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FACTORS AFFECTING INTAKE AND DIGESTIBILITY OF WHEAT STRAW BY STEERS.

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# FACTORS AFFECTING INTAKE AND DIGESTIBILITY OF WHEAT STRAW BY STEERS

by

Hamadi Dicko

A Thesis Submitted to the Faculty of the

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2 april 1982
Date

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## ABSTRACT

Six high gaining and six low gaining steers were selected from a growing trial with wheat straw the only source of roughage. For this study, the steers were individually fed and continued on wheat straw as the only roughage. In trial one, a digestion trial was conducted to determine the difference in digestibility between the two groups of steers. Straw intake was significantly higher for the high gaining group. Digestibilities of dry matter, organic matter, crude protein and gross energy were insignificantly higher for the low gaining steers.

In trial two, the steers were allotted so that half received the wheat straw plus supplement with monensin and half without monensin. Monensin significantly decreased feed intake and daily gain. Digestibilities of dry matter, neutral detergent fiber, acid detergent fiber and gross energy were significantly increased due to monensin. In trial three, the steers were put on an intake trial based on a high energy supplement or a protein supplement only. Daily straw intake was similar between the two groups, however, the high gaining steers consumed more straw than the low gaining steers. Average daily gain was significantly higher for the steers receiving the protein supplement.

# INTRODUCTION

Several studies have been conducted on methods to improve the use of low quality roughages in ruminant feeding. The main problem associated with feeding roughages and particularly low quality roughages is their low content of digestible energy and protein.

Low quality roughages and roughages in general are the main feedstuff for ruminants in developing countries. In these countries, cereals constitute the main food of the human population and little, if any, is used in animal feeding. The soaring cost of fossil fuels may jeopardize the use of cereals grains in animal feeding in the developing countries and may considerably reduce their use in the industrialized countries. Improving the utilization of roughages by the ruminant animal then becomes a necessity.

Improving voluntary intake and digestibility of low quality roughages has been a great concern. Voluntary intake is the most important factor determining total energy consumption. Fiber mass appears to become a limiting factor of voluntary intake when cell-wall content lies between 50 and 60% of the forage dry matter (Van Soert, 1965). Voluntary intake is also directly related to the mean apparent digestibility of the roughages (Blaxter et al., 1962).

Changing or improving the physical form in which the roughages are fed or providing proper supplementation in order to achieve reasonable performance have been the objectives of several workers. Grinding forages has been found to increase intake and rate of passage resulting in decreased digestibility (Montgomery and Baumgardt, 1965). Pelleting improves feed intake of low-quality roughages and reduces digestibility of high quality roughages (Greenhalgh and Reid, 1973).

Supplementing cattle fed roughage ad libitum with protein or starch may produce different results. Grain supplementation to cattle fed low-quality roughages has been reported to depress intake and digestibility of neutral detergent fiber (Carrillo, 1979). This is probably due to competition between the amylotic and the cellulotic bacteria (Shazly et al., 1961) and a decrease of the pH in the rumen.

Protein supplementation usually increases feed intake, dry matter and cellulose digestibilities of low quality roughage (Horn et al., 1981; Raleigh and Wallace, 1963). However, the use of protein supplements is limited due to their high cost.

A new feed additive, monensin, has been introduced recently. This compound when fed orally increases the production of propionic acid. Propionic acid is produced more efficiently in the rumen than acetic acid which is the main source of energy for the ruminant animal. Increasing the proportion of the propionic acid would increase the available energy from straw. Monensin given to cattle fed a high roughage diet has been found to improve feed efficiency by reducing intake without affecting gain (Raun et al., 1974) and digestibility of neutral detergent fiber (Pond et al., 1981).

Research was conducted at the Campbell Avenue Farm to obtain more information on the utilization of wheat straw by cattle. The purpose of this research was to study the following:

1. Intake, performance and diet digestibility by high and low gaining steers fed wheat straw ad libitum.
2. The effect of monensin on intake, performance and digestibility by steers fed wheat straw ad libitum.
3. The effect of a 44% and a 30% protein supplement on intake and performance by steers fed wheat straw ad libitum.

## LITERATURE REVIEW

### Factors Affecting Voluntary Intake and Digestibility of Low Quality Roughages

In his literature review on physical regulations of voluntary intake Campling (1969) pointed out that the voluntary intake of low-quality low protein roughages such as wheat straw is controlled partly by physical factors and particularly by the rate of breakdown of digesta in the rumen. He also stated that voluntary intake in roughages is related to particle size. For example cattle or sheep ate more ground roughage than long roughage because of retention time.

Montgomery and Baumgardt (1965) measured the regulation of food intake in 12 Holstein heifers by feeding eight rations varying in physical form and energy concentrations. They found that total ration dry matter intake was increased when pelleted corn was fed with long-oat straw and long-alfalfa hay compared to the roughage fed alone. They also found that grinding of the oat straw decreased intake, whereas grinding and pelleting of the alfalfa hay increased consumption.

Greenhalgh and Reid (1973) using 18 British Friesian steers and 18 suffolk or suffolk-cross wethers fed rye grass cut at different stages of maturity to study the effects of pelleting various diets on intake and digestibility. There were three diets: diet A was high-quality dried rye grass cut early, diet B was low-quality dried rye grass cut very late and diet C was composed of 60% of diet B and 40% of barley. The experiment lasted 6 weeks during which the animals were fed the grass in the long form for the first 3 weeks and ground and pelleted for the last three weeks. The authors reported that pelleting increased the feed intake in sheep from 56.8 g to 82.4 g DM per kg $w^{.75}$ per day and in cattle from 81.8 g to 90.7 g DM per kg $w^{.75}$. The increase was greater for the diet of low-quality roughage. They also found that pelleting reduced dry matter digestibility from 67.2 to 58.0% in sheep and 69.9% to 56.9% in cattle. The reduction was greater for the high quality roughage.

Van Soest (1965) in a symposium on factors influencing voluntary intake of herbage by ruminants stated that fiber mass appears to become a limiting factor of voluntary intake when cell-wall content lies between 50 and 60% of the forage dry matter.

Blaxter and Wilson (1962) used 8 steers to study the voluntary intake of roughages (hay, dried grass and oat straw). The hay and the straw were chaffed and the steers were fed ad libitum. The authors reported that mean voluntary intake of dry matter was directly related to mean apparent digestibility of the roughages.

Campling et al. (1961) conducted an experiment to determine the relationship between voluntary intake of roughages, amount of the digesta in the reticulo-rumen and disappearance of digesta from the alimentary tract. Four dry shorthorn cows were used in the experiment. The cows were fed once daily either hay or oat straw ad libitum, or controlled levels (10 and 15 lbs). The authors found that the mean voluntary intake of hay was more than twice that of straw. They associated the lower voluntary intake of straw to a lower overall digestibility, and in the reticulo-rumen, to a lower digestibility of crude fiber and a longer time of retention of food residues. Immediately after the cows had eaten food offered ad libitum the dry weight of digesta in the reticulo-rumen of cows offered hay was 35% greater than in cows offered straw. However, as a result of the slower rate of disappearance of straw the difference was less than 6% immediately before the next meal. It is suggested that the voluntary intake of these roughages was regulated in relation to their respective rates of disappearance from the alimentary tract in such a way as to maintain a constant amount of residue in the reticulo-rumen immediately before feeding.

Poppi et al. (1981) measured the voluntary intake and digestibility of leaf and stem fractions of Pangola and Rodesgrasse cut at 6 and 12 weeks regrowth. The two grasses were dried, chopped, and separated into leaf and stem fractions using a gravity separator. There were eight diets. Each diet was given to 4 cattle and 8 sheep fitted with a ruminal cannula. The authors found that cattle consumed 35% more leaf than stem fractions. Sheep consumed 21% more leaf. The higher intake of the leaf fraction was associated with the shorter time that it was retained in the rumen of both cattle and sheep. They also found that leaf and stem fractions were digested to the same extent by cattle and sheep. It was concluded that both cattle and sheep consumed more leaf than stem fractions of grasses and that the higher intake of leaf was associated with the shorter retention time in the rumen.

Andrew et al. (1972) studied the effect of several levels of supplementary energy (3.71, 4.44, 5.17, 5.90 and 6.63 Mcal metabolizable energy per head, per day) and protein (approximately 185, 375, 570 and 765 g crude protein per head/day on the voluntary intake and performance by young cattle weighing 200 to 300 kg fed long barley straw. They found that at the lowest protein level (diets containing 6.6% crude protein or less), the intake of straw was low at all energy levels and the live-weight gain of the cattle was not increased by the energy supplement. They also found that there was no difference in performance between the other protein levels which gave diets containing 8.8% crude protein or more in the dry matter.

Fick et al. (1973) conducted an experiment with 68 yearling wethers to study the influence of supplemental nitrogen (feed grade biuret) and supplemental energy on voluntary intake and nutrient digestibility of low-quality (3.28 and 4.51% crude protein) pangola grass hay. The sheep were supplemented 0 to 10 g of nitrogen and 0, 50, 100 or 200 g of energy supplement per sheep daily. The energy supplement contained 50% corn meal, 25% sucrose and 25% starch. The authors reported increases in hay intake and apparent digestibilities of nitrogen and cellulose ($p < .01$) with supplemental nitrogen. Supplemental energy did not increase hay intake and depressed cellulose digestibility ($p < .01$).

Freer et al. (1962) determined factors affecting the voluntary intake of food by 7 dry fistluated cows fed hay, oat straw and oat straw with urea administered by intraruminal infusion. The roughages were offered ad libitum and in controlled quantities (10.0, 15.0, 22.0 lbs/day). There was a linear relationship between the amount of food eaten, regardless of the type of food, and the amount of organic matter transferred to the omasum. It was suggested that the limit to the amount of each of these roughages eaten was the result of the time required for breakdown of food particles by chewing and digestion to a size at which they can be transferred through the reticulo-omasal orifice.

Bhattacharya and Pervez (1973) studied with sheep the effect of urea supplementations on digestibility of diets containing low-quality roughages. The diets used were 50% of ground wheat or ground barley hay, each supplemented with three levels of urea (0, 1, and 2%) and two control rations containing soybean meal as the only protein supplement. The lambs were fed twice a day. The authors found no significant difference in the digestibilities of the various nutrients between the urea supplemented rations and the control rations. However, the crude fiber, energy and ether extract digestibilities tended to increase with urea supplementation. In a second experiment, Bhattacharya and Pervez (1973) determined the effect of urea supplementations on intake and performance of a low-quality roughage in growing lambs. Twenty Awasi growing wether lambs randomly allotted into two groups of 10 each on the basis of their body weight were used. The lambs were fed ad libitum for 90 days. The diet was ground wheat straw supplemented with two levels of urea (0, 1.5%). The authors found no significant difference ($p < 0.05$) in intake (.85 vs .67 kg) and in average daily gain (0.08 vs 0.05 kg) between the control group and the group supplemented with 1.5% of urea respectively.

Coleman and Barth (1977) studied the digestibility of low-quality roughages supplemented with biuret and urea. Twelve Hereford yearling steers averaging 221 kg in weight were fed a diet of low-quality fescue and bromegrass hay (average crude protein content 6.7%) and one of four supplements: urea, biuret alone and biuret with corn or blackstrap molasses. The animals were allowed 42 days to adapt to their respective NPN source. The hay was chopped with a hammermill. The authors reported similar nutrient digestibilities and nitrogen utilization. Addition of dry corn meal or molasses to the biuret increased digestibility of dry matter and energy, but did not ($p > .05$) affect nitrogen utilization. In a second experiment Coleman and Barth (1977) examined the influence of biuret and various forms of supplemental energy on intake of pangola digit grass hay. Twelve yearling steers of Hereford and Simmental breeding were fed pangola digitgrass hay supplemented with biuret or no biuret. The energy factors were corn meal plus citrus pulp, molasses and no supplemental energy. The hay was fed 15% excess at two feedings per day. They reported that steers consumed significantly ($p < .05$) more hay than animals on control diets and that there was no significant ($p < .05$) effect from supplemental energy.

el Shazly et al. (1961) measured the effect of starch on the digestion of cellulose by rumen microorganisms in an in vitro and in vivo study. In the in vitro fermentations, resuspended cells were prepared by centrifuging rumen fluid at 250 x G for 3 minutes and the sediment discarded. After centrifuging supernatant at 3000 x G for 20 minutes, the sediment was resuspended in $CO_2$ saturated buffer and used on the inoculum. Two gm of powdered cellulose and 1 gm or 2 gm of starch were used as substrates in a 100-ml fermentation fluid. In the in vivo fermentation, 2 wether lambs with permanent rumen fistulae were used. Cellulose digestion was measured by inserting nylon bags filled with shredded filter paper into the rumen. The wethers were consuming diets with different ratios of hay to grain: 2:1, 1:1 and 1:2. Chopped hay and ground shelled corn constituted the diet. Following the completion of the in vivo study at one hay-grain ratio the two wethers were then placed on a different hay-grain ratio and the in vivo study continued. Results of the in vitro studies indicated an inhibition of cellulose digestion due primarily to a competition between the cellulotic and amylotic bacteria for nutrients. In vivo trials with filter paper showed similar inhibition of cellulose digestion when the sheep were fed increased proportions of corn in hay and corn rations. Partial or complete alleviations of the inhibition of cellulose digestion could be obtained by additions of urea to the ratios of hay to grain: 2:1, 1:1; however, when the ratio was 1:2, supplemental nitrogen as urea was ineffective.

Burroughs et al. (1969a) in their study to determine the influence of corn starch upon roughage digestion in cattle used three types of rations which consisted first, a basal ration of corn cobs (4 lbs) and dried skim milk (1.6 lb) fed at constant level to which varying amounts of mineralized corn starch (1.6, 3.2, 4.0 lbs) were added. The second ration was composed of high quality alfalfa hay (5 lbs) to which varying amounts (2.0, 4.0, 6.0 lbs) of mineralized corn starch were added; and the third ration consisted of a constant mixture of corn cobs and alfalfa hay with the addition of different amounts of mineralized starch. They found a decrease in roughage dry matter digestibility when starch was added in the rations in which corn cobs or corn cobs and limited alfalfa constituted the roughage proportion of the ration. No significant decrease in dry matter digestibility was observed when alfalfa hay alone made up the roughage part of the diet.

Raleigh and Wallace (1963) measured the effect of different nitrogen supplements on average daily gain, feed intake and efficiency, and apparent digestibility values for dry matter, organic matter, nitrogen and cellulose of low quality irrigated meadow roughages (5.5% crude protein) fed to growing steers. The supplement was either urea, cottonseed meal and a mixture of urea or cottonseed meal to set desired crude protein levels of 6, 9 and 12%. When urea and cottonseed meal were used together in a diet, they were supplied in amounts so that one-half the nitrogen came from urea and one-half from cottonseed meal. The steers were tied to feed mangers and fed individually twice a day. The experiment lasted 15 weeks. Results showed body weight gain, feed intake and feed efficiency were ($p < .01$) greater when the 9 and 12% protein diets were fed as compared to the 6% protein diet or meadow hay alone. Source of nitrogen did not effect ($p > .05$) feed intake, feed efficiency, gain and digestibility of the nutrients studied. However, the 9 and 12% levels of protein improved ($p < .05$) daily gains, cellulose and dry matter digestibility when compared to the 6% level of supplement.

Burroughs et al. (1949b) studied the effect of protein on roughage digestion. The rations used consisted of one series using corn cobs as the sole roughage and one series containing alfalfa hay. Protein levels (7, 9, 13.5) were varied by substituting dried skim milk for mineralized starch. Improvement in roughage digestion occurred in every series with dried skim milk additions where starch formed a part of the ration. Little or no improvement in corn cob digestion was observed with dried skim milk additions when no starch was fed.

Carrillo (1979) fed 10 yearling Okie steers to measure the effect of three levels of starch and two levels of protein supplement on the digestibility of fiber fractions of wheat straw, feed intake and live weight gains. There were four treatments and all steers were given straw ad libitum. In treatment one, 800 grams of cottonseed meal per head per day were added. In treatment two, steers received in addition to the straw 650 grams of starch per head per day. In treatment three, steers received straw ad libitum plus 1300 grams of starch per head per day. In treatment four, 1600 grams of cottonseed meal and 1300 grams of starch per head per day were added. The steers were fed twice a day for 63 days. Results showed that average daily gain increased linearly from .44 to 1.0 kg per head as supplement feeding levels was increased. Straw intake was reduced by 21% when starch was added and the highest straw intake was with treatment one. Dry matter digestibility was higher with treatment 4; however, the difference was not significant ($p < .05$) as compared to the other treatments. Crude protein digestibility increased with protein level and was higher ($p < .05$) with the diet with higher protein content. There was no significant difference in NDF digestibility between the treatments. However, when starch was added to the diet with low levels of protein the digestibility of NDF was depressed by 15%.

Horn et al. (1981) studied the effect of supplemental protein on intake and digestibility of untreated wheat straw by lambs. Sixty lambs (23.1 kg) were fed chopped wheat straw ad libitum and supplemented with 58 or 116 g of crude protein. Within each protein level the supplements were fed at 200, 400 or 600 g. Compositions of supplements were not given. The authors found that straw intake, dry matter and cellulose digestibility increased ($p < .01$) with increased supplemental crude protein and decreased ($p < .01$) with increasing levels of supplement.

## Effects of Monensin on Intake and Digestibility on Low-Quality Roughages

Richardson et al. (1976) tested monensin in vitro fermentation by using concentrate as a substrate and in vivo fermentation in concentrate and pasture-fed fistulated cattle. In the in vitro fermentation, monensin was tested at .1, .25, .5, 5 and 25 ppm. In the in vivo fermentation, 6 fistulated steers were used to study the effect of 0, 25, 50, 100, 200 and 500 mg of monensin per head per day upon ruminal fermentation using concentrate and pasture as substrates. The authors found that in the in vitro fermentation at 1 ppm in the concentrate substrate monensin increased propionic acid 50% and decreased both acetic and valeric acid. Butyric acid production was reduced at 5 ppm or greater. Propionic acid was increased at all monensin levels and total volatile fatty acids was increased at dosages of 1 ppm or less. In the in vivo fermentation, total fatty acid concentrations was decreased at 50 mg/head/day and increased at 100 and 500 mg/head/day. Decrease of acetic acid at 100 mg/head/day and an increase of propionic acid at each dosage were observed. In the pasture-fed fistulated cattle (148 days), they reported a significant decrease ($p < 0.5$) of acetic acid at 200 mg/head/day dosage of monensin and an increase of propionic acid from 20.7 to 28.1 molar percentage at the 200 mg/head/day dosage.

Hale et al. (1975) conducted an experiment to study the effect of monensin on growing and finishing cattle by adding 20, 30 or 40 gm of monensin per ton of diet. The growing diet was 70% chopped alfalfa hay and 30% dry rolled milo. The finishing diet was 80% concentrate. They reported that the feed intake was reduced at the 30 and 40 gm levels during the growing phase. But there was no effect on feed intake during the finishing phase. They also found a decrease in acetate and an increase in propionate concentrations in rumen fluid during the growing phase and a tendency of an increase of acetic acid during the finishing stage with an improvement of feed requirement of 6%. Gain was not affected during 115 days of growing phase, but during the 160 days of finishing stage, the 30 gm/ton level of monensin improved gain by 0.3 lb.

Correa et al. (1981) used 18 male Nubian goats (average weight 30 kg) to determine the effect of monensin on feed intake and feed conversion. The goats were randomly assigned to groups fed an 11% protein, 50% concentration ration with or without 20 mg of monensin. Results showed that the feed intake for the monensin group was 81.4 kg and 90.1 kg for the control group. Feed efficiency and average daily gain were 6.4 and 7.6 and .21 and .19 kg for the monensin and control groups respectively.

Dinius et al. (1976) fed steers a forage diet (90% chopped orchardgrass, 7% cane molasses, 1% urea, 1% trace mineral salt and 1% dicalcium) in which monensin was added at levels of 0, 11, 22, 33 ppm to measure the effects of monensin on diet digestibility. There were no differences in dry matter, crude protein, or cellulose digestibilities of the forage diet. However, they found a decrease in the proportion of acetic acid from 66.7 to 61.3% and an increase of the propionic acid from 20.1 to 23.0%.

Raun et al. (1974) in three trials studied the effect of monensin on feeding efficiency, feed intake and gain. In trial one, cattle were fed for 148 days feedlot rations containing 0, 13 and 71 g/ton (0, 14.3 and 78.3 ppm) of monensin and feed efficiency (F/G) values were 8.99, 7.48 and 7.54 respectively. In trial two, steers and heifers were fed for 152 days. The monensin levels used were 0, 5.5, 11, 22, 33, and 44 ppm and feed efficiency values of 11.06, 10.33, 10.77, 9.37, 9.35 and 9.54 were respectively obtained. In the third trial a higher roughage growing ration was fed the first 112 of the 177 days. Dosages of 0, 11, 22, 33 and 44 ppm of monensin resulted in feed efficiency values of 12.33, 11.32, 11.16, 10.48 and 11.25 respectively. Feed intake decreased with increased dosages of monensin in all trials while gain was unaffected by dosages of 40 g/ton and below. Monensin values were significantly different ($p < .05$) from controls.

Carrillo (1979) conducted an experiment with 8 steers to determine the effect of monensin at a level of 33 ppm on rumen volatile fatty acid concentrations, digestibility of the diet and nitrogen utilization. The diet used contained 85% wheat straw. The steers were fed the diet with or without monensin. Feed intake was reduced by 15% as compared with a similar diet without monensin. Monensin had no effect on the digestibility of gross energy or any of the fractions of the diet. Nitrogen retention did not improve by the addition of monensin. Molar percent of propionate acid increased from 20.2 to 26.5% ($p < .05$) and acetate decreased from 73.3 to 66.8 ($p < .05$).

Pond et al. (1981) determined the effects of monensin on the intake, digestibility, gastrointestinal fill and flow of ingesta in cattle grazing ryegrass. Eight Brahman x Jersey cows and heifers fitted with rumen and esophageal cannulae were placed in four separate pastures in early May. The pasture adjustment period was 3 weeks after which the animals were fed twice daily via rumen cannulae with 4g chromic oxide impregnated paper to serve as a fecal output indicator. One animal from each pasture also received a capsule containing .87 g monensin premix via the rumen cannulae while the others received .87 g cottonseed meal placebo. A decrease in forage intake (1.26 vs 1.40 kg), a reduction in rate of passage (6.50 vs 8.57%/hour), an increase in organic matter and neutral detergent fiber digestibility and an increase in gastrointestinal fill (.92 vs .74 kg) were observed when monensin was given to the animals.

Rouquette et al. (1981) measured in two trials the influence of monensin on live weight gain and efficiency of forage utilization of calves grazing bermudagrass. In trial I, 32 calves with an average weight of 250 kg were grazed on bermudagrass from July 20 to October 13. Eight steers and eight heifers were randomly divided into two groups receiving either 200 mg of monensin per head or 0 mg monensin per head in a .91 kg/head/day ration of pelleted 14% protein feed. Monensin fed calves gained .52 kg/head/day whereas the control calves gained .42 kg/head ($p < .01$). Estimates of forage gain ratio were: 15:1 and 19:1 respectively for monensin and control. In trial II, 48 steers randomly divided into three groups were assigned to the following grazing treatment: (1) bermudagrass only, (2) bermudagrass plus .91 kg/head, 14% protein feed, (3) bermudagrass plus .91 kg/head plus 200 mg/head monensin. An average daily gain of .45, .47 and .68 kg were respectively reported for steers which had bermudagrass alone, bermudagrass plus .91 kg/head 14% protein feed and bermudagrass plus .91 kg/head protein feed plus 200 mg monensin.

Huston and Spiller (1981) reported the results obtained in an experiment with calves (460 lbs) designed to study the effect of monensin on rate of gain in calves grazing dormant, native rangeland in west-central Texas. There were 4 treatments: (1) control with mineral supplement only, (2) 3 pounds/head/day of supplemental feed (70% cottonseed meal, 28% sorghum grain, 2% molasses), (3) supplemental feed plus 100 mg of monensin/head, (4) supplemental feed plus 200 mg of monensin/head. The experiment was conducted for 100 days. Results showed that the calves gained 0.56 lb/head in treatment 1, 1.06 lb/head in 2, 1.01 lb/head in 3 and .86 lb/head in treatment 4. Monensin at 100 mg did not significantly ($p < .01$) affect gain and monensin at 200 mg/head significantly ($p < .01$) depressed growth rate. Under the conditions of this study, it is suggested that monensin at 100 mg/head and above will not affect growth rate and may have an adverse effect.

Delaney and Ellis (1981) conducted an experiment to determine the effect of dietary supplementation of monensin and crude protein on intake and fiber digestibility. Thirty Angus or Hereford heifers grazing dormant common bermudagrass were used. The experimental animals were divided into two groups of 15 each and supplemented with 454 gm of sorghum grain (12% crude protein) per head or cottonseed meal (46% crude protein). Groups were further divided into three subgroups of five animals each to receive 0, 100 or 200 mg monensin/head/day. Both protein alone and monensin alone increased ($p < .05$) digestibility of NDF as compared to controls. Monensin (100 and 200 mg/head) significantly ($p < .05$) decreased feed intake as compared to controls (0 mg monensin).

Pond and Ellis (1981) determined in four trials the effect of monensin on digestibility of organic matter and neutral detergent fiber by Brahman x Jersey heifers grazing control bermudagrass at different maturity stages. The level of monensin in the feeding was 0 and 200 mg/head. One half-pound grain mixture was fed in trial 1 and 2 and one pound of cottonseed meal containing 43 percent crude protein was fed in trials 3 and 4. Animals receiving monensin showed consistently higher dry matter digestibility as compared to the control (51.0 vs 50.5) in trial 4; (55.6 vs 51.4) in trial 2 and

(38.5 vs 35.1%) in trial 3. NDF digestibility was approximately 50% for animals receiving monensin and 43-49% for control.

Wooten et al. (1981) utilized 92 and 76 grazing steers and heifer calves (Hereford and Angus x hereford) averaging 188 and 225 kg respectively to study the effect of monensin on growth rate and feed efficiency. The levels of monensin fed were 0, and 200 mg/head. The supplement consisted of .06 kg of biuret mixed with .23 kg of finely ground barley subsequently combined with 1.13 kg ground barley. The finely ground barley served as a carrier of monensin. Results indicated that during the growing period (111 days) steers and heifers gained .68, .86 and .82 and .88 respectively by the control group and the animals receiving monensin. Feed efficiency for steers and heifers was improved by 24 and 27% respectively as compared to the control group (0 mg monensin).

## TRIAL I: INTAKE, PERFORMANCE, AND DIGESTIBILITY BY STEERS AS AFFECTED BY SELECTION OF HIGH OR LOW GAINING STEERS

### Introduction

Twelve steers used in this study were selected from 38 steers which had been group-fed straw plus 1.8 kg of supplement/steer/day during a 56-day growing trial at Yuma. Av. daily gain for the 38 steers was .58 kg day. Based on performance during this initial 56 days, 6 high-gaining (.83 kg/day) and 6 low-gaining (.43 kg/day) were brought to Campbell Avenue Farm, Tucson for further study. Prior to the beginning of this trial (12 days), the average daily gain of both high and low gaining steers was .03 kg at Tucson (12 days). During this 12 day period they were fed straw ad libitum plus 1.8 kg supplement (Table 1). The wheat straw source was different from that fed at the Yuma station.

The purpose of this trial is to study the effect of selection in high and low gaining steers on intake, performance and digestibility.

### Methods

The six high and six low gaining steers with an average weight of 245 and 211 kg respectively were used in this trial. The steers were housed in individual concrete floor pens. They received ad libitum ground straw and 1.8 kg of supplement daily (Table 1). The straw was ground through the Miller mill with the hay screen (10.2 X 15.2 cm

Table 1. Experimental supplement, trial 1.

| Ingredient | Supplement Trial % |
|---|---|
| Cracked corn | 60.5 |
| Soybean meal | 28.0 |
| Molasses | 3.0 |
| Urea | 3.5 |
| Dicalcium phosphate | 3.0 |
| Limestone | 1.0 |
| Salt | 1.0 |
| | 100.0 |

opening) at the Casa Grande Highway feed lot. Feeding was twice a day: 6 AM and 2 PM. Daily feed intakes and weigh backs were recorded. The steers had access to drinking water at all times. The experiment was conducted for 80 days including the digestion trial period.

During the first 48 days the steers were fed straw ad libitum. For the next 14 days the steers were fed straw at 95% of the previous ad libitum intake and was followed by a 7-day total collection. During the last 11 days of the 80-day period the steers were fed straw ad libitum. Ninety grams of wheat straw fiber containing 12% chromium oxide were fed to each steer at the beginning of the digestion trial to determine the rate of passage. The results of the rate of passage will not be published in this thesis. Feces were picked up from the concrete floor using a dustpan every 6-hr during the first 3 days and every 12 hours for the remaining 4 days. Total feces from each steer were obtained and weighed daily. Daily samples of feed and feces were taken and dried in a forced air oven at 50°C for 48 hrs. These samples were composited over the 7-day collection period. The composite samples were ground in a Wiley mill through a 1-mm screen. An aliquot was taken and stored in glass jars.

The feed and the feces samples were analyzed for dry matter (DM), ash, Acid detergent fiber (ADF), neutral detergent fiber (NDF), crude protein (CP), and gross energy (GE). Acid detergent fiber, lignin and NDF were determined as described by Van Soest and Goering (1970). Gross energy was determined by using a Parr adiabatic bomb colorimeter. Dry matter and ash were determined according to A.O.A.C. (1970). Crude protein was determined by the Kjeldahl procedure.

The Newman-Keuls range test was used to test the differences of significance on means.

## Results and Discussion

Feed intake and performance of high and low gaining steers are shown in Tables 2 and A2. Chemical analysis of feed and feces are presented in Tables 3 and A3. Total dry matter intake and total fecal dry matter are in Table A1. The apparent digestion coefficients for DM, OM, ADF, NDF, CP, and CE are presented in Table 4.

As the ad libitum and restricted feed intake data have been added together for the 80 day trial it is recognized that the daily gain and feed intake values do not have the same significance as might be expected for a conventional feeding trial. However it is believed that the intake values have some validity and would be useful in planning additional studies with wheat straw. Straw intake was significantly lower ($p < .05$) for the low gaining steers (3.3 kg) as compared to the high gaining steers (4.3 kg). The difference in straw intake on a metabolic weight basis between the high and low gaining steers (67.0 vs 56.0 g/kg $wt^{.75}$) was significant ($p < .05$). The high gaining steers consumed (g/kg $wt^{.75}$) 16% more straw than the low gaining steers. Feed requirement per kg of gain was significantly higher ($p < .05$) for the high gaining steers as compared to the low gaining steers (13.6 vs 10.8 g). Average daily gain was similar between the high and low gaining steers (.45 vs .47 kg).

The digestion coefficients for ADF (49.4 vs 49.0%), NDF (49.4 vs 48.7%) were higher for the low gaining steers as compared to the high

Table 2. Intake and performance of high and low gaining steers, trial 1 (80 days).

| Item | No. of Steers | Initial Weight (kg) | Average Daily Gain (kg) | Daily Straw Intake (kg) | Total Daily Feed Intake (kg) | Straw Intake % Body Weight | Straw Intake $g/kg^{.75}$ | Feed Requirement/ kg Gain |
|---|---|---|---|---|---|---|---|---|
| High gainers | 6 | 245 | .45 | 4.3 | 6.1 | 1.7 | 67 | 13.6 |
| Low gainers | 6 | 211 | .47 | 3.3 | 5.1 | 1.4 | 56 | 10.8 |

Table 3. Chemical analysis of wheat straw and supplement, trial 1, dry matter basis.

| Item | Dry Matter % | Ash % | Acid Detergent Fiber % | Neutral Detergent Fiber % | Crude Protein % | Gross Energy cal/g |
|---|---|---|---|---|---|---|
| Wheat straw | 92.4 | 11.1 | 55.7 | 69.7 | 2.7 | 3553 |
| Supplement | 97.4 | 10.2 | 3.37 | 20.7 | 32.3 | 3682 |

Table 4. Apparent digestion coefficients, trial 1.

| Item | Dry Matter % | Organic Matter % | Acid Detergent Fiber % | Neutral Detergent Fiber % | Crude Protein % | Gross Energy % |
|---|---|---|---|---|---|---|
| High gaining steers | 57.4 | 59.0 | 49.0 | 48.7 | 63.6 | 50.0 |
| Low gaining steers | 61.0 | 62.4 | 49.4 | 49.4 | 69.3 | 54.2 |

gaining steers, but the differences were not significant ($p > .05$). The low gaining steers had a significantly higher ($p < .05$) digestion coefficient for DM (61.0 vs 57.4%), OM (62.4 vs 59.0%) CP (69.3 vs 63.6%), GE (54.2 vs 50.0%) as compared to the high gaining steers.

The lower digestion coefficients of the high gaining steers may be due to their higher intake ($p < .05$) as compared to the low gaining steers. The lower digestion coefficients for all the ration components of the high gaining steers may also explain why they did not have a higher average daily gain than the low gaining steers. In this trial, the original selection of the animals as high gaining steers had no effect on performance and digestibility.

## Summary

Straw intake was significantly higher ($p < .05$) for the high gaining steers than for the low gaining steers (4.3 vs 3.3 kg). On a metabolic weight basis, the high gaining steers consumed more ($p < .05$) straw than the low gaining steers (67 vs 56 g/kg $w^{.75}$). Feed requirement per kg of gain was lower ($p < .05$) for the low gaining steers as compared to the high gaining steers (10.8 vs 13.6 kg/kg gain). Average daily gain was similar (.45 vs .47 kg) between the two groups.

There was no significance difference ($p < .05$) in the digestion of ADF and NDF between the two groups. The low gaining steers had higher ($p < .05$) digestion coefficients for DM, OM, CP, and GE as compared to the high gaining steers.

## TRIAL II: INTAKE, PERFORMANCE AND DIGESTIBILITY AS AFFECTED BY MONENSIN AND SELECTION OF STEERS

### Introduction

Monensin when fed orally to cattle alters the ratio of rumen volatile fatty acids in favor to propionic acid. Propionic acid is mostly used as a substrate for gluconeogenesis in the ruminant animal. Propionic acid is more efficiently produced in the rumen fermentation than acetic acid.

Several studies have been conducted to determine the effect of monensin on the utilization of roughage diet and on performance. It appears that monensin improves feed efficiency usually by reducing feed intake without affecting gain (Raun et al., 1974). The results on performance and digestibility are not consistent. Carrillo (1979) and Dinius et al. (1976) found that additions of monensin to the diet did not affect gain and digestibility. But other workers indicated that the addition of monensin significantly increased ($p < .05$) weight gain and digestibility of neutral detergent fiber (NDF) and organic matter (Pond and Ellis; Wooten et al., 1981).

The purpose of this trial was to determine the effect of monensin at the level of 100 mg/day on intake, performance and digestibility by steers consuming wheat straw ad libitum.

## Methods

The same steers used in trial I were used in this trial. The steers were allotted in two groups based on weight and high or low gaining animals. Six animals were fed ad libitum ground wheat straw plus 1.0 kg of the control supplement (0 mg monensin) and the other six received ad libitum ground wheat straw plus 1.0 kg of the monensin supplement (Table 5). The straw was ground as previously described in trial I. The straw used in trial II was different from the straw used in trial I. The steers were fed once daily at 6 am. They had access to water at all times. Daily feed intake and refusals were recorded. The experiment was conducted for 51 days including the digestion trial period. During the first 41 days the steers were fed straw ad libitum followed by a 3 day constant intake period at 95% of the previous ad libitum intake and this was followed by a 7-day total collection. Sixty grams of wheat straw fiber containing 9% of chromium oxide were fed to each steer at the beginning of the digestion trial to study the rate of passage. The results of this study will not be published in this thesis. Samples of feed and feces were taken daily and composited over the 7-day period for chemical analysis. Procedures for sampling, preparation of samples and analytical procedures were as described in trial I. Chemical analyses of the wheat straw, supplements, and feces are presented in Table 7 and Table A4. Total dry matter intake and total fecal dry matter are presented in Table A6. There are no explanations for the differences in gross energy value of the two supplements.

The Newman-Keuls range test was used to test the difference of significance on means.

Table 5. Experimental supplements, trial 2.

| Ingredients | As Fed Basis | |
|---|---|---|
| | % | |
| | Control | Rumensin |
| Soybean meal | 94.2 | 94.2 |
| Dical | 4.5 | 4.5 |
| Salt | 1.0 | 1.0 |
| Vitamin A-10-P gm | 93 | 93 |
| $CoCo_3$ gm | .5 | .5 |
| $ZnSO_4$ gm | 12.5 | 12.5 |
| Rumensin Premix 60 gm/lb. gm | - | 35 |
| TOTAL | 100.0 | 100.0 |

Table 6. The effect of monensin and high or low gaining steers on feed intake and performance of growing steers, trial 2 (51 days).

| Item | Steers | Initial Weight (kg) | Average Daily Gain (kg) | Daily Straw Intake (kg) | Total Daily Feed Intake (kg) | Straw Intake % Body Weight | Straw Intake $g/kg^{.75}$ | Total Feed Requirement/ kg Gain |
|---|---|---|---|---|---|---|---|---|
| Control | | | | | | | | |
| High gainers | 3 | 262 | .64 | 6.9 | 7.9 | 2.5 | 101 | 12.3 |
| Low gainers | 3 | 257 | .36 | 6.5 | 7.5 | 2.4 | 99 | 20.8 |
| Average | | 260 | .50 | 6.7 | 7.7 | 2.4 | 100 | 16.6 |
| Monensin | | | | | | | | |
| High gainers | 3 | 301 | .55 | 7.0 | 8.0 | 2.2 | 94 | 14.5 |
| Low gainers | 3 | 241 | .23 | 5.2 | 6.2 | 2.1 | 83 | 26.9 |
| Average | | 271 | .39 | 6.1 | 7.1 | 2.2 | 88 | 20.7 |
| High gainers | 6 | 281 | .46 | 6.9 | 8.0 | 2.3 | 97 | 17.4 |
| Low gainers | 6 | 249 | .29 | 5.8 | 6.8 | 2.3 | 91 | 23.4 |

Table 7. Chemical analysis of wheat straw and supplements, trial 2, dry matter basis.

| Item | Dry Matter % | Ash % | Acid Detergent Fiber % | Lignin % | Neutral Detergent Fiber % | Crude Protein % | Gross Energy cal/g |
|---|---|---|---|---|---|---|---|
| Straw | 93.7 | 17.0 | 67.0 | 6.0 | 71.0 | 7.6 | 3648 |
| Supplement | | | | | | | |
| Control | 93.4 | 10.3 | 7.2 | 2.7 | 31.2 | 50.7 | 4426 |
| Monensin | 93.4 | 10.0 | 7.7 | 2.5 | 31.0 | 50.5 | 4056 |

## Results and Discussion

Feed intake and performance of the control and the monensin group and the high and low gaining steers are shown in Tables 6 and A5. The apparent digestion coefficients for DM, OM, ADF, NDF, CP and GE for the control and the monensin group and the high and low gaining steers are shown in Table 8.

The ad libitum and restricted feed intake have been added together for the 51 days trial. Straw intake for the control group was significantly higher ($p < .05$) than for the monensin group (6.7 vs 6.1 kg). Straw intake for the low gaining steers was significantly lower ($p < .05$) than straw intake for the high gaining steers (5.8 vs 6.9 kg). Intake was 100 g/kg wt$^{.75}$ for the steers on the control treatment as compared to 88 g/kg wt$^{.75}$ for the group on monensin treatment; however the difference was not significant ($p > .05$). On a metabolic weight basis, low gaining steers consumed less straw than high gaining steers (91 vs 97 g/kg wt$^{.75}$) but the difference was not significant ($p > .05$).

Average daily gain was significantly lower ($p < .05$) for the steers consuming the monensin supplement as compared to the steers consuming the control supplement (.39 vs .50 kg). Average daily gain was significantly higher ($p < .05$) for the high gaining steers than for the low gaining steers (.46 vs .29 kg). Feed requirement per kg of gain for the group on the control treatment, (16.6 kg/kg gain), was lower than the feed requirement per kg of gain for the group on the monensin treatment (20.7 kg/kg gain), however the difference was not

Table 8. Apparent digestion coefficients, trial 2.

| Item | No. of Steers | Dry Matter % | Organic Matter % | Acid Detergent Fiber % | Neutral Detergent Fiber % | Crude Protein % | Gross Energy % |
|---|---|---|---|---|---|---|---|
| Control | 6 | 47.2 | 62.1 | 49.8 | 43.1 | 67.6 | 56.6 |
| Monensin | 6 | 50.3 | 63.4 | 52.5 | 46.5 | 70.0 | 60.0 |
| High gainers | 6 | 49.2 | 64.0 | 52.1 | 45.4 | 69.0 | 58.8 |
| Low gainers | 6 | 48.2 | 61.5 | 50.1 | 44.3 | 68.6 | 57.8 |

significant ($p > .05$). Feed requirement per kg of gain between the high and low gaining steers (17.4 vs 23.4 kg/kg/gain) was not different ($p > .05$).

There were no significant differences ($p < .05$) in the digestibility of OM (63.4 vs 62.1%), CP (70.0 vs 67.7%) between the monensin and control groups. The digestibility of DM (50.3 vs 47.2%), ADF (52.5 vs 49.8%), CE (60.0 vs 56.0%) and NDF (46.5 vs 43.1%) was significantly higher ($p < .05$) for the group on the monensin treatment than for the group on the control treatment. There was no difference ($p > .05$) in digestibility for any of the diet components between the high and low gaining steers.

Straw intake (Table 6) of the steers on the monensin treatment was significantly reduced ($p < .05$) as compared to the control. This result is in agreement with results obtained by (Raun et al. 1976; Delaney and Ellis, 1981) where the addition of monensin to the diet reduced feed intake but had no effect on liveweight gain. In this trial, monensin significantly ($p < .05$) reduced average daily gain as compared to the control (.39 vs .50 kg).

The addition of monensin did not significantly reduce intake on a metabolic weight basis and the feed requirement per kg of gain of the rumensin fed group was higher as compared to the control. These results are in disagreement with results reported by Carrillo (1979) where on a metabolic weight basis dry matter intake was significantly less on the monensin treatment and by Wooten et al. (1981) and Rouquette et al. (1981) where the addition of monensin improved feed efficiency as compared to the control. In this trial there was a reduction of feed intake due to monensin on a metabolic weight basis although the reduction was not significant ($p > .05$).

The addition of monensin significantly improved ($p < .05$) the digestibility of neutral detergent fiber as compared to the control. Similar results were found by Delaney and Ellis (1981), Pond and Ellis (1981) and Pond et al. (1981).

These workers also reported a significant increase ($p < .05$) in organic matter digestibility with the addition of monensin to the diet. This is in disagreement with the results obtained in this trial where the addition of monensin failed to significantly increase ($p < .05$) the digestibility of organic matter as compared to the control. The results obtained on the digestibility of crude protein on the monensin treatment agree with those obtained by Carrillo (1979) where monensin had no effect on the digestibility of this fraction.

## Summary

The addition of monensin in the diet significantly decreased ($p < .05$) daily straw intake (6.1 vs 6.7 kg) and significantly decreased ($p < .05$) average daily gain (.39 vs .50 kg/head) as compared to the control. On a metabolic weight basis, the straw intake was not significantly different ($p > .05$) between the monensin fed group and the control group, and between the high and low gaining steers. Feed requirement per kg of gain for the monensin fed group (20.7 kg/kg gain) and high gaining steers (17.4 kg/kg gain) was higher than for the control group (16.6 kg) and the low gaining steers (23.4 kg/kg gain) respectively.

The steers on the monensin treatment had a higher digestibility of crude protein, organic matter than the steers on the control treatment; however the difference was not significant ($p > .05$). The monensin fed group had a significantly higher ($p < .05$) digestibility of DM, NDF, ADF, and GE as compared to the control. There was no significant difference ($p > .05$) in the digestibility of DM, OM, ADF, NDF, CP and GE between the high and low gaining steers.

## TRIAL III: FEED INTAKE AND GAIN OF HIGH AND LOW GAINERS AS AFFECTED BY SUPPLEMENT TYPE

### Introduction

Protein and starch supplement have been shown by several studies to have different effects on intake and digestibility of low quality roughages such as wheat straw. Protein supplement usually increases feed intake, dry matter and cellulose digestibility of low quality roughages (Horn et al., 198; Burrough et al., 1969; Raleigh and Wallce, 1963). Starch supplement may depress feed intake of low quality roughages (Carrillo, 1979) because of the inhibitory effect of starch on cellulose digestion (Shazly et al., 1961).

The purpose of this trial is to study the effect of a 44% and 30% protein supplement on intake and performance of steers consuming wheat straw.

### Methods

The twelve steers used in trial I and II were used in this trial. The steers with an average weight of 282 kg were divided into two groups of 6 steers each. Within each group were three high gaining and three low gaining steers. Steers were housed in individual pens as previously described. They were fed straw ad libitum and 6 animals received 1.0 kg of a 44% protein supplement/steer and the other 6 received 1.8 kg of a 30% protein supplement/steer. The straws were ground through the Miller mill with the hay screen (10.2 x 15.2 cm opening) at the Casa Grande Highway feedlot. The steers were fed once a day at 6 am. Daily feed intake and weighbacks were recorded. The steers had access to water at all times. The 44% protein supplement used was the same control supplement used in trial II (Table 5). The 30% protein supplement was the same formulation as in trial I except ground sorghum grain replaced cracked corn (Table 1). The experimental period was 28 days and the steers were weighed every 7 days. This type of comparisons should be repeated with a longer feeding period. The Newman-Keuls range test was used to test the difference of significance on means.

## Results and Discussion

Feed intake and performance of the two groups are shown in Tables 9 and A7. Daily straw intake (g/kg $wt^{.75}$) was not different ($p > .05$) between the two groups (102 vs 100 g/kg $wt^{.75}$). Daily straw intake (g/kg $wt^{.75}$) of the high gaining steers was higher than for the low gaining steers (104 vs 99 g/kg $wt^{.75}$), however, the difference was not significant ($p > .05$). Daily straw intake was similar between the two groups (7.3 vs 7.2 kg). Daily straw intake was significantly higher ($p < .05$) for the high gaining steers as compared to the low gaining steers (7.8 vs 6.8 kg). Average daily gain was significantly higher ($p < .05$) for the group supplemented with the 44% protein supplement (1.4 kg/head) as compared to the group supplemented with 30% protein supplement (.86 kg/head). Average daily gain of the low gaining steers was lower ($p < .05$) as compared to the high gaining steers

Table 9. Feed intake and gain of high and low gainers as affected by supplement type - trial 3, 28 days.

| Item | No. of Steers | Initial Weight (kg) | Average Daily Gain (kg) | Daily Straw Intake (kg) | Total Daily Feed Intake (kg) | Straw Intake % Body Weight | Straw Intake $g/kg^{.75}$ | Total Feed Requirement /kg Gain |
|---|---|---|---|---|---|---|---|---|
| 30% Protein Supplement | | | | | | | | |
| high gainers | 3 | 311.0 | .80 | 7.7 | 9.5 | 2.4 | 101 | 11.9 |
| low gainers | 3 | 263.0 | .93 | 6.8 | 8.6 | 2.5 | 100 | 9.2 |
| average | | 287.0 | .86 | 7.2 | 9.0 | 2.4 | 100 | 10.6 |
| 44% Protein Supplement | | | | | | | | |
| high gainers | 3 | 289.7 | 1.7 | 8.0 | 9.0 | 2.5 | 107 | 5.3 |
| low gainers | 3 | 264.4 | 1.0 | 6.7 | 7.7 | 2.4 | 98 | 7.7 |
| average | | 277.0 | 1.4 | 7.3 | 8.4 | 2.4 | 102 | 6.5 |
| High gainers | 6 | 300.0 | 1.2 | 7.8 | 9.2 | 2.4 | 104 | 7.7 |
| Low gainers | 6 | 264.0 | .96 | 6.8 | 8.2 | 2.4 | 99 | 8.5 |

(.96 vs 1.2 kg/head). Feed requirement per kg of gain was significantly higher ($p < .05$) for the 30% protein supplement group (10.6 vs 6.5 kg/kg gain) than for the 44% protein supplement. Feed requirement per kg of gain was different between the high and low gaining steers (7.7 vs 8.5 kg/kg gain); but the difference was not significant ($p > .05$).

The higher daily gain of the 6 animals consuming the 44% protein supplement was probably due to the improved efficiency of feed utilization. The lower in daily gain of the 6 animals consuming the 30% protein supplement may represent a depression in fiber digestibility due to the high soluble carbohydrate in that supplement. This is in agreement with results obtained by Carrillo (1979) where NDF digestibility was depressed by 15% when starch was added to the diet.

The increase in straw intake, average daily gain and a decrease of total feed consumption per kg of gain of the high gainers were probably due to the original selection of the animals.

## Summary

Daily straw intake was similar between the two different supplemented groups (7.3 kg vs 7.2 kg). The high gainers consumed more straw than the low gainers ($p < .05$) straw intake (g/kg $w^{.75}$) was higher for the group consuming the 44% protein supplement and the low gainers respectively as compared to the group consuming the 30% protein supplement and the high gaining steers respectively. The difference was not signifiant ($p > .05$).

Average daily gain was significantly higher ($p < .05$) for the group consuming the 44% protein supplement (1.4 kg/head) as compared to the group consuming the 30% protein supplement (.86 kg/head). Average daily gain was higher ($p < .05$) for the high gaining steers than for the low gaining steers (1.2 vs .96 kg). Feed requirement per kg of gain for the 44% protein supplement group (6.5 kg) was significantly lower ($p < .05$) than feed requirements per kg of gain for the 30% protein supplemented group (10.6 kg). Feed requirement per kg of gain for the low gaining steers was higher than feed requirement per kg of gain of the high gaining steers (8.5 vs 7.7 kg); however the difference was not significant ($p > .05$).

## GENERAL DISCUSSION

The steers in this study were fed wheat straw as the only roughage for a total of 226 days which included 56 days at the Yuma station, 11 days at Campbell Avenue farm prior to the 159 days on the three experiments. During the period covering the three trials (159 days) the 12 steers used remained healthy and no medication was used. The steers were apparently well adapted to the wheat straw. In the second trial, the daily straw intake (94 g/kg wt$^{.75}$) was higher than the daily straw intake in trial 1 (61 g/kg wt$^{.75}$). A possible explanation might be the change of type of straw or supplement (in trial II, a 44% protein supplement replaced the 30% protein supplement of trial 1). However in trial III the straw intake (g/kg wt$^{.75}$) was similar between the 30 and 44% protein supplement groups (102 vs 100 g/kg wt$^{.75}$).

On the three experiments reported, feed intake and performance for the 159 days of the three trials are presented in Table 10. Individual steer performance is shown in Table A8. During the 159 days, straw intake (5.9 vs 4.8 kg) and average daily gain (.58 vs .51 kg) was significantly higher ($p < .05$) for the high gaining steers as compared to the low gaining steers. Feed requirement per kg of gain was not significantly ($p > .05$) different between the two groups (12.6 vs 12.2 kg gain).

In two of the three trials the steers originally selected as high gainers had high average daily gain than low gainers. However

Table 10. Summary of feed intake and daily gain for the three trials (159 days).

| Item | No. of Steers | Initial Weight (kg) | Average Daily Gain (kg) | Daily Straw Intake (kg) | Straw Intake % Body Weight | Total Feed Intake (kg) | Straw Intake $g/kg^{.75}$ | Feed Requirement/ kg Gain |
|---|---|---|---|---|---|---|---|---|
| High gaining steers | 6 | 245 | .58 | 5.9 | 2.0 | 7.3 | 82 | 12.6 |
| Low gaining steers | 6 | 211 | .51 | 4.8 | 1.9 | 6.2 | 76 | 12.2 |

in trial 1 which was the only direct comparison between high and low gaining steers, no difference was observed in average daily gain; however low gaining steers had higher digestibility value for ration components. The difference between high and low gaining steers was probably due in intake. Low gaining steers had a lower feed intake in all the three trials.

In trial II, on a metabolic weight basis, the addition of monensin at the level of 100 mg/day/steer did not significantly decrease ($p > .05$) feed intake. This is in disagreement with results obtained by Carrillo (1979) where the addition of monensin at level of 106 mg/head/day decreased ($p < .05$) dry matter intake on a metabolic weight basis as compared to the control. Average daily gain was decreased ($p < .05$) by the addition ofmonensin in this trial. This agrees with results obtained by Hurton and Spiller (1981) where monensin at levels of 200 mg/head/day fed to calves grazing dormant, native rangeland in west-central Texas significantly ($p < .01$) depressed growth rate.

Monensin-supplemented animals had increased ($p < .05$) digestibility of DM, ADF, GE and NDF. This higher digestibility was probably due to the lower intake of the monensin supplemented group as compared to the control. These results are in agreement with results obtained by Pond et al. (1981) where 200 mg of monensin fed to Brahman X Jersey cows and heifers grazing rye grass had increased digestibility of NDF. But this is in disagreement with previous results with high roughage diet in which the addition of monensin had no effect on the digestibility of wheat straw (Carrillo, 1979) or orchardgrass diets (Dinus et al., 1976). Selection of high and low gaining steers had no signifi-ant effect ($p < .05$) on the digestibility of any fraction of the ration.

In trial III, the 6 animals consuming the 44% protein supplement had a significant higher ($p < .05$) average daily gain as compared to the 6 animals consuming the 30% protein supplement. This significant increase in average daily gain may be due to the improved efficiency of feed utilization of the group consuming the 44% protein supplement. Another possible explanation of the lower average daily gain of the group consuming the 30% protein supplement might be a depression in fiber digestibility due to high soluble carbohydrate. This is in agreement with Carrillo (1979) where NDF digestibility was depressed by 15% when starch was added to the diet. This trial should be repeated with a much longer feeding period as the feeding period in this trial was only 28 days. As this trial was conducted immediately following trial 2 there may have been a carry over effect which influenced the performance of the steers.

At the end of the 226 days total straw feeding period, the steers were placed on a 80% concentrate diet for 143 days to study the compensatory gain. Average daily gain, average daily feed intake and feed efficiency were 1.2, 12.7 and 10.4 kg respectively. The average daily gain for the high and low gaining steers were 1.3 and 1.2 kg respectively. The performance of the steers were disappointing. A higher gain was expected. The steers were healthy and not fleshy. There is no explanation for the apparent lack of compensatory gain.

# CONCLUSION

Twelve steers were selected from 38 steers which had been group fed wheat straw for 56 days. Within the 12 selected steers there were 6 high and 6 low gaining steers. Three trials were conducted with these 12 steers. In trial 1, the steers were fed for 80 days wheat straw ad libitum and 1.8 kg of 30% protein supplement (Table 1) including a 7-day total collection period to determine feed intake, performance and the difference in digestibility between the high and low gaining steers. In trial II, the steers were allotted so that half received wheat straw plus a 44% protein supplement with monensin and half without monensin. The purpose of this trial was to study the effect of monensin at level of 100 mg/day on intake, performance and digestibility. In trial II, the steers were put for a 28 day period on an intake trial based on a 30% or 44% protein supplement.

The results of these three trials are the basis for the following conclusions:

Trial I

1. Daily straw intake (g/kgwt$^{.75}$) was significantly lower ($p < .05$) for the low gaining steers as compared to the high gaining steers (56 vs 67 g/kgwt$^{.75}$).
2. Average daily gain was similar between the high and low gaining steers (.45 vs .47 kg).

3. Low gaining steers had a significantly higher ($p < .05$) digestion coefficients for dry matter, organic matter and gross energy as compared to the high gaining steers.

Trial II

1. Straw intake on a metabolic weight basis was not significantly different ($p > .05$) between the group on monensin and control treatment (100 vs 88 $g/kgwt^{.75}$).
2. Straw intake ($g/kg/wt^{.75}$) was not significantly different ($p > .05$) between high and low gaining steers/97 vs 91 $g/kgwt^{.75}$).
3. Average daily gain was significantly lower ($p < .05$) for the group consuming the monensin supplement as compared to the steers consuming the control supplement (.39 vs .50 kg).
4. Average daily gain was significantly higher for the high gaining steers as compared to the low gaining steers (.46 vs .29 kg).
5. Feed requirement per kg of gain between the monensin and the control group, and between the high and low gaining steers was not significantly different ($p > .05$).
6. Addition of monensin significantly increased ($p < .05$) the digestibility of dry matter, neutral detergent fiber, acid detergent fiber, and gross energy as compared to the control.
7. There was no significant difference ($p > .05$) in digestibility for any of the ration components between the high and low gaining steers.

Trial III

1. When steers fed wheat straw ad libitum were supplemented with a 44%, or a 30% protein supplement, daily straw intake on a metabolic weight basis was not significantly different ($p > .05$) between the two groups (102 vs 100 g/kgwt$^{.75}$).
2. Daily straw intake was not significantly different ($p > .05$) between high and low gaining steers (104 vs 99 g/kgwt$^{.75}$).
3. Average daily gain was significantly higher ($p < .05$) for the group consuming the 44% protein supplement as compared to the group consuming the 30% protein supplement (1.4 vs .86 kg).
4. Average daily gain of the low gaining steers was lower ($p < .05$) as compared to the high gaining steers (.96 vs 1.2 kg/head).
5. Feed requirement per kg of gain for the 44% protein supplement group (6.5 kg) was significantly lower ($p < .05$) than feed requirements per kg of gain for the 30% protein supplement group (10.6 kg).
6. Feed requirement per kg of gain between the high and low gaining steers was not significantly different ($p > .05$) (7.7 vs 8.5 kg).

For the 159 days covering the three trials, average daily gain was significantly higher ($p < .05$) for the high gaining steers as compared to the low gaining steers (.58 vs .51 kg). Daily straw intake on a metabolic weight basis was not significantly different ($p < .05$) between the high and low gaining steers during that period (82 vs 76 g/kg wt$^{.75}$). Feed requirement per kg of gain was not significantly different ($p < .05$) between the two groups (12.6 vs 12.2 kg).

APPENDIX A

STEERS INDIVIDUAL DATA

Table A1. Total feed and feces, dry matter basis, trial 1.

| Steer No. | Total Straw Consumed (g) | Total Suppl. Consumed (g) | Total Feed Consumed (g) | Total Feces (g) |
|---|---|---|---|---|
| High gaining steers | | | | |
| 307 | 28937 | 11886 | 40823 | 17690 |
| 32 | 30807 | 11886 | 42693 | 17896 |
| 43 | 23161 | 11886 | 35047 | 14249 |
| 198 | 28975 | 11886 | 40861 | 17666 |
| 294 | 28686 | 11886 | 40572 | 18086 |
| 177 | 27399 | 11886 | 39285 | 16382 |
| Low gaining steers | | | | |
| 154 | 20655 | 11886 | 32541 | 11855 |
| 319 | 20719 | 11886 | 32605 | 12042 |
| 287 | 23791 | 11886 | 35677 | 14653 |
| 302 | 22885 | 11886 | 34771 | 14370 |
| 305 | 16344 | 11886 | 28230 | 10445 |
| 332 | 22665 | 11886 | 34551 | 10426 |

Table A2. Individual feed intakes and performance, trial 1 (80 days).

| Steer No. | Initial Weight (kg) | Average Daily Gain (kg) | Daily Straw Intake (kg) | Total Feed Intake (kg) | Straw Intake % Body Weight | Total Feed % Body Weight | Metabolic Weight (kg) | Straw Intake $g/kg^{.75}$ | Total Feed $g/kg^{.75}$ | Feed Requirement/ kg Gain |
|---|---|---|---|---|---|---|---|---|---|---|
| High gainers | | | | | | | | | | |
| 32 | 275.4 | .55 | 4.7 | 6.5 | 1.6 | 2.2 | 71.6 | 66 | 91 | 11.5 |
| 43 | 218.2 | .48 | 3.6 | 5.4 | 1.5 | 2.3 | 60.4 | 59 | 89 | 11.8 |
| 198 | 256.4 | .32 | 4.7 | 6.4 | 1.7 | 2.4 | 66.4 | 70 | 97 | 20.2 |
| 294 | 196.4 | .62 | 4.3 | 6.1 | 2.2 | 3.2 | 51.2 | 83 | 118 | 9.3 |
| 177 | 265.4 | .46 | 4.2 | 6.0 | 1.5 | 2.1 | 62.1 | 60 | 99 | 13.0 |
| 307 | 257.3 | .31 | 4.3 | 6.1 | 1.6 | 2.3 | 66.5 | 65 | 92 | 19.8 |
| Low gainers | | | | | | | | | | |
| 319 | 231.8 | .42 | 3.1 | 4.9 | 1.2 | 2.0 | 62.6 | 50 | 78 | 11.6 |
| 302 | 184.5 | .48 | 3.5 | 5.3 | 1.7 | 2.6 | 53.9 | 65 | 98 | 11.0 |
| 332 | 193.6 | .51 | 3.5 | 5.3 | 1.6 | 2.5 | 55.9 | 62 | 94 | 10.4 |
| 154 | 219.1 | .34 | 3.4 | 5.2 | 1.6 | 2.2 | 59.5 | 57 | 87 | 15.3 |
| 287 | 209.1 | .56 | 3.7 | 5.5 | 1.6 | 2.4 | 59.4 | 62 | 93 | 9.8 |
| 305 | 225.45 | .58 | 2.8 | 4.6 | 1.0 | 1.7 | 62.6 | 46 | 73 | 7.9 |

Table A3. Chemical analysis of feces, trial 1, dry matter basis.

| Item | No. of Steer | Dry Matter % | Ash % | Acid Detergent Fiber % | Lignin % | Neutral Detergent Fiber % | Crude Protein % | GE cal/g |
|---|---|---|---|---|---|---|---|---|
| High gaining steers | 307 | 91.5 | 13.2 | 48.2 | 12.5 | 65.0 | 10.2 | 4260 |
| | 22 | 91.6 | 14.2 | 47.2 | 12.0 | 67.1 | 9.3 | 4178 |
| | 43 | 91.4 | 14.8 | 47.4 | 11.1 | 65.0 | 10.0 | 4168 |
| | 198 | 91.3 | 13.6 | 48.4 | 10.8 | 66.7 | 10.2 | 4266 |
| | 294 | 91.2 | 14.2 | 48.4 | 11.0 | 66.0 | 8.8 | 4267 |
| | 177 | 91.3 | 14.9 | 48.7 | 10.8 | 68.7 | 10.2 | 4175 |
| Low gaining steers | 154 | 91.4 | 13.7 | 47.2 | 11.8 | 68.0 | 10.1 | 4265 |
| | 319 | 91.5 | 13.8 | 47.6 | 11.7 | 68.6 | 10.8 | 4241 |
| | 287 | 91.6 | 14.2 | 48.0 | 11.0 | 67.2 | 10.5 | 4219 |
| | 302 | 91.6 | 14.6 | 46.2 | 10.1 | 64.5 | 10.1 | 4212 |
| | 305 | 92.0 | 14.1 | 48.5 | 12.0 | 68.4 | 11.0 | 4205 |
| | 332 | 90.7 | 13.0 | 48.5 | 12.0 | 68.6 | 10.5 | 4256 |

Table A4. Chemical analysis of feces, trial 2, dry matter basis.

| Treatment | | No. of Steers | Dry Matter % | ASH % | ADF % | Lignin % | NDF % | Crude Protein % | Gross Energy cal/g |
|---|---|---|---|---|---|---|---|---|---|
| Control | L | 154 | 93.6 | 35.4 | 55.0 | 9.5 | 70.0 | 8.6 | 3203 |
| | L | 287 | 94.0 | 38.7 | 56.7 | 8.0 | 71.8 | 8.1 | 3062 |
| | L | 305 | 93.0 | 36.0 | 58.6 | 9.6 | 74.6 | 8.0 | 2978 |
| | H | 43 | 93.4 | 38.7 | 57.3 | 7.7 | 72.0 | 7.7 | 2930 |
| | H | 307 | 93.6 | 37.0 | 57.0 | 8.2 | 71.4 | 7.7 | 3012 |
| | H | 294 | 93.0 | 31.0 | 55.0 | 9.5 | 70.0 | 7.3 | 3297 |
| Monensin | L | 319 | 91.2 | 36.3 | 56.7 | 10.5 | 71.3 | 8.5 | 3345 |
| | L | 302 | 93.3 | 36.5 | 56.1 | 7.7 | 71.7 | 8.1 | 2892 |
| | H | 32 | 93.4 | 41.2 | 56.2 | 9.3 | 70.5 | 8.3 | 2850 |
| | L | 332 | 94.2 | 41.3 | 57.4 | 7.7 | 68.0 | 7.7 | 2789 |
| | H | 198 | 93.7 | 36.2 | 56.4 | 8.7 | 70.2 | 8.5 | 3011 |
| | H | 294 | 93.0 | 31.0 | 55.0 | 9.5 | 70.0 | 7.3 | 3297 |

L = low gaining steers
H = high gaining steers

Table A5. Individual feed intake and performance, trial 2 (51 days).

| Steers Number Low Gainers | Steers Number High Gainers | Initial Weight | Average Daily Gain (kg) | Daily Straw Intake (kg) | Total Feed Intake (kg) | Straw Intake % Body Weight | Total Feed % Body Weight | Metabolic Weight (kg) | Straw Intake $g/kg^{.75}$ | Total Feed $g/kg^{.75}$ | Feed Requirement/ kg Gain |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | | | | | | | | | | | |
| 154 | | 246.4 | .55 | 6.6 | 7.6 | 2.5 | 2.9 | 64.8 | 101 | 116 | 13.7 |
| | 307 | 281.8 | .77 | 7.6 | 8.6 | 2.5 | 2.8 | 72.3 | 105 | 118 | 11.1 |
| 287 | | 253.6 | .39 | 7.1 | 8.1 | 2.7 | 3.1 | 65.4 | 109 | 124 | 20.8 |
| 305 | | 271.8 | .11 | 6.0 | 6.9 | 2.2 | 2.5 | 67.4 | 88 | 102 | 62.8 |
| | 43 | 256.4 | .48 | 6.0 | 6.9 | 2.2 | 2.6 | 66.4 | 90 | 105 | 14.4 |
| | 297 | 246.4 | .69 | 7.2 | 8.2 | 2.7 | 3.1 | 65.5 | 109 | 125 | 11.8 |
| Monensin | | | | | | | | | | | |
| 319 | | 265.4 | .21 | 4.8 | 5.8 | 1.8 | 2.1 | 66.8 | 72 | 87 | 27.7 |
| 302 | | 222.7 | .32 | 5.7 | 6.7 | 2.5 | 2.9 | 59.2 | 96 | 113 | 20.9 |
| | 32 | 319.4 | .47 | 6.7 | 7.7 | 2.0 | 2.3 | 77.7 | 86 | 99 | 16.4 |
| 332 | | 234.6 | .16 | 5.3 | 6.3 | 2.2 | 2.6 | 60.7 | 87 | 104 | 39.6 |
| | 198 | 281.8 | .54 | 7.2 | 8.1 | 2.4 | 2.8 | 71.3 | 101 | 114 | 15.1 |
| | 177 | 301.8 | .64 | 7.3 | 8.3 | 2.3 | 2.6 | 75.3 | 97 | 110 | 12.9 |

Table A6. Total feed and feces dry matter basis, trial 2.

| Steer No. | Total Straw Consumed (g) | Total Suppl. Consumed (g) | Total Food Consumed (g) | Total Feces (g) |
|---|---|---|---|---|
| Control | | | | |
| 154L | 3967 | 6241 | 45917 | 24587 |
| 307H | 50164 | 6241 | 56405 | 30345 |
| 287L | 47420 | 6241 | 53661 | 29295 |
| 305L | 39929 | 6241 | 46170 | 23912 |
| 43H | 41049 | 6241 | 47290 | 25483 |
| 294H | 40550 | 6241 | 46791 | 23025 |
| Monensin | | | | |
| 319L | 30665 | 6262 | 36927 | 18022 |
| 302L | 39248 | 6262 | 45510 | 22492 |
| 32H | 47150 | 6262 | 53412 | 25637 |
| 332L | 38032 | 6262 | 44294 | 22949 |
| 198H | 46311 | 6262 | 52573 | 25594 |
| 177H | 50468 | 6262 | 56730 | 29219 |

L = low gaining steers
H = high gaining steers

Table A7. Individual feed intake and performance, trial 3 (28 days).

| Steers Number: Low Gainers | Steers Number: High Gainers | Initial Weight (kg) | Average Daily Gain (kg) | Daily Straw Intake (kg) | Total Feed Intake (kg) | Straw Intake % Body Weight | Total Feed % Body Weight | Metabolic Weight (kg) | Straw Intake $g/kg^{.75}$ | Total Feed Intake $g/kg^{.75}$ | Feed Requirement/ kg Gain |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 44% Protein Supplement | | | | | | | | | | | |
| 154 | | 274.5 | 1.03 | 6.9 | 7.9 | 2.4 | 2.7 | 70.1 | 98 | 113 | 7.7 |
| 319 | | 276.4 | .90 | 6.4 | 7.4 | 2.2 | 2.6 | 70.1 | 91 | 105 | 8.2 |
| | 307 | 320.9 | .75 | 8.3 | 9.3 | 2.5 | 2.8 | 77.7 | 107 | 120 | 12.4 |
| 332 | | 242.6 | 1.19 | 6.8 | 7.8 | 2.6 | 3.0 | 64.6 | 105 | 120 | 6.5 |
| | 294 | 246.4 | 2.29 | 7.4 | 8.5 | 2.7 | 3.0 | 68.2 | 109 | 124 | 3.7 |
| | 177 | 301.8 | 2.21 | 8.2 | 9.2 | 2.4 | 2.6 | 77.9 | 105 | 117 | 4.1 |
| 30% Protein Supplement | | | | | | | | | | | |
| 287 | | 273.6 | 1.32 | 7.6 | 8.6 | 2.6 | 3.2 | 70.6 | 107 | 133 | 7.1 |
| 305 | | 277.3 | 1.30 | 6.8 | 7.8 | 2.3 | 2.9 | 71.3 | 95 | 120 | 6.6 |
| 302 | | 239.1 | 0.16 | 6.1 | 7.1 | 2.5 | 3.2 | 61.2 | 100 | 130 | 49.6 |
| | 32 | 343.6 | 0.66 | 8.1 | 9.19 | 2.3 | 2.8 | 81.4 | 100 | 121 | 15.0 |
| | 43 | 280.9 | .84 | 6.9 | 7.8 | 2.4 | 2.9 | 70.8 | 97 | 122 | 10.3 |
| | 198 | 309.1 | 0.92 | 8.0 | 9.0 | 2.5 | 3.0 | 76.0 | 105 | 129 | 10.6 |

Table A8. Individual feed intake and daily gain for the three trials (159 days).

| Steer No. | Initial Weight (kg) | Average Daily Gain (kg) | Daily Straw Intake (kg) | Total Fed Intake (kg) | Straw Intake % Body Weight | Straw Intake $g/kg^{.75}$ | Feed Requirement/ kg Gain |
|---|---|---|---|---|---|---|---|
| High Gainers | | | | | | | |
| 32 | 275.4 | .55 | 6.0 | 7.4 | 1.9 | 79 | 10.8 |
| 43 | 218.2 | .54 | 4.9 | 6.3 | 1.9 | 76 | 9.1 |
| 198 | 256.4 | .49 | 6.0 | 7.4 | 2.0 | 85 | 12.4 |
| 294 | 196.4 | .72 | 5.8 | 7.2 | 2.3 | 91 | 8.0 |
| 177 | 265.4 | .62 | 5.9 | 7.3 | 1.9 | 79 | 9.5 |
| 307 | 257.3 | .59 | 6.1 | 7.5 | 2.0 | 84 | 10.3 |
| Average | 244.8 | .58 | 5.8 | 7.2 | 2.0 | 82 | 10.0 |
| Low Gainers | | | | | | | |
| 319 | 231.8 | .44 | 4.2 | 5.6 | 1.6 | 64 | 9.6 |
| 302 | 184.5 | .37 | 4.7 | 6.1 | 2.2 | 83 | 12.6 |
| 332 | 193.6 | .52 | 4.7 | 6.1 | 2.0 | 78 | 9.0 |
| 154 | 219.1 | .53 | 5.0 | 6.4 | 1.9 | 77 | 9.5 |
| 287 | 209.1 | .64 | 5.5 | 6.9 | 2.1 | 84 | 8.6 |
| 305 | 225.1 | .56 | 4.5 | 5.9 | 1.7 | 67 | 8.0 |
| Average | 210.5 | .51 | 4.8 | 6.0 | 1.9 | 76 | 9.5 |

## LITERATURE CITED


A.O.A.C. 1970. Official Methods of Analysis (11th Ed.). Association of Official Agricultural Chemists, Washington, D.C.

Andrews, R. P., J. Escuder-Volonte, M. K. Curran and W. Holmes. 1972. The influence of supplement of energy and protein on the intake and performance of cattle fed on cereal straws. Anim. Prod. 15: 167.

Bhattacharya, A. N. and E. Pervez. 1973. Effect of urea supplementation on intake and utilization of diets containing low quality roughages in sheep. J. Anim. Sci. 36: 976.

Blaxter, K. L., and R. S. Wilson. 1962. The voluntary intake of roughages by steers. Anim. Prod. 4: 351.

Burroughs, W., P. Gerlaugh, B. H. Edington and R. M. Bethke. 1949a. Further observations on the effect of protein upon roughage digestion in cattle. J. Anim. Sci. 8: 9.

Burroughs, W., P. Gerlaugh, B. H. Edington and R. M. Bethke. 1949b. The influence of corn starch upon roughage digestion in cattle. J. Anim. Sci. 8: 271.

Campling, R. E. "Physical Regulation of Voluntary Intake" In Physiology of Digestion and Metabolism in the Ruminant. (A. T. Phillipson, ed.), Newcastle upon Tyne, England, Oriel Press, 1967.

Campling, R. C., M. Freer and C. C. Bolch. 1961. Factors affecting voluntary intake intake of foods by cows. 2. The relationship between the voluntary intake of roughages, the amount of digesta in the reticulo-rumen and the rate of disappearance of digesta from the alimentary tract. Brit. J. Nutr. 15: 531.

Carrillo, L. E. 1979. Wheat straw: digestibility and utilization by steers as affected by processing and the addition of monensin, starch and protein. Ph.D. dissertation, University of Arizona, Tucson.

Coleman, S. W. and K. M. Barth. 1977. Utilization of supplemental nonprotein nitrogen and energy sources by beef steers consuming low protein hays. J. Anim. Sci. 45: 1180.

Correa-Gumbe, J. E. and N. M. Stott. 1981. The effect of monensin on feed intake, feed conversion and carcass traits of male goats. J. Anim. Sci. 53: 382. Suppl-1 (Abstr.).

Delaney, D. S. and W. C. Ellis. 1981. Interaction between levels of monensin and dietary protein on grazed forage utilization. Tex. Agr. Exp. Sta. Prog. Rep. 3764.

Dinus, D. A., M. E. Simpson and P. B. Marsh. 1976. Effect of monensin fed with forage on digestion and the ruminal ecosystem of steers. J. Anim. Sci. 42: 229.

Fick, K. R., C. B. Ammerman, C. H. McGowan, P. E. Loggins and J. A. Cornell. 1973. Influence of supplemental energy and biuret nitrogen on the utilization of low quality roughage by sheep. J. Anim. Sci. 36: 137.

Freer, M., R. C. Campling and C. C. Balch. 1962. Factors affecting the voluntary intake of food by cows. 4. The behavior and reticular motility of cows receiving diets of hay, oat straw and oat straw with urea. Brit. J. Nutr. 16: 279.

Greenhalgh, J. F. D. and G. W. Reid. 1973. The effect of pelleting various diet on intake and digestibility in sheep and cattle. Anim. Prod. 16: 223.

Hale, W. H., B. Theurer, J. A. Marchello, B. Taylor and J. Kuhn. 1975. Effect of monensin on growing and finishing cattle. Arizona Cattle Feeders Day. Series p-36.

Horn, G. H., D. W. Pace and C. L. Streeter. 1981. Effect of amount of supplemental protein and supplement level on intake and digestibility of untreated wheat straw by lambs. J. Anim. Sci. 51: 406. Suppl. 1 (Abstr.)

Huston, J. E. and D. Spiller. 1981. Effect of monensin on rate of gain in stocker calves grazing dormant, native rangeland in West Central Texas. Tex. Agr. Exp. Sta. Prog. Rep. 3762.

Montgomery, M. J. and B. R. Baumgardt. 1965b. Regulations of food intake in ruminants. 2. Rations varying in energy concentration and physical form. J. Dairy Sci. 48: 1623.

Pond, K. R. and W. C. Ellis. 1981. Effect of monensin on digestibility of grazed coastal bermudagrass. Tex. Exp. Agr. Exp. Sta. Prog. Rep. 3765.

Pond, K. R., J. P. Teford and W. C. Ellis. 1981. Effect of monensin on utilization of grazed ryegrass. Tex. Agr. Exp. Sta. Prog. Rep. 3759.

Poppi, D. P., D. J. Minson and J. H. Ternouth. 1981. Studies of cattle and sheep eating leaf and stem fractions of grasses. I. The voluntary intake, digestibility and retention time in the reticulo-rumen. Aust. J. Agric. Res. 32: 99.

Raleigh, R. J. and J. D. Wallace. 1963. Effect of urea at different nitrogen levels on digestibility and on performance of growing steers fed low quality flood meadow roughage. J. Anim. Sci. 22: 330.

Raun, A. P., C. O. Cooley, E. L. Potters, L. F. Richardson and R. P. Rathmacher. 1974b. Effect of monensin on feed efficiency on cattle. J. Anim. Sci. 39: 250 (Abstr.)

Richardson, L. F., A. P. Raun, E. L. Potter, C. O. Colley and R. P. Rathmacher. 1976. Effect of monensin on rumen fermentation in vitro and in vivo. J. Anim. Sci. 43: 657.

Shazly, K. El., B. A. Dehority and R. R. Johnson. 1961. Effect of starch on the digestion of cellulose in vitro and in vivo by rumen microorganism. J. Anim. Sci. 33: 151.

Van Soest, P. J. 1965. Symposium of factors influencing the voluntary intake of herbage by ruminants; voluntary intake in relation to chemical composition and digestibility. J. Anim. Sci. 24: 834.

Wooten, D. G., H. A. Turner and R. J. Raleigh. 1981. Monensin and zeranol alone and in combination for growing-finishing steers and growing heifers. Proc. West Sec. Amer. Soc. Anim. Sci. 32: 11.