	1.39	1.32[b]	0.80	0.94	0.17
	6	0.94	0.87[a]	1.08	1.00	0.17
	9	0.98	0.81[a]	0.87	0.76	0.17
Butyrate	0	12.95	9.89[a]	10.09[ab]	9.92	1.52
	3	15.84	15.02[b]	6.15[a]	10.73	1.52
	6	16.38	13.35[a]	14.43[b]	14.15	1.52
	9	14.29	12.09[a]	11.93[b]	16.67	1.52
Isovalerate	0	1.45	1.15	1.23	1.15	0.14
	3	1.49	1.34	0.83	0.97	0.14
	6	1.00	0.97	1.06	0.86	0.14
	9	0.99	0.84	0.63	0.80	0.14
Valerate	0	1.17	0.84[a]	0.96	0.85[a]	0.15
	3	1.65	1.50[b]	0.94	0.99[a]	0.15
	6	1.58	1.24[ab]	1.45	1.39[b]	0.15
	9	1.21	1.03[a]	1.18	1.08[ab]	0.15

[1] C1 = SBM; C2 = SBM + YE; C3 = urea; C4 = urea + YE.

[ab] Values in columns for each VFA with different superscripts differ ($P<0.05$).

SE = Pooled standard error.

Table 4.10. Volatile fatty acid production (millimoles/liter) by steers fed high-concentrate diets within each time period.

Item	Time after feeding (h)	Diets[1] C1	C2	C3	C4	SE
Acetate	0	78.38	65.33	72.43	67.06	8.33
Propionate	0	22.03	17.62	19.85	17.82	2.96
Iosbutyrate	0	1.28	0.99	1.25	1.01	0.17
Butyrate	0	12.95	9.89	10.09	9.92	1.52
Isovalerate	0	1.45	1.15	1.23	1.15	0.14
Valerate	0	1.17	0.84	0.96	0.85	0.15
Acetate	3	92.46^{ab}	94.33^{a}	63.44^{c}	69.37^{bc}	8.38
Propionate	3	27.45^{a}	27.28^{a}	17.94^{b}	19.79^{ab}	2.96
Iosbutyrate	3	1.39	1.33	0.80	0.94	0.17
Butyrate	3	15.84^{a}	15.02^{a}	6.15^{b}	10.73^{ab}	1.52
Isovalerate	3	1.49^{a}	1.34^{ab}	0.83^{b}	0.97^{ab}	0.14
Valerate	3	1.65^{a}	1.50^{ab}	0.94^{c}	0.99^{bc}	1.15
Acetate	6	92.44	84.49	101.40	88.75	8.33
Propionate	6	26.80	24.67	28.39	24.84	2.96
Iosbutyrate	6	0.93	0.87	1.08	1.00	0.17
Butyrate	6	16.38	13.35	14.43	14.15	1.52
Isovalerate	6	1.00	0.97	1.06	0.86	0.14
Valerate	6	1.58	1.24	1.45	1.39	0.15
Acetate	9	80.49	70.45	82.76	72.65	8.33
Propionate	9	25.10	20.31	24.07	20.56	2.96
Iosbutyrate	9	0.98	0.81	0.87	0.76	0.17
Butyrate	9	14.29	12.09	11.93	11.67	1.52
Isovalerate	9	0.99	0.84	0.63	0.80	0.14
Valerate	9	1.21	1.03	1.18	1.08	0.15

[abc] Values in rows for each VFA with different superscripts differ ($P<0.05$).

SE = Pooled standard error.

Table 4.11. Rumen and blood profiles at different time period post-feeding of steers fed high-roughage diets.

Item	Time after feeding (h)	Diets[1] R1	R2	R3	R4	SE
Ruminal pH	0	6.68	6.87	6.72	6.71	0.17
	3	6.60	6.59	6.66	6.62	0.17
	6	6.36	6.46	6.54	6.51	0.17
	9	6.30	6.39	6.45	6.52	0.17
Ruminal ammonia-N (mg/dl)	0	10.88[a]	9.85[a]	10.90[a]	10.87[a]	2.37
	3	15.9[a]	14.68[b]	23.23[b]	18.98[b]	2.37
	6	10.14[ab]	8.85[a]	14.53[a]	11.93[a]	2.37
	9	9.03[b]	7.27	11.80[a]	9.74[a]	2.37
Plasma ammonia-N (μg/ml)	0	0.92	0.86	1.14	0.83	0.24
	3	1.21	1.57	1.34	1.17	0.24
	6	1.27	1.32	1.22	1.04	0.24
	9	1.09	1.22	1.05	1.12	0.24
Plasma urea-N (mg/dl)	0	14.70[a]	14.54[ab]	14.35	12.57[a]	1.56
	3	14.28[a]	17.28[a]	16.31	14.60[ab]	1.56
	6	15.00[a]	14.98[ab]	17.67	17.48[b]	1.56
	9	10.59[b]	12.35[b]	16.10	14.00[ab]	1.56

[1] R1 = SBM; R2 = SBM + YE; R3 = urea; R4 = urea + YE.

[ab] Values in columns for each item with different superscripts differ ($P < .05$).

SE = Pooled standard error.

Table 4.12. Rumen and blood profiles of steers fed high-roughage diets each time post-feeding.

Item	Time after feeding (h)	Diets[1]				
		R1	R2	R3	R4	SE
Rumen pH	0	6.68	6.87	6.72	6.71	0.17
Rumen NH_3N (mg/dl)	0	10.88	9.85	10.90	10.87	2.37
Plasma NH_3N (μg/ml)	0	0.92	0.86	1.14	0.83	0.24
Plasma urea-N (mg/dl)	0	14.70	14.54	14.35	12.57	1.56
Rumen pH	3	6.60	6.59	6.66	6.62	0.17
Rumen NH_3N (mg/dl)	3	15.98	14.68	23.23	18.98	2.37
Plasma NH_3N (μg/ml)	3	1.21	1.57	1.34	1.17	0.24
Plasma urea-N (mg/dl)	3	14.28	17.28	16.31	14.60	1.56
Rumen pH	6	6.36	6.46	6.54	6.51	0.17
Rumen NH_3N (mg/dl)	6	10.14	8.85	14.53	11.93	2.37
Plasma NH_3N (μg/ml)	6	1.27	1.32	1.22	1.04	0.24
Plasma urea-N (mg/dl)	6	15.00	14.99	17.67	17.48	1.56
Rumen pH	9	6.30	6.39	6.45	6.52	0.17
Rumen NH_3N (mg/dl)	9	9.03	7.27	11.80	9.74	2.37
Plasma NH_3N (μg/ml)	9	1.09	1.22	1.05	1.12	0.24
Plasma urea-N (mg/dl)	9	10.59	12.36	16.10	14.00	1.56

[1] R1 = SBM; R2 = SBM + YE; R3 = urea; R4 = urea + YE.

SE = Pooled standard error.

Table 4.13. Rumen and blood profiles at different hours post-feeding for steers fed high-concentrate diets.

Item	Time after feeding (h)	Diets[1] C1	C2	C3	C4	SE
Ruminal pH	0	6.24[b]	6.18[a]	6.45[a]	6.25	0.13
	3	5.86[ab]	5.80[ab]	6.23[ab]	6.17	0.13
	6	5.60[a]	5.65[b]	5.89[b]	5.83	0.13
	9	5.53[a]	5.64[b]	5.81[b]	5.77	0.13
Ruminal NH_3-H (mg/dl)	0	10.34[a]	8.35	9.84[a]	9.42[a]	2.48
	3	11.38[a]	10.73	17.47[b]	17.02[b]	2.48
	6	6.58[ab]	4.40	7.16[a]	9.39[a]	2.48
	9	3.39[b]	4.05	8.95[a]	6.17[a]	2.48
Plasma NH_3-N (μg/ml)	0	1.11	0.86	0.91	0.74	0.24
	3	1.20	0.64	1.17	1.12	0.24
	6	1.16	1.02	1.11	1.01	0.24
	9	1.24	0.91	1.34	1.51	0.24
Plasma urea-N (mg/dl)	0	14.67[ab]	10.82	12.68	12.70[ac]	1.44
	3	17.35[a]	14.13	15.31	16.09[c]	1.44
	6	13.69[ab]	11.41	15.12	15.10[c]	1.44
	9	10.31[b]	9.71	11.92	11.69[a]	1.44

[1] C1 = SBM; C2 = SBM + YE; C3 = urea; C4 = urea + YE.

[abc] Values in columns for each item with different superscripts differ ($P<0.05$).

SE = Pooled standard error.

Table 4.14. Rumen and blood profiles of steers fed high-concentrate diets each hour post-feeding.

Item	Time after feeding (h)	Diets[1] C1	C2	C3	C4	SE
Rumen pH	0	6.24	6.18	6.45	6.25	0.13
Rumen NH_3N (mg/dl)	0	10.34	8.35	9.84	9.42	2.48
Plasma NH_3N (μg/ml)	0	1.01	0.86	0.91	0.74	0.24
Plasma urea-N (mg/dl)	0	14.67	10.82	12.68	12.70	1.44
Rumen pH	3	5.86[ab]	5.80[b]	6.23[a]	6.17[ab]	0.13
Rumen NH_3N (mg/dl)	3	11.38	10.73	17.47	17.02	2.48
Plasma NH_3N (μg/ml)	3	1.20	0.64	1.17	1.12	0.24
Plasma urea-N (mg/dl)	3	17.35	14.13	15.31	16.09	1.44
Rumen pH	6	5.60	5.65	5.89	5.83	0.13
Rumen NH_3N (mg/dl)	6	6.58[ab]	4.40[b]	7.15[ab]	9.39[a]	2.48
Plasma NH_3N (μg/ml)	6	1.16	1.02	1.11	1.01	0.24
Plasma urea-N (mg/dl)	6	13.69	11.41	15.12	15.00	1.44
Rumen pH	9	5.53	5.64	5.81	5.77	0.13
Rumen NH_3N (mg/dl)	9	3.39	4.05	8.95	6.17	2.48
Plasma NH_3N (μg/ml)	9	1.24	0.91	1.34	1.51	0.24
Plasma urea-N (mg/dl)	9	10.31	9.71	11.92	11.69	1.44

[1] C1 = SBM; C2 = SBM + YE; C3 = urea; C4 = urea + YE.

[ab] Values in the rows with different superscripts differ ($P < .05$).

SE = Pooled standard error.

REFERENCES

Al-Bar, A., Ismail, A., Cheeke, P.R. and Nakaue, H.S., 1993. Effect of dietary *Yucca schidigera* extract (deodorase) on environmental ammonia and growth performance of chickens and rabbits. Proc. West. Sec. Am. Soc. Anim. Sci., 44: 106-108.

Association of Official Analytical Chemists. 1990. Official Methods of Analysis 15th ed. AOAC. Inc. Arlington, VA.

Bosch, M.W., Tamminga, S., Post, G., Leffering, C.P. and Maylaert, J.M., 1992. Influence of stage of maturity of grass silages on digestion processes in dairy cows. I. Composition, nylon bag degradation rates, fermentation characteristics, digestibility and intake. Livestock Prod. Sci., 32: 245-264.

Cai, Y., Zimmerman, D.R. and Ewan, R.C., 1993. Responses of plasma urea and free amino acid concentrations in pigs of two breed combinations to energy intakes. J. Anim. Sci., 71 (Suppl. 1): 318.

Colucci, P.E., Macleod, G.K., Grovum, W.L., Cahill, L.W. and McMillan, I., 1989. Comparative digestion in sheep and cattle fed different forage to concentrate ratios at high and low intakes. J. Dairy Sci., 72: 1774-1785.

Cromwell, G.L., Stahly, T.S. and Monegue, J.J., 1985. Efficacy of sarsaponin for weanling and growing finishing swine housed at two animal densities. J. Anim. Sci., 61 (Suppl. 1): 111.

Cronje, P.B., Nolan, J.V. and Leng, R.A., 1991. Acetate clearance rate as a potential index of the availability of glucogenic precursors in ruminants fed on roughage-based diets. Br. J. Nutr., 66: 301-312.

Ellenberger, M.A., Rumpler, W.V., Johnson, D.E. and Goodall, S.R., 1985. Evaluation of the extent of ruminal urease inhibition by sarsaponin and its fractions. J. Anim. Sci. 61 (Suppl. 1): 491.

Foster, J.R., 1983b. Sarsaponin for growing finishing swine alone or in combination with an antibiotic at different pig densities. J. Anim. Sci. 7 (Suppl 1) : 245.

Gibson, M.L., Preston, R.L., Pritchard, R.H. and Goodall, S.R., 1985. Effect of sarsaponin and monensin on ruminal ammonia levels and in vitro dry matter digestibilities. J. Anim. Sci., 61 (Suppl. 1): 492.

Glimp, H.A. and Tillman, A.D., 1965. Effect of jackbean urease injections on performance, anti-urease production and plasma ammonia and urea levels in sheep. J. Anim. Sci., 24: 105-108.

Goering, H.K. and Van Soest, P.J., 1970. Forage Fiber Analysis (Apparatus, Reagents, Procedures and some applications). USDA-ARS Agri. Handbook No. 379. Washington, D.C.

Goetsch, A.L. and Owens, F.N., 1985. Effects of sarsaponin on digestion and passage rates in cattle fed medium to low concentrates. J. Dairy Sci., 68: 2377-2384.

Goodall, S.R., Brady, P., Horton, D. and Beckner, B., 1982. Steam flaked versus high moisture corn rations with and without sarsaponin for finishing steers. J. Anim. Sci. West. Sec. Procd., 45 (Abstr.).

Goodall, S.R. and Matsushima, J.K., 1980. The effects of sarsaponin on ruminant digestion and rate of passage. J. Anim. Sci. 51 (Suppl 1):491.

Goodall, S.R. and Matsushima, J.K., 1978. The effects of sarsaponin on ruminant digestion and rates of passage. J. Anim. Sci. (suppl. 1):363.

Grobner, M.A., Johnson, D.E., Goodall, S.R. and Benz, D.A., 1982. Sarsaponin effects on in vitro continuous flow fermentation of a high grain diet. J. Anim. Sci., 55 (Suppl. 1): 491.

Haaland, G.L., Tyrell, H.F., Moe, P.W. and Wheeler, W.E., 1982. Effect of crude protein level and limestone buffering capacity and VFA concentration of cattle. J. Anim. Sci., 55: 943-950.

Headon, D.R., 1991. Glycofractions of the Yucca plant and their role in ammonia control. In: Biotechnology in the Feed Industry. Proc. 7th Alltech Symposium, Alltech Technical Publications, Nicholasville, KY, pp 95-108.

Horton, G.M.J., 1979. Feeding value of rations containing nonprotein N or natural protein and of ammoniated straw for beef cattle. J. Anim. Sci., 48: 38-44.

Johnston, N.L., Quarles, C.L., Fagerberg, D.J. and Caveny, D.D., 1981. Evaluation of yucca saponin on broiler performance and ammonia suppression. Poul. Sci., 60: 2289-2292.

Kellogg, D.W. and Owen, F.G., 1969. Alterations of in vitro rumen fermentation pattern with various levels of sucrose and cellulose. J. Anim. Sci., 52: 1458-1460.

Mader, T.L. and Brumm, M.C., 1987. Effect of feeding sarsaponin in cattle and swine diets. J. Anim. Sci., 65: 9-15.

Preston, R.L., Bartle, S.J., May.T. and Goodall, S.R., 1987. Influence of sarsaponin on growth, feed and nitrogen utilization in growing male rats fed diets with added urea or protein. J. Anim. Sci., 65: 481-487.

Preston, T.R. and Leng, R.A., 1987. Matching Ruminant Production Systems With Available Resources in the Tropics and Sub-tropics. Penambul Books, Armidale, N.S.W., 245 pp.

Putnam, P.A., Yarns, D.A. and Davis, R.E., 1966. Effects of pelletting rations and hay:grain ratio on salivary secretions and ruminal characteristics of steers. J. Anim. Sci., 25: 1176-1182.

Rowland, L.O.Jr., Plyler, J.E. and Bradley, J.W., 1976. *Yucca schidigera* extract effects on egg production and house ammonia levels. Poul. Sci., 55: 2086 (Abstr.).

Rumsey, T.S., Bond, J., Hart, R.H. and Carlson, G.E., 1970. Ruminal ammonia, pH and VFA of beef cattle on orchardgrass pasture and self-fed liquid molasses-urea or ground corn-fat supplements. J. Anim. Sci., 33: 507-513.

Russell, J.B., 1984. The effect of sarsaponin on ammonia levels in rodent cages. District Convention Am. Assoc. Lab. Anim. Sci., (Abstr).

Ryan, J.P. Leek, B.F. and Jacques, K., 1993. The complementary effects of *Saccharomyces cerevisiae* yeast culture (Yaa-Sacc 1026) and yucca schidigera extract (solid de-odorase) on ruminal metabolism in sheep. J. Anim. Sci., 71 (Suppl. 1): 287.

Statistical Analysis Systems., 1987. SAS- Institute, Cary, NC, USA.

Sutton, J.D., 1968. The fermentation of soluble carbohydrates in rumen contents of cows fed diets containing a large proportion of hay. Br. J. Nutr., 22: 689-712.

Tagari, H., Dror, Y., Ascarelli, I. and Bondi, A., 1964. The influence of levels of protein and starch in rations of sheep on the utilization of protein. Br. J. Nutr., 18: 333-356.

Waldern, D.E., 1971. A rapid micro-digestion procedure for neutral and acid detergent fiber. Can. J. Anim. Sci., 51: 67-69.

Willms, C.L., Berger, L.L., Merchen, N.R. and Fahey, Jr. G.C., 1991. Effects of supplemented protein source and level of urea on intestinal amino acid supply and feedlot performance of lambs fed diets based on alkaline hydrogen peroxide-treated wheat straw. J. Anim. Sci., 69: 4925-4938.

Wu, Z., Sadik, M., Huber, J.T., Sleiman, F.T., Simas, J. and Pessarakli, M., 1993. Influence of yucca extract (Deodorase) on ruminal metabolism in cows. J. Anim. Sci., 71 (Suppl. 1): 266.

CHAPTER 6

EFFECTS OF FEEDING *YUCCA SCHIDIGERA* EXTRACT (DEODORASE) ON GROWTH PERFORMANCE AND CECUM AND BLOOD METABOLIC PROFILES OF RABBITS.

I. Hussain and P.R. Cheeke

Animal Sciences Department

Oregon State University, Corvallis, OR 97331

Abstract

Two experiments were undertaken using New Zealand White weanling rabbits (5-6 weeks of age). In both experiments, yucca extract (YE) was mixed at 250 mg kg^{-1} of diet, and six individually-fed rabbits were used per treatment. In experiment 1, four feeds were: 1) High-protein (HP), 2) HP+YE (HPYE), 3) Medium-protein (MP), 4) MP+YE (MPYE). The 2 protein levels were 22.5 and 19 percent. Weight gain was significantly lower in HP vs HPYE while it was similar in MP vs MPYE. Feed intake was similar among 4 treatments. Feed efficiency in HPYE was significantly better than HP, and numerically better in MPYE vs MP. Cecal urea-N (CUN) was similar among HP, HPYE and MP, but was significantly lower in MPYE vs HPYE. Cecal ammonia-N (CAN) and cecal pH (pH) were similar among the four treatments. Plasma urea-N (PUN) in HP and HPYE was similar, but was higher ($P < .05$) than MP and MPYE, and similar between MP and MPYE. Plasma ammonia-N (PAN) was significantly higher in HP vs HPYE, MP and MPYE. A similar trend was observed for acetate. Propionate in HPYE was higher ($P < .05$) than MP and MPYE. Butyrate concentration was similar among the four treatments. Total VFA concentration was

numerically higher in HP vs HPYE; and MPYE vs MP. Acetate to propionate ratio was numerically lower in YE treatments compared to non-YE diets. In experiment 2, feeds were; 1) low-protein (LP), 2) LP+YE (LPYE), 3) Low protein+ urea (LPU), and 4) LPU+YE (LPUYE). The two protein levels were 16.5% and 16.5% plus 2% urea. Weight gain in LPYE was significantly higher than for the other 3 treatments, while it was similar among the other 3 groups. Feed intake was significantly higher in LPYE compared to LP and LPUYE. Feed efficiency in LPYE was lower ($P < .05$) than LPUYE. The CUN, pH, PAN, acetate, propionate and butyrate concentrations were similar among four treatments. The CAN in LPUYE was significantly lower than other 3 treatments and PUN in urea diets was lower ($P < .05$) than non urea diets and it was significantly lower in LPUYE vs LPU diet. Numerically total VFA production was higher in YE treatments and acetate to propionate ratio was higher in YE treatments vs non-YE treatments. In conclusion, in both experiments weight gain and feed efficiency were better in diets with YE except for LPUYE, where ADG and FE were lower compared to LPU, and, in general, CAN, CUN, PUN, and PAN were lower in YE treatments, which may be due to sequestration and slow release of bound N in the cecum.

Introduction

Yucca extract (YE) which is the extract of the yucca plant (*Yucca schidigera*) contains glycosylated compounds which can bind ammonia (Headon, 1991). The commercial product Deodorase is the extract of *Yucca schidigera* plant and is marketed by Alltech Biotechnology, Nicholasville, KY. The YE is used commercially as a feed additive, mainly for controlling the environmental ammonia in confinement livestock housing. The glycosylated components in YE are excreted in the feces of the animals, and bind with ammonia produced by microbial action in the excreta, thus reducing the environmental ammonia levels. Dietary YE reduces ammonia levels in rabbit (Al-Bar et al., 1992) and broiler (Johnston et al., 1981; Al-Bar et al., 1993) confinement housing.

The YE contains several steroid saponins known collectively as sarsaponins (S). Goodall et al. (1982) reported that 66 ppm S increased gains in cattle receiving high-concentrate diets containing 10% CP, but performance did not respond to S with a 17% CP diet. Al-Bar et al. (1992) reported that dietary YE (125 mg kg^{-1}) increased the growth rate of rabbits. We hypothesized that the growth promoting activity of YE could involve reaction of YE with ammonia in the cecum, which may bind the released ammonia in the cecum, thus reducing the absorption of excess ammonia. Excess absorbed ammonia causes a stress to the liver, for converting it to urea, and it is also an energy expensive reaction. Thus YE may bind the ammonia when it is produced in excess, and later slowly release it when its concentration goes below the optimal level for cecal fermentation.

The objective of this study was to determine if dietary YE will influence feed intake, weight gain, feed efficiency, cecal and plasma ammonia-N and urea-N, cecal pH and cecal VFA production in rabbits. The effect of YE on utilization of a urea-containing diet was also studied.

Materials And Methods

Experiment 1

Twenty-four individually-caged New Zealand White (NZW) rabbits of 5-6 weeks of age and 650 g average weight were randomly assigned to 4 treatments. The treatments consisted of 2 levels of dietary protein (22.5% and 19%) with and without yucca extract (YE) added at the rate of 250 mg YE per kg of mixed feed. The four pelleted feeds tested were: 1) high-protein (HP); 2) HP+YE (HPYE); 3) medium-protein (MP); 4) MP+YE (MPYE). Ingredient and chemical composition of the diets is shown in Table 5.1. Feed and water were available free choice. Daily feed intake was recorded for each animal. All animals were weighed at the start and end of the experiment. Feed samples were taken three times during the experiment, dried at 50°C for 48 hours, ground to pass through a 1 mm screen and saved for further analysis. The DM and ash were analyzed by standard procedures (AOAC, 1990). Feed samples were analyzed for CP by kjeldahl method (AOAC, 1990).

After 14 days on the test diets, all animals were slaughtered and blood and cecal contents were collected, kept in an ice box, and transported to the laboratory as soon as possible, where cecal pH was determined using a pH meter. Blood samples were centrifuged at 3000 rpm for 15 minutes, plasma separated and stored at -20°C for further analysis of plasma urea-N (PUN). Plasma ammonia-N (PAN) and cecal ammonia-N (CAN) were measured immediately using Sigma kit (Sigma Chemical Co. St.Louis, MO). Blood and cecal ammonia and urea determinations were made spectrophotometrically using Sigma kits. Cecal VFA were measured by gas chromatography using a silica capillary column (Hewlett Packard, HP 5890, Series II). Cecal contents were prepared for VFA analysis by mixing 1 g cecal contents with 2 ml 25% metaphosphoric acid and 7 ml water, and filtering after 30 minutes. The filtered solution was injected into the gas chromatograph. Data were statistically analyzed

using the GLM procedure of SAS (SAS, 1987) and comparison of means was carried out using LSD procedure. Differences among means in both experiments were noted at 95% level of probability.

Experiment 2

Twenty-four individually caged New Zealand White (NZW) rabbits of 5-6 weeks of age and 650 g average weight were randomly assigned to 4 treatments. The treatments consisted of 2 levels of dietary protein (16.5% and 16.5% plus 2% urea) with and without yucca extract (YE) at the rate of 250 mg YE per kg of mixed feed. The four pelleted feeds tested were: 1) low-protein (LP); 2) LP+YE (LPYE); 3) low-protein+urea (LPU); 4) LPU+YE (LPUYE). Ingredient and chemical composition of the diets is shown in Table 5.2. Remaining protocol for this experiment was similar to experiment 1.

Results and Discussion

Experiment 1

The data on feed intake (FI), average daily gain (ADG), feed efficiency (FE), cecal urea-N (CUN), cecal ammonia-N (CAN), cecal pH (pH), plasma urea-N (PUN), and plasma ammonia-N (PAN) are presented in Table 5.3. Average daily weight gain in HPYE (41 g) was significantly higher ($P < .05$) than HP (31 g) and MP (32 g), while statistically it was similar between HPYE and MPYE (35 g) and among HP, MP and MPYE diets. Although statistically ADG was similar between MP and MPYE treatments, numerically it was 9% higher in MPYE treatment. The FI (g/h/d) was similar among the 4 treatments. Feed efficiency was significantly lower (best) in HPYE compared to HP (2.63 vs 3.47), a difference of 24%. Although FE was statistically similar between MP and MPYE (3.48 vs 3.23), numerically it was about 7% lower in MPYE vs MP treatment. Statistically FE was similar among HP, MP, MPYE, and between HPYE and MPYE. The CUN (mg/dl) was significantly higher in HPYE compared to MPYE (16.22 vs 15.04). Statistically CUN was similar among HP, HPYE, MP (15.53, 16.22, 15.61) and among HP, MP and MPYE (15.53, 15.61, 15.04). Statistically CAN (mg/dl) and pH did not differ among 4 treatments. Numerically CAN was higher in HP diets compared to MP diets, and pH was higher in MP diets compared to HP treatments. The PUN in HP (29.12 and 28.03) diets was higher ($P < .05$) than MP (22.6 and 20.24) diets, however, differences between HP and HPYE, and between MP vs MPYE, were not significant. Numerically PAN was lower in diets having YE. The PAN in HP (7.76) was higher ($P < .05$) compared to HPYE (6.14), MP (6.09) and MPYE (5.12). Although the difference between MP and MPYE was not significant, it was 16% lower in MPYE compared to MP diet. In HPYE, the PAN was 21% lower than HP diet.

The volatile fatty acid (VFA) production (mM/l) data is presented in Table 5.4. Acetate (mM/l) concentration was significantly higher in HP (80.17), compared to HPYE (64.73), MP (60.17), and MPYE (61.20). Acetate concentration among other 3 treatments was similar. Propionate concentration was higher ($P < .05$) in HPYE (5.22), compared to MP (3.85) and MPYE (4.09). Concentration among other 3 diets was statistically similar. The concentration of butyrate was similar among 4 treatments. Numerically total VFA concentration was higher in HP (99) compared to HPYE (83), and higher in MPYE (78) compared to MP (76). Acetate to propionate ratio was numerically lower in diets having YE, (HPYE and MPYE) compared to HP and MP (12.40 and 14.96 vs 18.06 and 15.63), respectively.

Experiment 2

Data on ADG, FI, FE, CUN, CAN, pH, PUN and PAN is given in Table 5.5. The ADG (g) was significantly higher (34.45) in LP plus YE (LPYE) diet, compared to LP (26.10), LP+urea (24.7) and LPUYE (21.94). The difference between these 3 treatments was not significant. The FI (g/h/d) was higher ($P < .05$) in LPYE (104), compared to LP (93) and LPUYE (90) and differences among LP, LPU and LPUYE were not significant.The FE was significantly lower (best) in LPYE (3.19) compared to LPUYE (4.26). Differences among LP, LPYE, LPU, and LP, LPU, LPUYE were not significant. The CUN (mg/dl), pH and PAN (μg/ml) did not differ ($P > .05$) among 4 treatments. The CAN (mg/dl) was significantly lower in LPUYE (17.97) compared to LP (23.68), LPYE (23.83), and LPU (27.00), and differences among these 3 were not significant. Plasma urea-N (mg/dl) in LP (15.61) and LPYE (14.62) were lower ($P < .05$) than LPU (30.95) and LPUYE (21.46), and differences between LPU and LPUYE were significant ($P < .05$).

Data on VFA production is presented in Table 5.6. Statistical differences in acetate, propionate and butyrate among 4 treatments were not significant. Numerically acetate and propionate levels were higher in YE diets, and butyrate in LPYE was higher than LP, and lower in LPUYE vs LPU. Numerically total VFA concentration was higher in YE diets and acetate to propionate ratio was higher in LPYE vs LP and higher in LPUYE vs LPU.

Discussion

In experiment 1, the ADG was significantly higher (31%) in high-protein plus YE (HPYE) treatment, compared to HP and medium-protein (MP) and numerically ADG in MPYE was 9% higher than MP treatment. Feed intake was similar among the four treatments, and animals on HPYE diet consumed 24% less feed per kg of weight gain and rabbits on MPYE diets consumed 7% lower feed per kg of body weight gain compared to MP diets. In experiment 2, ADG in LPYE fed rabbits was 24% higher than LP fed diets, however, ADG was lower in urea diets and it was about 11% lower in LPUYE vs LPU treatment. Feed intake was higher in LPYE compared to LP, and LPUYE. Feed efficiency was best in LPYE compared to LP, but it was lower in LPUYE compared to LPU. Al-Bar et al. (1992) found increased ADG in rabbits fed YE (125 and 250 mg/kg) compared to animals on the control diet. Johnston et al. (1981) reported that YE (63 ppm) feeding improved ADG and FE in broilers, and Al-Bar et al. (1993) found a significant growth response to YE in replacement pullet chicks. Cromwell et al. (1985) reported improved ADG after feeding YE to pigs. Mader and Brumm (1987) reported that ADG of steers fed urea plus YE was significantly higher than for steers fed the diet with only urea, and found the FI to be similar. Singh et al. (1990) noted that 2% urea reduced weight gain in rabbits, whereas 1% urea had no adverse effects. Gipp et al. (1988) observed no improvements in performance of pigs fed

YE. Yen and Pond (1993) found that pigs fed YE (125 ppm) showed increased FI but similar ADG compared with those fed 16% CP corn-soybean meal basal diet. Goodall and Matsushima (1980) reported lower intakes in steers by feeding YE in both corn grain and corn silage diets. However, Goetsch and Owens (1985) did not observe a consistent intake or passage rate response to feeding YE and suggested that interaction between YE and diet energy density or diet composition may exist, and they also found improved ruminal DM digestibility by supplementing silage diets with YE.

Cecal pH in both experiments did not differ among the 4 treatments, although it was numerically lower in YE diets in experiment 1, and lower in LPYE vs LP, and LPU vs LPUYE. Ryan et al. (1993) reported that YE did not affect rumen pH. Goetsch and Owens, (1985), in a study with dairy cows, found that when diets contained 50% concentrate either with or without YE added at 44 ppm, ruminal pH for animals given YE tended to be lower 4, 8 and 12 hours post-feeding (HPF). Grobner et al. (1982) reported that 30 ppm YE increased pH and 60 ppm decreased pH in a continuous flow fermentor.

In experiment 1, CAN was numerically lower in YE diets. In experiment 2, CAN was significantly lower in LPUYE diet vs LPU, LP and LPYE diets. Grobner et al. (1982) reported lower rumen ammonia-N (RAN) concentrations with YE supplementation. Gibson et al. (1985) found that RAN level was reduced by 27% when YE was fed to cattle in diets containing 0.87% urea. In our trial 2, CAN was 33% lower in LPUYE fed diet rabbits compared to LPU fed diets. Ellenberger et al. (1985) noted a decrease in vitro ruminal urease activity with YE supplement, which might result in lower conversion of urea to ammonia. Preston et al. (1987) reported that YE containing steroidal saponins lowered cecal urease activity in weanling rats fed diets with added urea or extra protein, and Sutton et al. (1992) found reduced activity in swine manure by using YE. However, Ryan et al. (1993) and Wu

et al. (1993) found that addition of YE had no effect on RAN. In most of the treatments where CAN was lower, the total VFA production was higher. Haaland et al. (1982) reported that higher OM intakes result in higher VFA production, which may result in better utilization of ammonia by rumen microbes, which might cause lower RAN levels.

In trial 1, PUN was numerically lower in YE diets compared to non-YE diets. Similar trend was observed in trial 2. Tagari et al. (1964) reported that there is an inverse correlation between PUN and the amount of N retained in the body. Preston et al. (1987) reported decreased PUN in rats supplemented with YE.

In both trials, total VFA concentration was numerically higher in YE supplemented diets, except in trial 1 where it was higher in HP vs HPYE. In trial 1, acetate to propionate ratio was lower in YE diets, however, the trend was the reverse in trial 2. Overall, total VFA concentration was higher in trial 1, where CP levels were higher compared to trial 2. Feed intake was also higher in trial 1 vs trial 2. Rumsey et al. (1970) reported that total VFA increased as intake increased, probably as a result of higher rate of ruminal fermentation in the presence of increased energy and nitrogen. They also reported a decrease in pH. We also observed a similar pattern in our trials. In trial 2, we did not see any difference in the concentration of different VFA. Wu et al. (1993) reported that addition of YE via ruminal cannulae had no effect on VFA and rumen pH. Ryan et al. (1993) reported that addition of YE numerically decreased total VFA production compared to control. Total VFA concentrations in LPUYE vs LPU, and MPYE vs MP, and LP vs LPYE were numerically higher in YE, which may be due to the reason that YE modulated the binding and release of ammonia-N, and thus improved the overall fermentation, resulting in higher VFA production.

The molar proportion of butyrate in cecal contents was higher than for propionate (Tables 5.4 and 5.6), in contrast to the rumen, in which acetate and propionate are the major

VFA and butyrate is a minor component. In the rabbit cecum, acetate and butyrate are the major VFA, and propionate is present as a minor component (Cheeke, 1987). This reflects the dominance of the rabbit cecal microflora by *Bacteroides* spp., which are butyrate producing organisms (Cheeke, 1987). Butyrate may have a specific role in controlling *Clostridia*-induced enteritis in rabbits (Cheeke, 1987), so increases in cecal butyrate levels could be beneficial. However, the YE did not have a consistent effect on cecal butyrate concentrations (Tables 5.4 and 5.6).

In conclusion, supplementation of rabbits diets with YE resulted in improved ADG and FE. In most of the cases it also improved total VFA production. Cecal ammonia was significantly reduced in LPUYE vs LPU treatments. In both trials, YE supplementation decreased PUN and PAN, which indicates that it has effects on nitrogen metabolism. Lack of consistency in some parameters may be due to the small number of animals and short experimental period. Overall, the results of the two trials suggest that YE may improve N utilization in rabbits. Although YE did not affect the growth rate of rabbits fed urea, it did reduce cecal ammonia and blood urea, which could under some circumstances improve urea utilization.

Table 5.1

Ingredient and chemical composition (percent DM basis) of feeds for rabbits (Experiment 1).

Item	Feeds[1]			
	HP	HPYE	MP	MPYE
Alfalfa meal	54	54	54	54
Soybean meal	21	21	10	10
Ground corn	0	0	11	11
Wheat mill run	20	20	20	20
Vegetable oil	1.25	1.25	1.25	1.25
Molasses	3	3	3	3
T.M.Salt	0.25	0.25	0.25	0.25
Dicalcium phosphate	0.25	0.25	0.25	0.25
Vitamins	0.25	0.25	0.25	0.25
Dry matter	90.16	90.35	90.28	90.15
Crude protein	23.41	22.41	18.79	19.09
Ash	8.73	9.02	8.56	8.37

[1] HP= High-protein; HYPE= High-protein plus yucca extract; MP= Medium-protein; MPYE= Medium-protein plus yucca extract.

Table 5.2

Ingredient and chemical composition (percent DM basis) of feed for rabbits (Experiment 2).

Item	Feeds[1]			
	LP	LPYE	LPU	LPUYE
Alfalfa meal	54	54	54	54
Soybean meal	0	0	0	0
Ground corn	21	21	19	19
Wheat mill run	20	20	20	20
Vegetable oil	1.25	1.25	1.25	1.25
Molasses	3	3	3	3
T.M.Salt	0.25	0.25	0.25	0.25
Dicalcium phosphate	0.25	0.25	0.25	0.25
Vitamins	0.25	0.25	0.25	0.25
Dry matter	90.81	90.70	91.17	90.12
Crude protein	16.63	16.34	22.13	22.33
Ash	9.20	8.90	9.01	8.80

[1] LP= Low-protein; LPYE= Low-protein plus yucca extract; LPU= Low-protein plus urea; LPUYE= Low-protein plus urea plus yucca extract.

Table 5.3
Effects of feeding yucca extract (YE) to rabbits on performance and nitrogen metabolism in cecum and blood (Experiment 1).

Parameters	Feeds[1]				
	HP	HPYE	MP	MPYE	SE
Weight gain (g h^{-1} d^{-1})	31.19[b]	40.93[a]	32.10[b]	35.07[ab]	2.47
Feed intake (g h^{-1} d^{-1})	103	106	110	111	3.77
Feed efficiency	3.47[a]	2.63[b]	3.48[a]	3.23[ab]	0.20
CUN[2] (mg dl^{-1})	15.53[ab]	16.22[a]	15.61[ab]	15.04[b]	0.12
CAN[3] (mg dl^{-1})	30.95	32.90	28.55	28.70	1.69
Cecal pH	6.02	6.01	6.22	6.20	0.05
PUN[4] (mg dl^{-1})	29.12[a]	28.03[a]	22.60[b]	20.24[b]	1.49
PAN[5] (μg dl^{-1})	7.76[a]	6.14[b]	6.09[b]	5.12[b]	0.21

[1] HP= High-protein; HYPE= High-protein plus yucca extract; MP= Medium-protein; MPYE= Medium-protein plus yucca extract.
[2] CUN= cecal urea nitrogen; [3] CAN= cecal ammonia-N; [4] PUN= plasma urea-N; [5] PAN= plasma ammonia-N.
[ab] Values in the same row with different superscripts differ ($P<.05$).
SE= Pooled standard error.

Table 5.4

Effects of feeding yucca extract (YE) to rabbits on volatile fatty acid production (Experiment 1).

Parameters	Feeds[1]				
	HP	HPYE	MP	MPYE	SE
Acetate (millimoles l^{-1})	80.17^{a}	64.73^{b}	60.17^{b}	61.20^{b}	3.81
Propionate (millimoles l^{-1})	4.44^{ab}	5.22^{a}	3.85^{b}	4.09^{b}	0.30
Butyrate (millimoles l^{-1})	14.15	12.86	11.98	13.06	1.65
Total VFAs (millimoles l^{-1})	98.76	82.81	76.00	78.35	-
A : P Ratio[2]	18.06	12.40	15.63	14.96	-

[1] HP= High-protein; HYPE= High-protein plus yucca extract; MP= Medium-protein; MPYE= Medium-protein plus yucca extract.

[ab] Values in the same row with different superscripts differ ($P < .05$).

SE= Pooled standard error. [2] = Acetate to propionate ratio.

Table 5.5

Effects of feeding yucca extract (YE) to rabbits on performance and nitrogen metabolism in cecum and blood (Experiment 2).

Parameters	Feeds[1]				
	LP	LPYE	LPU	LPUYE	SE
Weight gain (g h^{-1} d^{-1})	26.10^{a}	34.45^{b}	24.70^{a}	21.94^{a}	2.59
Feed intake (g h^{-1} d^{-1})	93^{a}	104^{b}	96^{ab}	90^{a}	2.98
Feed efficiency	3.70^{ab}	3.19^{b}	3.90^{ab}	4.26^{a}	0.31
CUN[2] (mg dl^{-1})	14,87	14.68	15.06	14.55	0.12
CAN[3] (mg dl^{-1})	23.68^{a}	23.83^{a}	27.00^{a}	17.97^{b}	1.55
Cecal pH	6.52	6.39	6.61	6.63	0.05
PUN[4] (mg dl^{-1})	15.61^{a}	14.62^{a}	30.95^{b}	21.46^{c}	1.45
PAN[5] (μg dl^{-1})	4.58	4.26	4.62	4.49	0.21

[1] LP= Low-protein; LPYE= Low-protein plus yucca extract; LPU= Low-protein plus urea; LPUYE= Low-protein plus urea plus yucca extract.
[2] CUN= cecal urea nitrogen; [3] CAN= cecal ammonia-N; [4] PUN= plasma urea-N; [5] PAN= plasma ammonia-N.
[abc] Values in the same row with different superscripts differ ($P < .05$).
SE= Pooled standard error.

Table 5.6

Effects of feeding yucca extract (YE) to rabbits on volatile fatty acid production (Experiment 2).

Parameters	Feeds[1]				
	LP	LPYE	LPU	LPUYE	SE
Acetate (millimoles l^{-1})	44.58	54.25	46.95	53.17	2.94
Propionate (millimoles l^{-1})	3.91	4.25	3.68	3.79	0.22
Butyrate (millimoles l^{-1})	9.07	11.35	11.08	10.36	0.97
Total VFAs (millimoles l^{-1})	57.56	69.85	61.71	67.32	-
A : P Ratio[2]	11.40	12.76	12,76	14.03	-

[1] LP= Low-protein; LPYE= Low-protein plus yucca extract; LPU= Low-protein plus urea; LPUYE= Low-protein plus urea plus yucca extract.

SE= Pooled standard error.

[2] = Acetate to propionate ratio.

REFERENCES

Al-Bar, A., Cheeke, P.R. and Nakaue, H.S., 1992. Effect of yucca extract (deodorase) on environmental ammonia levels and growth performance of rabbits. J. Appl. Rabbit Res., 15: 1105-1112.

Al-Bar, A., Ismail, A., Cheeke, P.R. and Nakaue, H.S., 1993. Effect of dietary yucca schidigera extract (deodorase) on environmental ammonia and growth performance of chickens and rabbits. Proc. West. Sec. Am. Soc. Anim. Sci., 44: 106-108.

Association of Official Analytical Chemists. 1990. Official Methods of Analysis 15th ed. AOAC. Inc. Arlington, VA.

Cheeke, P. R., 1987. Rabbit Feeding and Nutrition. Academic Press, San Diego.

Cromwell, G.L., Stahly, T.S. and Monegue, J.J., 1985. Efficacy of sarsaponin for weanling and growing finishing swine housed at two animal densities. J. Anim. Sci., 61 (Suppl. 1): 111.

Ellenberger, M.A., Rumpler, W.V., Johnson, D.E. and Goodall, S.R., 1985. Evaluation of the extent of ruminal urease inhibition by sarsaponin and its fractions. J. Anim. Sci. 61 (Suppl. 1): 491.

Gibson, M.L., Preston, R.L., Pritchard, R.H. and Goodall, S.R., 1985. Effect of sarsaponin and monensin on ruminal ammonia levels and in vitro dry matter digestibilities. J. Anim. Sci., 61 (Suppl. 1): 492.

Gipp, W.F., Newman, C.W., Elliott, D.O. and Roth, N.J., 1988. Influence of dietary yucca schidigera extract and antibiotic on starter pig performance. J. Anim. Sci., 66 (Suppl. 1): 330 (Abstr.).

Goering, H.K. and Van Soest, P.J., 1970. Forage Fiber Analysis (Apparatus, Reagents, Procedures and some applications). USDA-ARS Agri. Handbook No. 379. Washington, D.C.

Goetsch, A.L. and Owens, F.N., 1985. Effects of sarsaponin on digestion and passage rates in cattle fed medium to low concentrates. J. Dairy Sci., 68: 2377-2384.

Goodall, S.R., Brady, P., Horton, D. and Beckner, B., 1982. Steam flaked versus high moisture corn rations without sarsaponin for finishing steers. J. Anim. Sci., West. Sec. Procd., 45 (Abstr.).

Goodall, S.R. and Matsushima, J.K., 1980. The effects of sarsaponin on ruminant digestion and rate of passage. J.Anim.Sci. 51 (Suppl 1): 491.

Grobner, M.A., Johnson, D.E., Goodall, S.R. and Benz, D.A., 1982. Sarsaponin effects on in vitro continuous flow fermentation of a high grain diet. J. Anim. Sci., 55 (Suppl. 1): 491.

Haaland, G.L., Tyrell, H.F., Moe, P.W. and Wheeler, W.E., 1982. Effect of crude protein level and limestone buffering capacity and VFA concentration of cattle. J. Anim. Sci., 55: 943-950.

Headon, D.R., 1991. Glycofractions of the yucca plant and their role in ammonia control. In: Biotechnology in the Feed Industry. Proc. 7th Alltech Symposium, Alltech Technical Publications, Nicholasville, KY, pp 95-108.

Johnston, N.L., Quarles, C.L., Fagerberg, D.J. and Caveny, D.D., 1981. Evaluation of yucca saponin on broiler performance and ammonia suppression. Poul. Sci., 60: 2289-2292.

Mader, T.L. and Brumm, M.C., 1987. Effect of feeding sarsaponin in cattle and swine diets. J. Anim. Sci., 65: 9-15.

Preston, R.L., Bartle, S.J., May.T. and Goodall, S.R., 1987. Influence of sarsaponin on growth, feed and nitrogen utilization in growing male rats fed diets with added urea or protein. J. Anim. Sci., 65: 481-487.

Rumsey, T.S., Bond, J., Hart, R.H. and Carlson, G.E., 1970. Ruminal ammonia, pH and VFA of beef cattle on orchardgrass pasture and self-fed liquid molasses-urea or ground corn-fat supplements. J. Anim. Sci., 33: 507-513.

Ryan, J.P. Leek, B.F. and Jacques, K., 1993. The complementary effects of Saccharomyces cerevisiae yeast culture (Yaa-Sacc 1026) and yucca schidigera extract (solid de-odorase) on ruminal metabolism in sheep. J. Anim. Sci., 71 (Suppl. 1): 287.

Singh, B., Makkar, H.P.S. and Krishna, L., 1990. Urea utilization by rabbits fed low protein feeds. I. Nutrient utilization. J. Appl. Rabbit Res., 13: 80-87.

Statistical Analysis Systems., 1987. SAS- Institute, Cary, NC, USA.

Sutton, A.L., Goodall, S.R., Patterson, J.A., Mathew, A.G., Kelley, D.T. and Mayerholtz, K.A., 1992. Effects of odor control compounds on urease activity in swine manure. J. Anim. Sci., 70 (Suppl. 1): 160 (Abstr.).

Tagari, H., Dror, Y., Ascarelli, I. and Bondi, A., 1964. The influence of levels of protein and starch in rations of sheep on the utilization of protein. Br. J. Nutr., 18: 333-356.

Waldern, D.E., 1971. A rapid micro-digestion procedure for neutral and acid detergent fiber. Can. J. Anim. Sci., 51: 67-69.

Wu, Z., Sadik, M., Huber, J.T., Sleiman, F.T., Simas, J. and Pessarakli, M., 1993. Influence of yucca extract (Deodorase) on ruminal metabolism in cows. J. Anim. Sci., 71 (Suppl. 1): 266.

Yen, J.T. and Pond, W.G., 1993. Effect of carbadox, copper, or yucca schidigera extract on growth performance and visceral weight of young pigs. J. Anim. Sci., 71:2140-2146.

SUMMARY AND SUGGESTIONS FOR FURTHER RESEARCH

Silage prepared from corn juice and grass seed straw was evaluated as an animal feed in experiments involving beef and dairy cattle, water buffaloes and sheep. Three types of straw silages were prepared: ryegrass-corn juice, tall fescue-corn juice and ammoniated tall fescue-corn juice silage. Medium quality grass hay (GH) was used as the control standard to which the silages were compared. The major conclusions were:

1 In an experiment with growing beef cattle, all three types of silages were statistically equal to grass hay (GH) in terms of feed intake, weight gain (ADG) and feed efficiency (FE). However, numerically the FE was lower in animals fed silages than for GH fed animals. The FE in ammoniated fescue straw:corn juice (UFCJ) was 19% better than plain fescue straw:corn juice (FCJ) silage.

2 In a second experiment with growing beef cattle, supplementation of UFCJ with 125 g fishmeal and 1.36 kg of alfalfa hay per head per day compared to FCJ supplemented with only 1.36 kg of alfalfa hay, increased 20% weight gain and 44% feed efficiency. The factors involved behind the improved response, and specifically whether this is a response to rumen by-pass protein, should be further investigated.

3 Alfalfa hay supplementation of FCJ, UFCJ and ryegrass straw:corn juice silage (RCJ) at the rate of 1.36 kg/h/d, improved weight gain (89, 106 and 84 percent of the control) and feed efficiency was 29% and 18% lower and 12% higher compared to control in FCJ, UFCJ and RCJ, respectively.

4 In a sheep digestibility experiment, digestibilities of DM, NDF and ADF were similar between GH and UFCJ, however, digestibilities were significantly higher in UFCJ

compared to FCJ which shows the benefits of urea treatment. The digestible energy was maximum in UFCJ compared to GH, FCJ and RCJ.

5 In beef heifers fed ammoniated fescue straw:corn juice silage one animal showed symptoms of ammonia toxicity or ammonia hay toxicosis. Because corn juice is a good source of soluble sugars, its mixing with ammoniated straw may cause imidazole formation, which may cause toxicity. Further research needs to be undertaken to more understand this aspect. Similar problems may occur in ensiling cull onions with straws, and similar research may be undertaken as suggested in case of ammoniated straw:corn juice silages.

6 In an experiment with dairy heifers, supplementation of annual ryegrass straw:corn juice silage with 125 g fishmeal, significantly improved weight gain (24%) and FE (23%) compared to the non-supplemented silage group. Evaluation of some other sources of by-pass proteins and factors influencing the growth response need investigation.

7 Treatment of straw:onion silages with 3% and 5% urea gave similar improvements in terms of CP and IVDMD, therefore, the 3% level of urea seems more advisable because it is more safe.

8 Feeding cull onion:straw silage to sheep resulted in decreased blood packed cell volume and weight loss. Supplementation with 75 g alfalfa pellets did not reduce weight loss. The weight loss may have been due to high content of ash in the silage, due to mixing of soil when mixing straw with onions in the field. However, it may be due to the toxic factors of the onions or may be due to an inadequate level of alfalfa pellet supplementation. Therefore, further research on ammoniation of onion:straw silages is needed, with the hypothesis that ammoniation may inactivate the toxic

components, as well as increase N content which may result in improved feed efficiency. Supplementation with some protein sources like alfalfa pellets and fishmeal at different levels also may be further investigated.

9 If straw:corn juice silages are to be compared in future, the untreated straw should be included as a negative control, to document the effects of ensiling.

10 The digestibility of straw-corn juice silages was higher in water buffaloes than in cows. The factors that make water buffaloes better utilizers of LQR than cattle need investigation.

11 Results on in vitro dry matter digestibility (IVDMD) were similar to in vivo dry matter digestibility, suggesting the value of the IVDMD method for estimating in vivo digestibility

12 Yucca extract (YE), which binds ammonia, was studied as a feed additive which might facilitate ruminal metabolism of nitrogen, particularly with diets based on LQR. It was hypothesized that YE would bind ammonia when rumen concentrations were high immediately post-feeding, and serve as a source of slow-release nitrogen to maintain rumen ammonia levels adequate for optimal fiber digestion. The YE treatments in most cases showed lower rumen, cecal and plasma ammonia and plasma urea levels, which indicates that YE is binding the ammonia. However, it was not conclusively demonstrated that bound ammonia can be released from YE to maintain rumen ammonia levels. Further research investigating the release of ammonia from YE in rumen fluid needs to be undertaken.

BIBLIOGRAPHY

Agricultural Research Council. 1980. The nutrient requirements of ruminant livestock. Commonwealth Agricultural Bureaux, Slough, UK.

Ahmad, F.A. and Kay, M., 1975. A note on the value of molasses and tapioca as energy supplements to forage for grazing steers. Anim. Prod., 21: 191-194.

Aitchison, E.M., Gill, M., Dhanoa, M.S. and Osbourn, D.F., 1986. The effect of digestibility and forage species on the removal of digesta from the rumen and the voluntary intake of hay by sheep. Br. J. Nutr., 56: 463-476.

Al-Bar, A., Cheeke, P.R. and Nakaue, H.S., 1992. Effect of yucca extract (deodorase) on environmental ammonia levels and growth performance of rabbits. J. Appl. Rabbit Res., 15: 1105-1112.

Al-Bar, A., Ismail, A., Cheeke, P.R. and Nakaue, H.S., 1993. Effect of dietary *Yucca schidigera* extract (deodorase) on environmental ammonia and growth performance of chickens and rabbits. Proc. West. Sec. Am. Soc. Anim. Sci., 44: 106-108.

Anderson, S.J., Klopfenstein, T.J. and Wilkinson, V.A., 1988. Escape protein supplementation of yearling steers grazing smooth brome pastures. J. Anim. Sci., 66: 237-242.

Association of Official Analytical Chemists. 1990. Official Methods of Analysis 15th ed. AOAC. Inc. Arlington, VA.

Atwal, A.S. and Erfle, J.D., 1992. Effect of feeding fishmeal to cows on digestibility, milk production and milk composition. J. Dairy Sci., 75: 502-507.

Bailey, C.B., 1989. Rate and efficiency of gain from weaning to slaughter of steers given hay supplemented with ruminal undegradable protein, or concentrate. Can. J. Anim. Sci., 69: 691-706.

Bird, P.R., 1974. Sulphur metabolism and excretion studies in ruminants. XIII. Intake and utilization of wheat straw by sheep and cattle. Aust. J. Agric. Res., 25: 631-642.

Bird, S.H., Hill, M.K. and Leng, R.A., 1979. The effect of defaunation of the rumen on the growth of lambs on low-protein-high-energy diets. Br. J. Nutr., 42: 81-87.

Blauwiekel, R., Hoover, W.H., Slider, S.D. and Miller, T.K., 1990. Effect of fishmeal protein supplementation on milk yield and composition and blood constituents of dairy cows. J. Dairy Sci., 73: 3217-3221.

Blaxter, K.L., 1962. The Energy Metabolism of Ruminants. Hutchinson, London.

Blaxter, K.L. and Wainman, F.W., 1961. The utilization of food by sheep and cattle. J. Agri. Sci. (Camb.)., 57: 419-426.

Blaxter, K.L., Wainman, F.W. and Davidson, J.L., 1966. The voluntary intake of food by sheep and cattle in relation to their energy requirements for maintenance. Anim. Prod., 8:75-86.

Bosch, M.W., Tamminga, S., Post, G., Leffering, C.P. and Maylaert, J.M., 1992. Influence of stage of maturity of grass silages on digestion processes in dairy cows. I. Composition, nylon bag degradation rates, fermentation characteristics, digestibility and intake. Livestock Prod. Sci., 32: 245-264.

Brown, W.F., 1988. Maturity and ammoniation effects on the feeding value of tropical grass hay. J. Anim. Sci., 66: 2224-2232.

Bryant, M.P., 1973. Nutritional requirements of the predominant rumen cellulolytic bacteria. Federation Proc., 32: 1809-1813.

Buettner, M.R., Lechtenberg, V.L., Hendrix, K.S. and Hertel, J.M., 1982. Composition and digestion of ammoniated tall fescue (Festuca arundinaces Schreb.) hay. J. Anim. Sci., 54: 173-178.

Cai, Y., Zimmerman, D.R. and Ewan, R.C., 1993. Responses of plasma urea and free amino acid concentrations in pigs of two breed combinations to energy intakes. J. Anim. Sci., 71 (Suppl. 1): 318.

Campling, R.C., 1966. The effect of concentrates on the rate of disappearance of digesta from the alimentary tract of cows given hay. J. Dairy Res., 33: 13-23.

Caton, J.S., Freeman, A.S. and Galyean, M.L., 1988. Influence of protein supplementation on forage intake, in situ forage disappearance, ruminal fermentation and digesta passage rate in steers grazing dormant blue gama rangeland. J. Anim. Sci., 66: 2262-2271.

CH_2M Hill and Oregon State Univ., 1991. Opportunities in grass straw utilization, Corvallis, OR. USA.

Chalupa, W., 1975. Rumen by-pass and protection of proteins and amino acids. J. Dairy Sci., 68: 1198-1205.

Chaturvedi, M.L., Singh, U.B. and Ranjhan, S.K., 1973. Effect of feeding chopped and ground wheat straw on the utilization of nutrients and VFA production in growing cow calves and buffalo calves. Ind. J. Anim. Sci., 43: 382-385.

Cheeke, P.R., 1987. Rabbit Feeding and Nutrition. Academic Press, San Diego.

Cheeke, P.R. and Shull, C.R., 1985. Natural Toxicants in Feeds and Poisonous Plants. Avi. Pub. Co. Inc., Westport, CT.

Cherney, D.J.R., 1993. In vitro digestion kinetics and quality of perennial grasses as

influenced by forage maturity. J. Dairy Sci., 76: 790-797.

Chesson, A. and Orskov, E.R., 1984. Microbial degradation in the digestive tract. In: F. Sundstol and E. Owen (Editors), Straw and Other Fibrous By-products as Feed. Developments in Animal and Veterinary Sciences, Elsevier, Amsterdom, pp 305-339.

Chestnut, A.B., Berger, L.L. and Fahey,Jr. G.C., 1988. Effects of conservation methods and anhydrous ammonia or urea treatment on composition and digestion of tall fescue. J. Anim. Sci., 66: 2044-2056.

Chestnut, A.B., Berger, L.L. and Fahey,Jr. G.C., 1987. Effects of ammoniation of tall fescue on phenolic composition, feed intake, site and extent of nutrient digestion and ruminal dilution rates of steers. J. Anim. Sci., 64: 842-854.

Chiquette, J., Flipot, P.M. and Vinet, C.M., 1992. Effects of ammoniation and urea addition on chemical composition and digestibility of mature timothy hay, and rumen fluid characteristics of growing steers. Can. J.Anim. Sci., 72: 299-308.

Choung, J.J., Chamberlain, D.G., Thomas, P.C. and Bradbury, I., 1990. The effects of intraruminal infusions of urea on the voluntary intake and milk production of cows receiving grass silage diets. J. Dairy Res., 57: 455-464.

Church, D.C. and Peterson, R.G., 1960. Effect of several variables on in vitro fermentation. J. Dairy Sci., 43:81-89.

Cipolloni, M.A., Schneider, B.H., Lucas, H.L. and Pavlech, H.M., 1951. Significance of the differences in digestibility of feeds by cattle and sheep. J. Anim. Sci., 10: 337-342.

Cockrill, W.R., 1980. The ascendant water buffalo - key domestic animal. World Anim. Rev., 33: 2-12.

Colucci, P.E., Macleod, G.K., Grovum, W.L., Cahill, L.W. and McMillan, I., 1989. Comparative digestion in sheep and cattle fed different forage to concentrate ratios at high and low intakes. J. Dairy Sci., 72: 1774-1785.

Combellas, J., Priore, F., Paralta, J. and Zavarce, O., 1993. Influence of the addition of fishmeal to diets of roughage or roughage and concentrate on the composition and liveweight gain of growing cattle. Anim. Feed Sci. Technol., 42: 319-331.

Conklin, F.S., Taylor, M.L., Miles,Sr. T.R., Miles,Jr. T.R., Davis, E.F. and McHugh, E.J., 1991. Opportunities in grass straw utilization: an alternate viewpoint. Special report 881, Agric. Expt. Stat., Oregon State University.

Conklin, F.S., Young III, W.C. and Youngberg, H.W., 1989. Burning grass seed fields in Oregon's Willamette Valley: the search for solutions. O.S.U. Extension Service, OR. Agric. Expt. Stat. and USDA-ARS Cooperating Extension Miscellaneous 8397, Corvallis.

Cottyn, B.G. and DeBoever, J.L., 1988. Upgrading of straw by ammoniation. Anim. Feed Sci. Technol., 21: 287-294.

Craig, W.M., Ulloa, J.A., Watkins, K.L. and Nelson, B.D., 1988. Effects of level, form and time of urea application on the nutritive value of Alicia bermuda grass. J. Anim. Sci., 66: 185-193.

Cromwell, G.L., Stahly, T.S. and Monegue, J.J., 1985. Efficacy of sarsaponin for weanling and growing finishing swine housed at two animal densities. J. Anim. Sci., 61 (Suppl. 1): 111.

Cronje, P.B., Nolan, J.V. and Leng, R.A., 1991. Acetate clearance rate as a potential index of the availability of glucogenic precursors in ruminants fed on roughage-based diets. Br. J. Nutr., 66: 301-312.

Davies, O.D., 1992. The effects of protein and energy content of compound supplements offered at low levels to October-calving dairy cows given grass silage ad libitum. Anim. Prod., 55: 169-175.

DeGarcia, M. and Ward, J.K., 1991. Escape protein for beef cows: 2. Source and level of ammoniated wheat straw-corn silage diets. J. Anim. Sci., 69: 2289-2293.

DelCurto, T., Barton, R.K., Cheeke, P.R. and Turner, H.A., 1991. Urea-ammoniation and (or) supplementation strategies to improve the nutritive value of tall fescue straw for beef cattle production. Proc. West. Sec. Am. Soc. Anim. Sci., 42: 241-244.

DelCurto, T., Cochran, R.C., Harmon, D.L., Beharka, A.A., Jacqes, K.A., Towne, G. and Vanzant, E.S., 1990a. Supplementation of dormant tallgrass-prairie forage: 1. Influence of varying supplemental protein and (or) energy levels on forage utilization characteristics of beef steers in confinement. J. Anim. Sci., 68: 515-531.

DelCurto, T., Cochran, R.C., Nagaraja, T.G., Corah, L.R., Beharka, A.A. and Vanzant, E.S., 1990c. Comparison of soybean meal/sorghum grain, alfalfa hay and dehydrated alfalfa pellets as supplemental protein sources for beef cattle consuming dormant tallgrass-prairie forage. J. Anim. Sci., 68: 2901-2915.

Demment, M.W. and Van Soest, P.J., 1985. A nutritional explanation for body-size patterns of ruminants and non-ruminant herbivores. Am. Nat., 125: 641-646.

Dias-Da-Silva, A.A., 1986. Urea as a source of ammonia for improving the nutritive value of wheat straw. Anim. Feed Sci. Technol., 14: 67-79.

Dias-Da-Silva, A.A., Mascarenhas, F.A. and Cristina, V.M.G., 1988. Effects of moisture level, treatment time and soybean addition on the nutritive value of urea-treated maize stover. Anim. Feed Sci. Technol., 19: 67-77.

Dias-Da-Silva, A.A. and Sundstol, F., 1986. Urea as a source of ammonia for improving the nutritive value of wheat straw. Anim. Feed Sci. Technol., 14: 67-79.

Domingue, B.M.F., Delloe, D.W. and Barry, T.N., 1991. Voluntary intake and rumen digestion of a low-quality roughage by goats and sheep. J. Agric. Sci. (Camb.)., 117: 111-120.

Dryden, G.McL. and Leng, R.A., 1988. Effects of ammonia and sulphur dioxide gases on the composition and digestion of barley straw. Anim. Feed Sci. Technol., 19: 121-133.

El Hag, G.A., 1976. A comparative study between desert goats and sheep. Efficiency of feed utilization. Wld. Rev. Anim. Prod., 12(3): 43-48.

El-Shazly, K., 1952. Degradation of protein in the rumen of sheep. 2. The action of rumen microorganisms on amino acids. Biochem. J., 51: 647-653.

Ellenberger, M.A., Rumpler, W.V., Johnson, D.E. and Goodall, S.R., 1985. Evaluation of the extent of ruminal urease inhibition by sarsaponin and its fractions. J. Anim. Sci. 61 (Suppl. 1): 491.

Engels, F.M., 1987. Changes in the physical/chemical structures of cell walls during growth and degradation. In: J.M. van der Meer, B.A. Rajkens and M.P. Ferranti (Editors), Degradation of lignocellulosics in ruminants and in industrial processes. Elsevier, London, pp 13-20.

England, P. and Gill, M., 1985. The effect of fishmeal and sucrose supplementation on the voluntary intake of grass silage and liveweight gain of young cattle. Anim. Prod., 40: 259-265.

Erfle, J.D., Mahadevan, S., Teather, R.M. and Sauer, F.D., 1983. The performance of lactating cows fed corn silage in combination with soybean or fishmeal containing concentrates. Can. J. Anim. Sci., 63: 191-196.

Foster, J.R., 1983b. Sarsaponin for growing finishing swine alone or in combination with an antibiotic at different pig densities. J. Anim. Sci., 7 (Suppl 1) : 245.

Garstang, J.R., 1980. Silage supplements for calves. Anim. Prod., 32:355(Abstr).

Garstang, J.R., Thomas, C. and Gill, M., 1979. The effect of supplementation of grass silage with fishmeal on intake and performance of British Friesien calves. Anim. Prod., 28: 423(Abstr.).

Gibb, M.J. and Baker, R.D., 1987. Performance of young steers offered silage or thermo-ammoniated hay with or without fishmeal supplement. Anim. Prod., 45: 371-381.

Gibson, M.L., Preston, R.L., Pritchard, R.H. and Goodall, S.R., 1985. Effect of sarsaponin and monensin on ruminal ammonia levels and in vitro dry matter digestibilities. J. Anim. Sci., 61 (Suppl. 1): 492.

Gihad, E.A., 1976. Intake, digestibility and nitrogen utilization of tropical natural grass hay

by goats and sheep. J. Anim. Sci., 43: 879-883.

Gill, M., Beever, D.E., Buttery, P.J., England, P., Gibb, M.J. and Baker, R.D., 1987. the effect of oestradiol-17b implantation on the response in voluntary intake, liveweight gain and body composition, to fishmeal supplementation of silage offered to growing calves. J. Agric. Sci. (Camb.)., 108: 9-16.

Gill, M. and Beever, D.E., 1982. The effect of protein supplementation on digestion and glucose metabolism in young cattle fed on silage. Br. J. Nutr., 48: 37-47.

Gipp, W.F., Newman, C.W., Elliott, D.O. and Roth, N.J., 1988. Influence of dietary yucca schidigera extract and antibiotic on starter pig performance. J. Anim. Sci., 66 (Suppl. 1): 330 (Abstr.).

Glimp, H.A. and Tillman, A.D., 1965. Effect of jackbean urease injections on performance, anti-urease production and plasma ammonia and urea levels in sheep. J. Anim. Sci., 24: 105-108.

Goering, H.K. and Van Soest, P.J., 1970. Forage Fiber Analysis (Apparatus, Reagents, Procedures and some applications). USDA-ARS Agri. Handbook No. 379.

Goetsch, A.L. and Owens, F.N., 1985. Effects of sarsaponin on digestion and passage rates in cattle fed medium to low concentrates. J. Dairy Sci., 68: 2377-2384.

Goodall, S.R., Brady, P., Horton, D. and Beckner, B., 1982. Steam flaked versus high moisture corn rations with and without sarsaponin for finishing steers. J. Anim. Sci. West. Sec. Procd., 45 (Abstr.).

Goodall, S.R. and Matsushima, J.K., 1980. The effects of sarsaponin on ruminant digestion and rate of passage. J. Anim. Sci., 51 (Suppl 1):491.

Goodall, S.R. and Matsushima, J.K., 1978. The effects of sarsaponin on ruminant digestion and rates of passage. J. Anim. Sci., (suppl. 1): 363.

Grant, R.G., Van Soest, P.J. and McDowell, R.E., 1974. Influence of rumen fluid source and fermentation time on in vitro true dry matter digestibility. J. Dairy Sci., 57:1201-1207.

Grenet, E. and Barry, P., 1990. Microbial degradation in the rumen of wheat straw and anhydrous ammonia treated wheat straw observed by electron microscopy. Reprod. Nutr. Devel., 30: 533-540.

Grobner, M.A., Johnson, D.E., Goodall, S.R. and Benz, D.A., 1982. Sarsaponin effects on in vitro continuous flow fermentation of a high grain diet. J. Anim. Sci., 55 (Suppl. 1): 491.

Gruhzit, O.M., 1931. Anemia of dogs produced by feeding whole onions and onion fractions. Am. J. Med. Sci., 181: 812-814.

Haaland, G.L., Tyrell, H.F., Moe, P.W. and Wheeler, W.E., 1982. Effect of crude protein level and limestone buffering capacity and VFA concentration of cattle. J. Anim. Sci., 55: 943-950.

Hadjipanayiotou, M., 1982. The effect of ammoniation using urea on intake and nutritive value of chopped barley straw. Grass Forage Sci., 37: 89-93.

Headon, D.R., 1991. Glycofractions of the Yucca plant and their role in ammonia control. In: Biotechnology in the Feed Industry. Proc. 7th Alltech Symposium, Alltech Technical Publications, Nicholasville, KY, pp 95-108.

Holzer, Z., Levy, D., Samuel, V. and Bruckenthal, I., 1986. Interactions between supplementary N source and ration energy density on performance and N utilization in growing and fattening male cattle. Anim. Prod., 42: 19-28.

Horton, G.M.J., 1979. Feeding value of rations containing nonprotein N or natural protein and of ammoniated straw for beef cattle. J. Anim. Sci., 48: 38-44.

Horton, G.M.J. and Nicholson, H.H., 1981. Nitrogen sources for growing cattle fed barley and either wheat straw or dehydrated alfalfa. J. Anim. Sci., 52: 1143-1149.

Horton, G.M.J., Steacy, G.M., 1979. Effect of anhydrous ammonia treatment on the intake and digestibility of cereal straws by steers. J. Anim. Sci., 48: 1239-1249.

Hovell, F.D.DeB., Orskov, E.R., Grubb, D.A. and Macleod, N.A., 1983. Basal urinary nitrogen excretion and growth response to supplemental protein by lambs close to energy equilibrium. Br. J. Nutr., 50: 173-178.

Huhtanen, P., 1987. The effect of intraruminal infusions of sucrose and xylose on the N and fiber digestion in cattle receiving diets of grass silage and barley. J. Agri. Sci. Finl., 59: 405-424.

Hunt, C.W., Loeseke, J.A., Kivioja, D.A. and Haenny, S.C., 1990. Efficiency of urea application as a means of ammoniation of cool season forage. Proc.West Sec. Am. Soc. Anim. Sci., 41: 304-306.

Hussein, S.A. and Bryant, M.J., 1986. The response of store lambs to dietary supplements of fishmeal. 1. Effects of forage-to-concentrate ratio. Anim. Prod., 42: 223-232.

Hussein, H.S. and Jordan, R.M., 1991. Fishmeal as a protein supplement in ruminant diets: a review. J. Anim. Sci., 69: 2147-2156.

Hussein, H.S., Jordan, R.M. and Stern, M.D., 1991. Ruminal protein metabolism and internal amino acid utilization as affected by dietary protein and carbohydrate sources in sheep. J. Anim. Sci., 69: 2134-2146.

Hvelplund, T., 1985. Digestibility of rumen microbial protein and undegraded dietary protein estimated in the small intestine of sheep and by in sacco procedure. Acta Agric.

Scand., 25 (suppl.): 133-134.

Ibbotson, C.F., 1983. The effectiveness of urea as a source of ammonia for increasing the digestibility of straw. Anim. Prod., 36: 358 (Abstract).

Iwuanyanwu, I.E.J., Umuuna, N.N. and Din, N.I., 1990. Effects of urea supplement with or without molasses on the intake, digestibility and liveweight changes of beef heifers fed native hay. Anim. Feed Sci. Technol., 31: 277-284.

Jain, S. and Majumdar, B.N., 1962. A study on comparative digestibility in different species of farm ruminants. Biochem. Exp. Med., 22: 303-309.

James, L.F. and Binns, W., 1966. Effects of feeding wild onions (Allium validum) to bred ewes. J. Am. Vet. Med. Assoc., 149: 512-514.

Jayasuriya, M.C.N. and Pearce, G.R., 1983. The effect of urease enzyme on treatment time and the nutritive value of straw treated with urea as ammonia. Anim. Feed Sci. Technol., 8: 271-281.

John, H.K. and Marie, S.B., 1979. Effects of feeding cull domestic onions (Allium cepa) to sheep. Am. J. Vet. Res., 40: 397-399.

Johnston, N.L., Quarles, C.L., Fagerberg, D.J. and Caveny, D.D., 1981. Evaluation of yucca saponin on broiler performance and ammonia suppression. Poul. Sci., 60: 2289-2292.

Joy, M., Alibes, X. and Munoz, F., 1992. Chemical treatment of lignocellulosic residues with urea. Anim. Feed Sci. Technol., 38: 319-333.

Katiyar, R.C. and Bisth, G.S., 1989. Nutrient utilization in Murrah buffalo and Hariana cattle - A comparative study with oat-hay based rations. Proc. World Buffalo Congress., II: 189-193.

Katiyar, R.C. and Bisth, G.S., 1989. Nutrient utilization in Murrah buffalo and Hariana cattle - A comparative study with lucerne-hay-based rations. Proc. World Buffalo Congress., II: 194-198.

Keating, E.K., Saba, W.J., Hale, W.H. and Taylor, B., 1965. Future observations on the digestion of milo and barley by steers and lambs. J. Anim. Sci., 24: 1080-1089.

Kellems, R.O., Jones, R., Andrus, D. and Wallentine, M.V., 1991. Effect of moisture in total mixed ration on feed consumption and milk production and composition in Holstein cows. J. Dairy Sci., 74: 929-932.

Kellogg, D.W. and Owen, F.G., 1969. Alterations of in vitro rumen fermentation pattern with various levels of sucrose and cellulose. J. Anim. Sci., 52: 1458-1460.

Kernan, J.A., Crowle, W.L., Spurr, D.T. and Coxworth, E.C., 1979. Straw quality of cereal

cultivation before and after treatment with anhydrous ammonia. Can. J. Anim. Sci., 59: 511-518.

Khalili, H., 1993. Supplementation of grass hay with molasses in crossbred (Bos taurus * Bos indicus) non-lactating cows: effect of level of molasses on feed intake, digestion, rumen fermentation and rumen digesta pool size. Anim. Feed Sci. Technol., 41: 23-38.

Khalili, H. and Huhtanen, P., 1991a. Sucrose supplements in cattle given grass silage-based diets. 1. Digestion of organic matter and nitrogen. Anim. Feed Sci. Technol., 33: 247-261.

Klopfenstein, T. and Owen, F.G., 1981. Value and potential use of crop residues and by-products in dairy rations. J. Dairy Sci., 64: 1250-1268.

Koger, L.M., 1956. Onion poisoning in cattle. J. Am. Vet. Med. Assoc., 129: 75.

Kraiem, K., Abdouli, H. and Goodrich, R.D., 1991. Comparison of effects of urea and ammonia treatment of wheat straw on intake, digestibility and performance of sheep. Livestock Prod. Sci., 29: 311-321.

Kunkle, W.E., Leffel, E.C., Escobar, E.N. and Smith, L.W., 1980. Effect of method of harvest, anhydrous ammonia treatment and supplemental protein on the feeding value of corn residue. J. Anim. Sci., 52 (Suppl.1) : 241.

Laflamme, L.F., 1992. Carrot / grass silage as cattle feed. Can. J. Anim. Sci., 72: 441-443.

Lal, G.M. and Mudgal, V.D., 1967. Studies on the utilization of paddy straw (Oryza sativa) and berseem (Trifolium alexandrinium) as silage. Indian J. Dairy Sci., 20: 103-107.

Lalonde, C.M., Long, T.A., Harpster, H.W. and Saylor, W.W., 1975. Evaluation of cold flow ammonia treated corn silage and high moisture corn. J. Dairy Sci., 58: 1243 (Abstr.).

Leaver, J.D., Campling, R.C. and Holmes, W., 1969. The effect of level of feeding on the digestibility of diets for sheep and cattle. Anim. Prod., 11: 11-17.

Lee, G.J., Hennessy, D.W., Nolan, J.V. and Leng, R.A., 1987. Responses to nitrogen and maize supplements by young cattle offerer a low quality pasture hay. Aust. J. Agric. Res., 38: 195-207.

Lehr, D.A., Otterby, D.E., Johnson, D.G., Laz, J.G. and Landquist, R.G., 1983. Effect of moisture content of complete diets on feed intake and milk production by cows. J. Dairy Sci., 66: 1891-1898.

Leng, R.A., 1990. Some theoretical considerations on drought feeding recommendations. In: D.J.Ferrell (Editor), Recent Advances in Animal Nutrition in Australia, The Univ. of New England, Armidale, N.S.W., pp 104-111.

Leng, R.A., 1984. Supplementation of tropical and subtropical pastures for ruminant production. In: F.M.C. Gilchrist and R.I. Mackie (Editors), Herbivore Nutrition in the Tropics and Sub-tropics. Science Press, Pretoria, pp 129-144.

Lindberg, J.E., 1984. Nitrogen metabolism in sheep. I. Rumen fermentation and microbial synthesis in sheep fed with hay, barley and various protein supplements. Swed. J. Agric. Res., 43:37-43.

Lipple, H., 1980. Forage characteristics related to intake, digestibility and gain by ruminants. J. Anim. Sci., 50: 952-961.

Llamas-Lamas, G. and Combs, D.K., 1990. Effects of environmental temperature and ammoniation on utilization of straw by sheep. J. Anim. Sci., 68: 1719-1725.

MacRae, J.C., Smith, J.S., Dewey, P.J.S., Brewer, A.C., Brown, D.S. and Walker,A., 1985. The efficiency of utilization of metabolizable energy and apparent absorption of amino acids in sheep given spring and autumn harvested dried grass. Br. J. Nutr., 54: 197-202.

Mader, T.L. and Brumm, M.C., 1987. Effect of feeding sarsaponin in cattle and swine diets. J. Anim. Sci., 65: 9-15.

Males, J.R. and Gaskins, C.T., 1982. Growth, nitrogen retention, dry matter digestibility and ruminal characteristics associated with ammoniated wheat straw diets. J. Anim. Sci., 55: 505-515.

Mandell, I.B., Christison, G.I., Nicholson, H.H. and Coxworth, E.C., 1988. The effect of variation in the water content of wheat straw before ammoniation on its nutritive value for beef cattle. Anim. Feed Sci. Technol., 20: 111-124.

Marinucci, M.T., Dehorty, B.A. and Loerch, S.C., 1992. In vitro and in vivo studies of digestion of feeds in synthetic fiber bags. J. Anim. Sci., 70: 296-302.

Marten, G.C. and Barnes, R.F., 1980. Prediction of energy digestibility of forages with an in vitro rumen fermentation and fungal enzyme system. Page 61 in Standardization of Analytical Methodology for Feeds. In: W.J.Pigden, C.C.Balch and M. Graham (eds.) Int.Dev.Res.Ctr., Ottawa, On, Canada.

Mason, V.C., Cook, J.E., Dhanoa, M.S., Keene, A.S., Hoadley, C.J. and Hartley, R.D., 1990. Chemical composition, digestibility, in-vitro biodegradability of grass hays oven treated with different amounts of ammonia. Anim. Feed Sci. Technol., 29: 237-249.

McAllister, T.A., Beauchemin, K.A., McClelland, L.A. and Cheng, K.A., 1992. Effect of formaldehyde-treated barley or escape protein on nutrient digestibility, growth and carcass traits of feedlot lambs. Can. J. Anim. Sci., 72: 309-316.

McCollum, F.T., and Galyean, M.L., 1985. Influence of cotton seed meal supplementation on voluntary intake, rumen fermentation and rate of passage of prairie hay in beef

steers. J. Anim. Sci., 60: 570-577.

Meang, W.J., Cheng, M.B., Yun, H.S. and Choi, I., 1989. Dilution rate effect on the efficiency of rumen microbial growth in continuous culture. Asian-Australasian J. Anim. Sci., 2(3): 477-480.

Mohammad, H.H. and Owen, E., 1982. Goats versus sheep: effects of coat thickness and body composition on maintenance energy requirements. Anim. Prod., 34: 391 (Abstr.).

Moore, K.J., Lechtenberg, V.L. and Hendrix, K.S., 1985. Quality of orchardgrass hay ammoniated at different rates, moisture concentrations and treatment durations. Agron. J., 77: 67-71.

Mosi, A.K. and Butterworth, M.H., 1985. The voluntary intake and digestibility of cereal crop residues and legume hay for sheep. Anim. Feed Sci. Technol., 12: 241-251.

Naga, N.A. and El-Shazly, K., 1969. Activities of rumen microorganisms in water buffalo (Bos bubalis) and in zebu cattle. J. Dairy Res., 36:1-8.

Narang, M.P. and Pradhan, K., 1974. Studies on improving the utilization of poor quality roughages: Ensiling wheat straw with cowpea (Vigna linensis). Ind. J. Anim. Sci., 44:14-17.

Naseeven, M.R. and Kincaid, R.L., 1992. Ammonia and sulfur dioxide treated wheat straw as a feedstuff for cattle. Anim. Feed Sci. Technol., 37: 111-128.

National Research Council., 1985. Ruminant Nitrogen Usage. National Academy Press, Washington, D.C.

National Research Council., 1984. Nutrient requirements of beef cattle. 6th ed. NAS-NRC, Washington, D.C.

Ndlovu, L.R. and Buchanan-Smith, J.G., 1985. Utilization of poor quality roughages by sheep: effects of alfalfa supplementation on ruminal parameters, fiber digestion and rate of passage from the rumen. Can. J. Anim. Sci., 65: 693-703.

Nelson, B.D., Ellzey, H.D., Montgomery, C. and Morgan, E.B., 1972. Factors affecting the variability of an in vitro rumen fermentation technique for estimating forage quality. J. Dairy Sci., 55: 358-364.

Nelson, M.L., Klopfenstein, T.J., Britton, R.A. and Lowery, S.R., 1985. Protein supplementation of ammoniated roughages. III. Corncobs supplemented with a blood-meal-corn gluten meal mixture in steer studies. J. Anim. Sci., 61: 1567-1575.

Newbold, J.R., Garnsworthy, P.C., Buttery, P.J., Cole, D.J.A. and Haresign, W., 1987. Protein nutrition of growing cattle: Food intake and growth responses to rumen degradable protein and undegradable protein. Anim. Prod., 45: 383-394.

Nicholson, J.W.G., Charmley, E. and Bush, R.S., 1992. The effect of supplemental protein source on ammonia level in rumen fluid and blood and intake of alfalfa silage by beef cattle. Can. J. Anim. Sci., 72: 853-862.

Nicholson, J.W.G. and MacLeod, A.B., 1966. Effects of form of nitrogen fertilizer, a preservative, and a supplement on the value of high-moisture grass silage. Can. J. Anim. Sci., 46: 71-82.

Orskov, E.R., 1982. Protein Nutrition in Ruminants. Academic Press, London.

Owen, E., 1985. Crop residues as animal feeds in developing countries, use and potential use. p.25-42. In: Wanapat, M. and Devendra, C. (eds.). Relevance of crop residues as animal feeds in developing countries. Proc.Int. Workshop, Thailand.

Owens, F.N., Garza, J. and Dubeski. P., 1991. Advances in amino acid and N nutrition in grazing ruminants. Proc.Graging Livestock Conference.

Paterson, J.A., Klopfenstein, T.J., and Britton, R.A., 1979. Ammonia treatment of corn residues. J. Anim. Sci., 49: 270 (Abstr.)

Perdok, H.B. and Leng, R.A., 1987. Hyperexcitability in cattle fed ammoniated roughages. Anim. Feed Sci. Technol., 17: 121-143.

Phillip, L.E., Buchanan-Smith, J.G. and Grovum, W.L., 1981. Food intake and rumen osmolality in sheep. Differentiation of the effect of osmolality from that of the products of maize silage fermentation. J. Agric. Sci. (Camb.)., 96: 439-446.

Plyne, M.J., 1978. Differences between cattle and sheep in their digestion and relative intake of mature tropical grass hay. Anim. Feed Sci. Technol., 3: 41-49.

Poonappa, C.G., Nooruddin, M.D. and Raghavan, G.V. 1971. Rate of passage of food and its relation to digestibility of nutrients in Murrah buffaloes and Hariana cattle. Indian J.Anim. Sci., 41: 1026-1031.

Poppi, D.P., Minson, D.J. and Ternouth, J.H., 1980. Studies of cattle and sheep eating leaf and stem fractions of grasses. 1. The voluntary intake, digestibility and retention time in the reticulo-rumen. Aust. J. Agric. Res., 32: 99-108.

Pradhan, K., Bhatia, S.K. and Sangwan, D.C., 1991. Feed consumption pattern, nutrient digestibility and related physiological reactions in buffalo and cattle on high fibrous diets. Proc. Third World Buffalo Congress., I: 175.

Preston, R.L., Bartle, S.J., May.T. and Goodall, S.R., 1987. Influence of sarsaponin on growth, feed and nitrogen utilization in growing male rats fed diets with added urea or protein. J. Anim. Sci., 65: 481-487.

Preston, T.R. and Leng, R.A., 1987. Matching Ruminant Production Systems With Available

Resources in the Tropics and Sub-tropics. Penambul Books, Armidale, N.S.W., 245 pp.

Prigge, E.C., Baker, M.J. and Verga, G.A., 1984. Comparative digestion, rumen fermentation and kinetics of forage diets by steers and wethers. J. Anim. Sci., 59: 237-245.

Putnam, P.A., Yarns, D.A. and Davis, R.E., 1966. Effects of pelletting rations and hay:grain ratio on salivary secretions and ruminal characteristics of steers. J. Anim. Sci., 25: 1176-1182.

Ranjhan, S.K., 1991. Comparative efficiency of utilization of feeds and forages in Indian cattle and buffaloes. Proc. Third World Buffalo Congress. I: 160.

Razdan, M.N., Sharma, D.D., Bhargava, P.K. and Chawala, M.S. 1971. Utilization of urea and water metabolism by zebu cattle and buffalo under tropical conditions. J. Dairy Sci., 54: 1200-1207.

Rees, M.C. and Little, D.A., 1980. Differences between sheep and cattle in digestibility, voluntary intake and retention time in the rumen of three tropical grasses. J. Agric. Sci. (Camb.)., 94: 483-488.

Reid, R.L., Jung, G.A., Cox-Ganser, J.M., Rybeck, B.F. and Townsend, E.C., 1990. Comparative utilization of warm and cool season forages by cattle, sheep and goats. J. Anim. Sci., 68: 2986-2994.

Reid, R.L., Jung, G.A. and Thayne, W.V., 1988. Relationship between nutritive quality and fiber components of cool season and warm season forages: A retrospective study. J. Anim. Sci., 66: 1275-1291.

Romulo, B., 1986. Studies on the role of supplementation and of manipulation of protozoal population in the rumen on productivity of sheep given straw based diets. Ph.D. Thesis, Univ. of New England, Armidale.

Rooke, J.A., Lee, N.H. and Armstrong, D.G., 1987. The effects of intraruminal infusions in cattle receiving grass silage diets. Br. J. Nutr., 57: 89-98.

Rowland, L.O.Jr., Plyler, J.E. and Bradley, J.W., 1976. *Yucca schidigera* extract effects on egg production and house ammonia levels. Poul. Sci., 55: 2086 (Abstr.).

Rumsey, T.S., Bond, J., Hart, R.H. and Carlson, G.E., 1970. Ruminal ammonia, pH and VFA of beef cattle on orchardgrass pasture and self-fed liquid molasses-urea or ground corn-fat supplements. J. Anim. Sci., 33: 507-513.

Rusche, W.C., Cochran, R.C., Corah, L.R., Stevenson, J.S., Harmon, D.L., Brandt. R.T.Jr., and Minton, J.E., 1993. Influence of source and amount of dietary protein on performance, blood metabolites, and reproductive function of primiparous beef cows. J. Anim. Sci., 71: 557-563.

Russell, J.B., 1984. The effect of sarsaponin on ammonia levels in rodent cages. District Convention Am. Assoc. Lab. Anim. Sci., (Abstr).

Ryan, J.P. Leek, B.F. and Jacques, K., 1993. The complementary effects of *Saccharomyces cerevisiae* yeast culture (Yaa-Sacc 1026) and yucca schidigera extract (solid deodorase) on ruminal metabolism in sheep. J. Anim. Sci., 71 (Suppl. 1): 287.

Saadullah, M., Haque, M. and Dolberg, F., 1981. Effectiveness of ammoniation through urea in improving the feeding value of rice straw in ruminants. Trop. Anim. Prod., 6: 30-36.

Saadullah, M., 1986. Supplementing urea treated rice with fishmeal and its effects on the gut contents and dressed carcass weight. In: M.N.M.Ibrahim and J.B.Schiere (eds.). Rice straw and related feeds in ruminant rations. pp. 248-254., Agri. Univ. Wageningen.

Saenger, P.F., Lemenager, R.P. and Hendrix, K.S., 1983. Effects of anhydrous ammonia treatment of wheat straw upon its in vitro digestion, performance and intake by beef cattle. J. Anim. Sci., 56: 15-20.

Saenger, P.F., Lemenager, R.P. and Hendrix, K.S., 1982. Anhydrous ammonia treatment of corn stover and its effects on digestibility, intake and performance of beef cattle. J. Anim. Sci., 54: 419-425.

Sanderson, R., Thomas, C. and McAllan, A.B., 1992. Fish-meal supplementation of grass silage given to young growing steers: effects on intake, apparent digestibility and live-weight gains. Anim. Prod., 55: 389-396.

Seoane, J.R., Amyot, A.M., Christen, A.M. and Petit, H.V., 1993. Performance of growing steers fed either hay or silage supplemented with canola or fishmeal. Can. J. Anim. Sci., 73:57-65.

Sharma, V.V. and Jhanwar, B.M., 1973. Effect of supplementation of wheat straw with concentrate on voluntary intake, digestibility and growth in cattle. Ind. J. Anim. Sci., 43: 688-693.

Siebert, B.D. and Kennedy, P.M., 1972. The utilization of spear grass. 1. Factors limiting intake and utilization by cattle and sheep. Aust. J. Agric. Res., 23: 35-44.

Singh, U.B. and Mehra, V.R., 1990. Utilization of wheat straw given in a feed block and supplemented with varying quantities of fishmeal and oil-extracted rice bran. Anim. Feed Sci. Technol., 28: 129-134.

Singh, B.K.and Mudgal, V.D., 1967. The comparative utilization of feed nutrients from lucerne hay in buffalo and crossbred zebu heifers. Ind. J. Dairy Sci., 20: 142-148.

Sloan, B.K., Rowlison, P. and Armstrong, D.G., 1988. The influence of a formulated excess of rumen degradable protein or undegradable protein on milk production in dairy cows in early lactation. Anim. Prod., 46: 13-19.

Smith, T., Broster, V.J. and Hill, R.E., 1980. A comparison of supplementary nitrogen for young cattle receiving fiber-rich diets. J.Agric. Sci. (Camb.)., 95: 687-695.

Smith, T., Siviter, J.W. and Merry, R.J., 1985. Further comparison of energy and protein sources for growing cattle. J. Agric. Sci. (Camb)., 104: 485-491.

Spencer, R.R. and Akin, D.E., 1980. Rumen microbial degradation of potassium hydroxide-treated coastal bermudagrass leaf blades examined by electron microscopy. J. Anim. Sci., 51: 1189-1196.

Statistical Analysis Systems., 1987. SAS- Institute, Cary, NC, USA.

Steel, R.G.D. and Torrie, J.H., 1980. Principles and Procedures of Statistics. 2nd. ed. Mc Graw Hill, New York.

Steen, R.W.J., 1992. A comparison of soya-bean meal, fishmeal and maize gluten feed as protein sources for calves offered grass silage ad libitum. Anim. Prod., 54: 333-339.

Steen, R.W.J., 1989. A comparison of soya-bean, sunflower and fishmeal as protein supplements for yearling cattle offered grass silage-based diets. Anim. Prod., 48: 81-89.

Steen, R.W.J., 1988. The effect of supplementing silage-based diets with soybean and fishmeals for finishing beef cattle. Anim. Prod., 46: 43-51.

Steen, R.W.J., 1985. Protein supplementation of silage-based diets for calves. Anim. Prod., 41: 293-300.

Stern, M.D. and Hoover, W.H., 1979. Methods of determining and factors affecting rumen microbial protein synthesis: a review. J. Anim. Sci., 49: 1590-1603.

Streeter, C.L. and Horn, G.W., 1984. Effect of high moisture and dry ammoniation of wheat straw on its feeding value for lambs. J. Anim. Sci., 59: 559-566.

Sundstol, F., 1984. Ammonia treatment of straw: Methods for treatment and feeding experience in Norway. Anim. Feed Sci. Technol., 10: 173-187.

Sundstol, F. and Coxworth, E.M., 1984. Ammonia Treatment. In: F. Sundstol and E.Owen (Eds), Straw and Other Fibrous By-Products as Feed. Elsevier, Amsterdam/Oxford/New York/Tokyo, pp 196-247.

Sundstol, F., Said, A.N. and Arnason, J., 1979. Factors influencing the effect of chemical treatment on the nutritive value of straw. Acta. Agr. Scand., 29: 179-190.

Sutton, J.D., 1989. Altering milk composition by feeding. J. Dairy Sci., 72: 2801-2814.

Sutton, J.D., 1968. The fermentation of soluble carbohydrates in rumen contents of cows fed diets containing a large proportion of hay. Br. J. Nutr., 22: 689-712.

Sutton, A.L., Goodall, S.R., Patterson, J.A., Mathew, A.G., Kelley, D.T. and Mayerholtz, K.A., 1992. Effects of odor control compounds on urease activity in swine manure. J. Anim. Sci., 70(Suppl. 1):160 (Abstr.).

Suzuki, E.Y. and Early, R.J., 1991. Analysis of chromic oxide in small samples of feeds and feces using chlorine bleach. Can. J. Anim. Sci., 71: 931-934.

Tagari, H., Dror, Y., Ascarelli, I. and Bondi, A., 1964. The influence of levels of protein and starch in rations of sheep on the utilization of protein. Br. J. Nutr., 18: 333-356.

Teleni, E., King, W.R., Rowe, J.B. and McDowell, G.H., 1989. Lupins and energy yielding nutrients in ewes. 1. Glucose and acetate biokinetics and metabolic hormones in sheep fed a supplement of lupin grain. Aust. J. Agric. Res., 40: 913-924.

Theander, O., 1981. Chemical composition of low quality roughages as related to alkali treatment. In: J.A. Kategile, A.N., A.N. Said, and F. Sundstol (Editors). Utilization of low quality roughages in Africa. Rep.1, AUN-Agri. Development, Aas, Norway, 1-106.

Thomas, P.C., 1982. Utilization of conserved forages. In: Forage protein in ruminant animal production. (Eds. D.J. Thomson, D.E. Beever and R.G.Gunn), occasional publication, Br. Society Anim. Prod., no.6, pp 67-76.

Throp, F. and Harshfield, G.S., 1939. Onion poisoning in horses. J. Am. Vet. Med. Assoc., 94: 52-53.

Tilley, J.M.A. and Terry, R.A., 1963. A two-stage technique for the in vitro digestion of forage crops. J. Brit. Grassl. Soc., 18: 104-111.

Tiwari, S.P., Singh, U.B. and Mehra, U.R., 1990. Urea molasses mineral blocks as a feed supplement: Effect on growth and nutrient utilization in buffalo calves. Anim.Feed Sci.Technol., 29: 333-341.

Usmani, R.H. and Inskeep, E.K., 1989. Effect of prepartum feeding on milk yield and calf growth rate in limited-suckled and non-suckled buffaloes. J. Dairy Sci., 72: 2087-2094.

Van Kampen, K.R., James, L.F. and Johnson, A.E., 1970. Hemolytic anemia in sheep fed wild onions (Allium validum). J. Am. Vet. Med. Assoc., 156: 328-332.

Van Soest, P.J., 1982. Nutritional Ecology of the Ruminants. O & B Books, Corvallis, OR.

Van Soest, P.J., Mascarenhas, F.A. and Hartley, R.D., 1984. Chemical properties of fiber in relation to nutritive quality of ammoniated forages. Anim. Feed Sci. Technol., 10: 155-164.

Veira, D.M., Butler, G., Ivan, M. and Proulx, J.G., 1985. Utilization of grass silage by cattle: effect of barley and fishmeal supplements. Can. J. Anim. Sci., 65: 897-903.

Veira, D.M., Proulx, J.G., Butler, G. and Fortin, A., 1988. Utilization of grass silage by cattle: further observations on effect of fishmeal. Can. J. Anim. Sci., 68: 1225-1235.

Waagepetersen, J. and Thomsen, K.V., 1977. Effect on digestibility and nitrogen content of barley straw of different ammonia treatments. Anim. Feed Sci. Technol., 2: 131-136.

Wahed, R.A. and Owen, E., 1986. Comparison of sheep and goats under stall-feeding conditions: Roughage intake and selection. Anim. Prod., 42: 89-95.

Wahid, A., 1973. Pakistani buffaloes. World Anim. Rev., 7:22-28.

Waiss, A.C.Jr., Guggolz, J., Kohler, G.O., Waller Jr. H.G. and Garrett, W.N., 1972. Improving digestibility of straws for ruminant feed by aqueous ammonia. J. Anim. Sci., 35: 109-112.

Waldern, D.E., 1971. A rapid micro-digestion procedure for neutral and acid detergent fiber. Can. J. Anim. Sci., 51: 67-69.

Ward, M.G. and Ward, J.K., 1987. Ammoniation of warm-season grass hay for gestating beef cows. J. Anim. Sci., 65: 359-365.

Whitelaw, F.G., Milne, J.S., Orskov, E.R. and Smith, J.S., 1985. The effect of casein supplements given by abomasal infusion on the nitrogen and energy metabolism of lactating cows. Proc. Nutr. Soc.44.

Wiley, J.S., Petersen, M.K., Ansotegni, R.P. and Bellows, R.A., 1991. Production from first-calf heifers fed a maintenance or low level of prepartum nutrition and ruminally undegradable or degradable protein postpartum. J. Anim. Sci., 69: 4279-4293.

Wilkins, R.J., 1974b. The effects of partial neutralization with sodium bicarbonate or ammonia and the feeding of blood meal on the voluntary intake of whole crop barley silage by sheep. Anim. Prod., 19: 87-91.

Williams, P.E.V., Innes, G.M. and Brewer, A., 1984. Ammonia treatment of straw via the hydrolysis of urea. II Additions of soybean (urease), sodium hydroxide and molasses; effects on digestibility of urea treated straw. Anim.Feed Sci.Technol., 11: 115-119.

Williams, P.E.V., Innes, G.M. and Brewer, A., 1984b. Ammonia treatment of straw via the hydrolysis of urea. I. Effects of dry matter and urea concentrations on the rate of hydrolysis of urea. Anim. Feed Sci. Technol., 11: 103-113.

Williams, P.E.V. and Innes, G.M., 1982. Effects of ammonia from urea hydrolysis on the dry matter loss from decaron bags of barley straw. Anim. Prod., 34: 385 (Abstr.).

Willms, C.L., Berger, L.L., Merchen, N.R. and Fahey, Jr. G.C., 1991. Effects of supplemented protein source and level of urea on intestinal amino acid supply and feedlot performance of lambs fed diets based on alkaline hydrogen peroxide-treated

wheat straw. J. Anim. Sci., 69: 4925-4938.

Wu, Z., Sadik, M., Huber, J.T., Sleiman, F.T., Simas, J. and Pessarakli, M., 1993. Influence of yucca extract (Deodorase) on ruminal metabolism in cows. J. Anim. Sci., 71 (Suppl. 1): 266.

Yen, J.T. and Pond, W.G., 1993. Effect of carbadox, copper, or yucca schidigera extract on growth performance and visceral weight of young pigs. J. Anim. Sci., 71:2140-2146.

Yilala, k. and Bryant, M.J., 1985. The effects upon the intake and performance of store lambs of supplementing grass silage with barley, fishmeal and rapeseed meal. Anim. Prod., 40: 111-121.

Zorrilla-Rios, J., Horn, G.W. and McNew, R.W., 1991. Nutritive value of ammoniated wheat straw fed to cattle. J. Anim. Sci., 69: 283-294.