INFLUENCE OF SUPPLEMENTAL SILAGE ON FORAGE INTAKE AND UTILIZATION AND PERFORMANCE OF STOCKER CATTLE GRAZING WHEAT PASTURE AND BERMUDAGRASS

By

GARY JOHN VOGEL

Bachelor of Science in Agricultural Science

Texas Tech University

Lubbock, Texas

1983

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
December, 1985

INFLUENCE OF SUPPLEMENTAL SILAGE ON
FORAGE INTAKE AND UTILIZATION AND
PERFORMANCE OF STOCKER CATTLE
GRAZING WHEAT PASTURE
AND BERMUDAGRASS

Thesis Approved:

Gerald W. Horn
Thesis Adviser

William A. Phillips

James W. Stotzer

Norman N. Durham
Dean of the Graduate College

ACKNOWLEDGEMENTS

I wish to express sincere appreciation to Dr. G.W. Horn for his insight and guidance during the course of this study and in preparation of this thesis. I would also like to thank Drs. W.A. Phillips and J.W. Oltjen for having served as members as my committee and for their helpful suggestions provided.

Appreciation is extended for the technical support provided by Ann Worthington and her crew in El Reno and Donna Perry for her assistance in laboratory analysis. I would also like to thank my fellow graduate students (former and present) for their assistance and friendship provided.

A special thank you is extended to my parents, Herbert and Elizabeth, and my wife's parents, Robert and Marcy, for their continual support and encouragement.

Finally, to my wife, LeAnne, I owe a very special thank you for her patience, encouragement, and understanding during the course of this study.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

It has been estimated that 75 percent of all feed consumed by all beef cattle comes from forage sources alone (Hodgson, 1967). Available forage supplies are dependant on environmental conditions and can be considered as a highly unstable feed resource. Since weight gains of stocker cattle are a key in determining the profitability of stocker cattle enterprises, any attempt to add stability to the existing forage supply may aid in improving stocker cattle performance. Supplementation on pasture is one such method that can aid in adding stability to the forage supply. In addition to adding stability, supplementation may improve animal performance by improving the overall nutrient balance and may increase total beef production per acre by allowing increased stocking densities (Newton and Young, 1974). However, reported research on increasing cattle performance through supplementation has been conflicting. In most cases the response to supplementation occurs when the forage is of low nutritive value, when forage availability is low, or when some component of forage composition such as high moisture content limits intake (Davies and Lemcke, 1977; Davies, 1962).

Feeding grain is a convenient method for supplementation on pasture. However, this has been shown to result in substitution of grain for forage (Lake et al., 1974; Taylor and Wilkenson, 1972), depresses the potential extent of forage digestion (Miller and Montifering, 1985; Mertens and Loften, 1980), and reduces the feed efficiency of the grain itself (Elder et al., 1967).

The use of silage as a supplemental feed on pasture appears promising. Utley et al. (1973) showed stocker weight gains were maintained with supplemental silage for steers grazing oat or ryegrass pastures as stocking density was increased by 33 percent. The supplemental silage allowed for a more complete utilization of the basal forage by allowing a more favorable balance between protein and energy intake.

Therefore, the objectives of this research were to investigate the effects of supplemental silage on: (1) performance and silage intake of stocker cattle grazing wheat pasture and bermudagrass, (2) forage intake of wheat pasture and bermudagrass and flow through the gastrointestinal tract, and (3) ruminal degradability and rate of forage digestion of wheat pasture and bermudagrass.

CHAPTER II

REVIEW OF LITERATURE

Feed intake regulation is a complex mechanism much of which is not understood. Yet,it appears energy demand is a major factor that induces animals to eat (Baumgardt, 1970; Dulphy et al., 1980). Adolph (1947) demonstrated that animals are able to adjust the amount of feed consumed to maintain a constant energy intake. Similarly, Lofgreen et al. (1972) showed dry matter intakes decreased with increasing energy intake. However, total digestible energy intake was identical for all treatments. Thus, it has been said, "animals eat for calories". Yet, if energy were the sole factor in determining feed intake, then an animal would increase intake to meet energy requirements. This does not occur on all diets because the physical size of the rumen and fill of the gastrointestinal tract limit the amount of feed voluntarily consumed. Ellis (1984b) suggested feed intake of animals under grazing conditions is limited by the amount of available forage and both physical and chemical mechanisms. With chemical regulation, various absorbed nutrients alter intake. Some chemical regulators known to influence intake include volatile fatty acids (Simkins et al.,1965; Bhattacharya et al.,1968), free fatty acids (Thye

et al.,1969), protein nutritional status (Egan et al.,1965), and ruminal pH (Wine et al.,1968). However with forage diets, the physical regulation of feed intake may be more important than chemical regulation. Voluntary intake of forages appears to be limited by rumen volume (Blaxter et al., 1961; Minson, 1982), volume occupied therein by residues undergoing digestion (Ellis, 1978; Conrad et al., 1964), and rates of chemical and physical processes which determine the residence time of undigested residues in the rumen (Crampton, 1957; Gill et al, 1969).

In reality, feed intake regulation is not regulated by any single factor, but rather by a complex interaction of physical, chemical, and physiological effects. This literature review concentrates specifically on the physical aspects of forage intake and utilization and concludes with the methodology of assessing such factors.

Physical Regulation of Forage Intake

Forage intake appears to be controlled primarily by physical factors. Conrad et al.(1964) suggested that when the dry matter digestibilty of a feed was less than 66 percent,intake was primarily regulated by body weight (reflecting rumen capacity) and the amount of undigested residues per unit of body weight (reflecting rate of passage). When the digestibility was greater than 66 percent,intake appeared to be dependant upon metabolic body size and level of production. Contrary to this, Ellis et

al. (1984) indicated that with ryegrass, a forage greater than 66 percent digestibility, "attributes related to its digestibility" were involved in the regulation of intake.

When ruminants consume forage diets, they tend to eat to a constant fill. Blaxter et al. (1961) fed sheep either poor, medium, or high quality hays to study this relationship. Although dry matter intakes for these hays were 50.7,77.2, and 94.0 g/kg body weight$^{\cdot 75}$, rumen fill at slaughter was 99.7,100, and 99.0 g/kg body weight$^{\cdot 75}$ for the poor, medium, and high quality hays, respectively. Ulyatt et al. (1967) fed sheep dried grass and two different hays with similar results. Voluntary dry matter intakes were 1.94, 1.48, and 1.28 kg per day while rumen fill was 1.73, 1.74, and 1.86 kg for the dried grass and two hays, respectively. Campling et al. (1961) measured the actual amount of digesta by removing and weighing the rumen contents of cows that had ad libitum access to hay and dried grass. Cows fed the dried grass consumed 35 % more dried grass than hay. However, fill for the cows receiving hay was 6.55 kg. compared to 6.18 kg. of dry matter for cows receiving dried grass. This difference in rumen fill was only 6 %, and indicated that eating ceased when the rumen contained similar amounts of dry matter. Therefore, if fill of undigested residues in the rumen and rumen volume limit intake of forages, faster removal of residues from the gastrointestinal tract should increase intake. Relief of fill can be accomplished by digestion and passage of

undigested residues.

Rate of Particle Reduction

All feed consumed must eventually be broken down to particles small enough to pass through the reticulo-omasal orifice. Balch et al. (1965) concluded the most important factor regulating feed intake and rate of passage of roughages out of the rumen was the rate at which particles were broken down to small particles by mastication and rumination. The reticulo-omasal orifice selectively filters particles based on size.

Poppi et al.(1980) described the concept of critical particle size. This concept relies on the assumption that above a certain particle size, particles cannot leave the rumen until they are further reduced in size. Conversely, particles below this size flow without resistance. Ulyatt et al. (1976) and Reid et al. (1977) suggested that 1 mm be assumed as the critical particle size in sheep, while Poppi et al. (1980) suggested that 1.18 mm be assumed in both cattle and sheep. The latter researchers supported this size by showing that only 5% of particles greater than 1.18 mm left the rumen. Van Soest (1966) reported that mean size of fecal particles tended to increase with increasing level of intake in dairy cows. This would therefore require passage of larger particles from the rumen. Therefore, the rate at which feed particles are broken down to sufficiently small particles to pass through the reticulo-omasal orifice may

eventually influence feed intake. Those particles which break down faster may leave sooner and reduce fill of the rumen. Breakdown rate of particles appears to be a property of feed composition, in particular its cell wall content, and the physical properties that influence the ease or difficulty of comminuting fibrous feeds to small particles (Troelson et al.,1968). The main processes that appear to be involved in particle reduction include chewing, rumination, and microbial fermentation (Evans et al.,1973; Pearce et al.,1964; Lee,1984).

Mastication. Chewing of food serves two distinct purposes. First, chewing reduces particle size to allow greater ease in passage. Second,by reducing particle size, chewing exposes more internal plant tissue to microbial attack (Gill et al.,1966; Pond et al.,1984).

Moseley et al. (1981) fed sheep white clover and perennial ryegrass to establish the relationship between chewing during eating and rate of disappearance from the rumen. During this study, sheep where fed once daily and total rumen contents were removed serially over 24 hours. Disappearance of dry matter from the rumen was 10 times faster during the first 3 hours following consumption in which 60 % of the dry matter disappeared. In a similar trial, Moseley et al. (1984) fed sheep either 300 or 600 grams of ryegrass or white clover. The rate of disappearance during the first 3 hours was 10 times greater

at the high intake level and 7 times greater at the low level of intake. Data clearly show that during the first stages of digestion, neither rumination nor microbial fermentation play a significant role in particle breakdown (Pearce et al.,1965). Consequently in both studies, the high degree of particle breakdown was attributed solely to chewing during eating.

Most data suggest that the amount of particle breakdown attributed to chewing during eating is significant. Chai et al. (1984) fed steers bromegrass and alfalfa hay. The initial mastication reduced the proportion of large particles (i.e. greater than 3.35 mm) by 23 to 27 % where as chewing during rumination reduced the mean particle size 58 to 75 %. Reid et al. (1977) showed that chewing during eating alone caused a 50 percent reduction in a lucerne diet fed to sheep while Lee et al. (1984) observed a 34.8 % decrease in particle size with a range of 21 to 47 percent. In the latter study, sheep were fed restricted amounts of pea straw, lucerne straw, ryegrass hay, oat straw, or barley straw. The corresponding intakes of these roughages were 120, 297, 160, 270, and 131 grams. Chewing resulted in a 30.8, 36.2, 35.5, 36.5 and 39.2 % decrease in particle size, respectively. These results tended to indicate that not all forages were broken down to the same extent during chewing.

Poppi et al. (1984) showed the degree of particle breakdown by mastication was dependant upon several factors. In this study both sheep and cattle were fed ad libitum

amounts of leaf and stem fractions of pangola and rhodes grass at two stages of maturity. Chopped leaf and stem fractions contained 85 and 86 % particles greater than 1.18 mm, respectively, which was assumed to be the large particle fraction. Mastication by cattle reduced the proportion of large particles to 58 and 76 % while mastication by sheep reduced the proportion to 56 and 67 % for the leaf and stem fractions, respectively. Sheep were more efficient in reducing the particle size by chewing than cattle. They were able to reduce the proportion of large particles by 22.4 % as compared with 18.4 % for the cattle. In addition to animal species, the plant fraction and stage of maturity also played a significant role in the amount of particle breakdown. As expected the leaf was broken down to smaller particles much more readily than the stem fraction (27.6% vs 13.2%) by chewing and material of the later stage of maturity was broken down more readily than that of the earlier maturity (23.6 vs 17.8%).

In addition to particle size reduction, Pond et al. (1984) stressed that the act of mastication itself may increase the surface area of the plant tissue available for microbial attack. In this study, these researchers used cannulated steers that grazed ryegrass and bermudagrass pastures or were fed bermudagrass hay. Mastication of grazed bermudagrass appeared to be more extensive yielding a larger proportion of smaller size particles. The total percentage by weight that was greater than 1 mm was 84.5,

48.0, and 74.3 % for the bermudagrass hay, grazed bermudagrass, and grazed ryegrass, respectively. These data indicated that a wide variety of particle sizes were derived solely from the initial mastication. However, microscopic evaluation of the tissues led these researchers to conclude that the main effect of mastication was the exposure of more potentially digestible tissues previously encompassed within "barrier tissues".

Voluntary intake appears to be related to the time spent chewing. Ulyatt et al. (1982) fed sheep either white clover (WC), perennial ryegrass (PY), early bloom ryegrass (PM), or lucerne chaff (LC) and reported intakes of 11.2, 6.5, 4.1, and 9.9 grams per minute, respectively. After mastication, the proportion of particles less than 1 mm were 21.9, 21.1, 34.7, and 35.2 % for WC, PY, PM, and LC, respectively. There was a strong relationship between the level of intake and the extent of particle breakdown by chewing. At the lower levels of intake, there was a tendancy for feed particles to be broken down more readily than at higher intake levels. Bae et al. (1981) showed that animals were able to consume more hay daily by increasing chewing time and/or rate of chewing. Conversely, Gill et al. (1966) increased the amount of hay given to cows by 50 % and observed no significant increase in the size of particles swallowed or the rate at which chewing occured indicating that regardless of intake all particles were

broken down to the same extent.

Rumination. Welch et al. (1982) defined rumination as the process of regurgitation of fibrous ingesta from the rumen to the mouth, remastication and reinsalvation, followed by swallowing and returning of the material to the mouth. The amount of time that ruminants spend ruminating is substantial. Bae et al. (1979) and Welch et al. (1982) estimated that sheep and cattle on roughage diets ruminated up to 10 to 11 hours daily. The time spent ruminating depends on the cell wall load, forage intake, and the physical nature of the feed. Rumination appears to be induced by sensory factors within the rumen wall (Van Soest, 1982). Consequently, as the rumen fills, rumination is initiated to relieve the rumen load.

The primary role of rumination is particle size reduction. Pearce et al.(1965) attempted to separate the effects of microbial breakdown of particles from that of rumination by pastuerization of the rumen contents. Results showed that 58 % of the dry matter disappeared within 24 hours after pastuerization and was attributed to particle breakdown by rumination. Similarly, Chai et al. (1984) showed that 58 to 75 % of particle reduction occured from rumination alone. Pearce et al. (1964) fitted sheep with muzzles to prevent rumination of sheep fed a mixed diet of chaffed oat hay and lucerne chaff. Sheep wearing muzzles could not ruminate and consequently had dry matter retention

times 295 % longer than sheep allowed to ruminate freely because the feed could not be broken down to particles small enough to leave the rumen.

As mentioned earlier, the time spent ruminating is substantial and tends to increase with increasing intakes. Welch et al. (1969) fed increasing amounts of hay ranging from 200 to 1800 grams of dry matter daily to sheep. The time spent ruminating increased from 231 to 588 minutes per day with increasing intakes. Similarly, Bae et al. (1979) fed sheep 400, 800, 1200, and 1600 grams daily of a mixed grass hay with mean ruminating times of 427, 658, 817, and 902 minutes per day. Rumination activity increased with increasing intakes but the response was quadratic indicating that sheep were reaching the upper limit of rumination. Moreover, it was noted in the latter study that sheep became more efficient in trying to reduce the rumen load by increasing the number of chews per minute and per bolus.

In addition to intake, the physical nature of the feed also affects rumination activity. Welch et al.(1971) showed that rumination time was decreased when sheep were fed alfalfa pellets rather than hay. Deswysen and Ehrlein (1981) showed that sheep were less efficient in the rumination of long-chopped silage when compared to short-chopped silage. Consequently, their voluntary intakes were lower on the long-chopped silage. Weston and Hogan (1967) fed sheep lucerne and wheat hay that was either ground or chopped. By grinding the feed, the amount of time

spent ruminating decreased by 3.7 and 7.5 h/day for wheat and lucerne, respectively. Gordon (1958) showed rumination time decreased by 180 minutes when a concentrate was added to a chopped hay diet.

Fermentation. It is well accepted that the production of small particles is due primarily to chewing and rumination. However, particle breakdown is also facilitated by microbial activity which weakens the structural components of the plant during fermentation. The effects of particle reduction by microbial action have only been studied indirectly from in situ fermentation or inhibition of rumination. Murphy et al. (1984) incubated ground alfalfa hay in nylon bags for 96 hours using cannulated steers. After the incubation period, there was a 19 percent reduction in particle size which was attributed to microbial fermentation. Similarly, Ehle et al. (1982) incubated wheat bran in cannulated steers using nylon bags. After 12 hours of incubation, the particle size of the wheat bran was reduced by 16 %. The former researchers considered the 19 % reduction as insignificant when compared to rumination, while the latter researchers considered the 16 % reduction as a substantial amount indicating that this was a minimal estimate for particle size reduction since some feed that was broken down was digested or disappeared through the pores in the nylon bags.

Pearce et al. (1964) fed sheep a mixed diet of lucerne

and oat chaff but restricted rumination with muzzles. Before the muzzles were placed on the sheep, they were able to consume approximately 750 grams of dry matter daily. Once the muzzles were in place sheep were still able to consume 500 grams daily indicating that microbial fermentation played a major role in the disappearance of feed. In a similar trial, Welch et al. (1982) observed that cattle could maintain up to 50 % of their normal intakes when muzzled to prevent rumination. In both of the above studies, the retention times of the feed in the rumen was considerably longer which caused concomitant increases in the dry matter and organic matter digestibilities.

Van Soest (1982) has argued that microbial fermentation does little to reduce the particle size of roughage diets. According to Van Soest, fermentation by ruminal microorganisms removes the soluble contents leaving the structural components in tact. This phenomenom is referred to as the "Hotel Theory". Results from Akin et al. (1975) and Akin et al. (1974) both tend to confirm this theory. From these studies, it appears that bacteria preferentially digest the mesophyll and phloem tissues of the plant leaving the less digestible cuticle and vascular bundles intact.

Microbial fermentation of roughages tends to be reduced by the addition of starchy feeds to the diet. el-Shazley (1961) listed the production of an inhibitor by a starch digesting microorganism, a decrease in pH due to acid

production from starch fermentation, and competition for essential nutrients with the results that starch digesting microorganisms proliferate preferentially as the three potential reasons for the decrease in digestibility. Mertens et al. (1980) studied this effect by using corn and wheat starch at 0, 40, 60, and 80 % of the total diet in combination with alfalfa, coastal bermudagrass, fescue, and orchardgrass. With increasing levels of starch, the potential extent of digestion was decreased. Miller and Montifering (1985) added cracked corn to fescue hay at 0, 20, 40, 60, and 80 % of the diet. Again the potential extent of digestion was decreased by the addition of starch although the rate of digestion was not affected. Both Mertens et al. (1980) and Miller and Montifering (1985) determined the potentially digestible fraction (PDF) by assuming that digestion was complete at 72 hours of fermentation. Potential extent of digestion was estimated by subtracting the residue remaining at 72 hours from the remaining sample at each incubation time. Thus, when starchy feeds are added to the diet this results in a decrease in the digestibility of the diet and adds to rumen fill of undigested residues which must leave the rumen by passage alone.

Passage

Ingested feed disappears by two routes, digestion and passage (Ellis et al.,1978). Consequently, both of these

processes compete for the same material with the likelihood that some potentially digestible matter will escape ruminal digestion and pass through the rumen. Van Soest (1982) defined rate of passage as the transit of undigested residue through the gastrointestinal tract. Passage rate is influenced by the level of feed intake and the physical nature of the feed. According to Owens and Isaacson (1977), increasing the passage rate results in: (1) increased microbial protein production, (2) decreased bacterial storage of carbohydrates, (3) increased ruminal escape of feed protein, and (4) decreased propionate, and increased acetate and butyrate production. Consequently, increased passage rates are advantageous for microbial protein production and ruminal escape of feed protein. However, increased passage rates are disadvantageous for forage diets because digestibility of fibrous components are dependant on residence time in the rumen.

Relationship with Intake. A distinct relationship exists between forage intake and rate of passage. Increasing the rate of passage removes more undigested residue from the rumen allowing for intake to be increased. In a study by Thorton and Minson (1973), sheep were fed six panicum diets at increasing levels of intake. As the intakes increased from 659 grams per day to 1355 grams, retention time of feed in the rumen decreased linearly from 27.1 to 13.3 hours. Similarly, Mudgal et al. (1982) fed

sheep alfalfa pellets at two intake levels. As intake increased, dilution rate of ruminal liquid increased from 7.79 to 12.0 %/h without decreasing organic matter digestibility. In a study by Varga and Prigge (1982) sheep were fed either alfalfa or orchardgrass at 60 and 90 % of ad libitum intake. As the intakes increased, the liquid dilution rate increased from 3.4 to 7.2 %/h while the particulate passage rate increased nonsignificantly from 5.3 to 6.6%/h. In addition, no differences were noted in passage rate estimates for the different forages.

The physical nature of feed also affects both passage rate and intake. Robles et al. (1981) fed sheep either alfalfa leaves, alfalfa leaves plus stems or alfalfa stems. The cell wall contents of these diets were 48, 56, and 64 %, respectively. Passage rates decreased from 2.73 to 1.95 %/h with increasing cell wall content. Consequently, daily forage intakes decreased from 1.7 to 1.2 kg with lower passage rates. Weston and Hogan (1967) fed sheep either ground or chopped diets of wheat and lucerne hays. The data clearly showed that grinding increased the intake of lucerne hay by 36 % and wheat hay by 42 %. These increases were accompanied by increased digesta flow rates from the abomasum by 21 and 28 % for the lucerne and wheat hays, respectively.

Relationship with Digestion. Increasing the rate of passage also affects the digestibility of the feed. Since

the extent of digestion is dependant upon the residence time in the rumen, it is logical to assume that any increase in passage will depress ruminal digestibility. Mertens (1977) used a simulation model to show that when passage was increased from 3 to 5 %/h, ruminal digestibility decreased by 7 %. Organic matter digestibility of lucerne chaff fed to sheep decreased as passage increased in studies of Grovum (1977). As intake increased from 400 to 1300 grams daily, rumen retention time decreased by 50 % and organic matter digestibility decreased by 4 %. However, the previously mentioned studies of Varga and Prigge (1982) and Mudgal et al. (1982) both showed that digestibility was not altered by increasing the rate of passage.

Methodology of Assessing Forage Utilization

From the preceding data, it is evident that both rate of digestion and rate of passage are important in regulating intake. Therefore, attention needs to be directed to the methodology of quantifying fiber digestion and passage.

Rate of Digestion. Rate of digestion refers to the quantity of feed that can be digested per unit of time (Van Soest, 1982). This rate is essentially a function of diet. Smith et al. (1972) reported that rate of cell wall digestion was more highly correlated to soluble dry matter percentage (r=.72) than with lignin (r=-.47) or lignin to cellulose ratio (r=-.18). This seems apparent because the

soluble matter ferments rapidly leaving the more slowly digestible insoluble dry matter for the later stages of digestion.

Digestion lag and potential extent of digestion are two factors that influence rate of digestion (Mertens, 1977). Digestion lag is the period of initial fermentation when digestion either does not occur or occurs at a greatly reduced rate. Mertens (1977) suggested that digestion lag is dependant on: (1) a limiting substance that must be removed before fiber digestion can occur, (2) hydration which must occur for the fiber to swell and allow enzymes to penetrate, or (3) microbial attachment. Wilkins (1969) defined the potential digestibility of a feed as the maximum digestibility obtainable when the conditions and duration of digestion are not limiting. In this study, the potential digestibility of a feedstuff was determined by measuring the extent of digestion that occured after 6 days in vitro. Plant factors, mainly lignin, appear to limit the potential extent of digestion.

Rate of digestion can be determined by in vitro fermentation or by in vivo incubation of feeds in nylon bags. Data of Smith et al. (1971) and Gill et al. (1969) showed that rate of digestion followed first order kinetics and could be quantified by first order kinetic rate constants even though each forage varied in its own digestion rate. Therefore, the rate of digestion was calculated by regressing the natural logarithm of the

proportion of DM remaining versus time. However, the problem in calculating rate of digestion in this manner is the variable extent to which digestion can occur among forages (Poppi, 1984). Moreover, calculations in this manner do not allow for comparisons of digestibility at any one time without considering the maximum extent of digestion. Therefore, rate of digestion is normally calculated by regression of the natural logarithm of the proportion of the potentially digestible fraction remaining versus time.

Rate of Passage. Two general methods exist to measure the rate of passage. The most direct estimation is the measurement of rumen volume and division of that quantity by intake to obtain turnover (Van Soest, 1982). This estimate is comparable to passage provided that an indigestible recoverable reference is used to form the basis of determination. The second approach, which has received considerable attention, is the administration of a pulse dose of an external marker followed by subsequent sampling of feces over time. This provides the basis for estimating dilution. Rate of dilution represents the replacement or turnover rate of particles (Ellis, 1984a).

Several investigators have used compartmental analysis to obtain estimates of passage rate. Compartmental analysis is based on the assumption that specific pools can be identified and that discharge of marker can be described by

exponential equations (Shipley and Clark, 1972). It is suggested that markers appear in the feces as though they flowed sequentially through two compartments. Consequently, Ellis et al. (1979) proposed that marker data fit to a fecal excretion curve could best be described as a two compartment time dependant-time independant model. The corresponding equation for this model is:

$$Y = K_0 e^{-k1(t-T)}\left(\frac{k_1^2(t-T)}{k_2-k_1} - \frac{k_1^2}{(k_2-k_1)^2}\right) + K_0 e^{-k_2(t-T)}\left(\frac{k_1}{k_2-k_1}\right)^2 \qquad t>T$$

$$Y = 0 \qquad t<T$$

where Y= the fecal marker concentration
Ko=initial marker concentration in the independant compartment
t=the time post-dosage of marker
T= the time of first appearance of marker in feces
K_1= the time dependant rate constant
K_2= the time independant rate constant

These researchers interpret K_1 to represent the rate at which newly ingested particles become mixed with the existing large particle pool, whereas K_2 is interpreted to represent the rate at which large particles undergo change allowing entry into the small particle-liquid pool of the rumen. Conversely, Grovum and Williams (1973) feel the two compartments are the rumen and the caecum and proximal colon. Consequently, K_1 is assumed to represent the rate of removal from the rumen while K_2 is assumed to be flow through the caecum and proximal colon. However, data of Ellis (1984) suggests that digesta flow through the gastrointestinal tract is largely accounted for by flow

through a single anatomical compartment, the rumen. Slow mixing within the rumen appears to be the major source of the second compartment that is detected by marker excretion in the feces.

A frequent problem that occurs when fitting data to a two compartment model occurs when the rate constants cannot be differentiated (Ellis, 1984). This frequently occurs on high quality forages such as wheat pasture where passage rates are rapid and little differentiation between rate constants occurs (Ford, 1984). Under these conditions, a one compartment model can be employed with satisfactory results. Ellis et al. (1979) presented a one compartment model as follows:

$$Y = K_0 * T * K_1^2 * e^{-k_1 T}$$

where Y= fecal marker concentrations
Ko= initial concentration of marker in the compartment
T= hour post dosage minus time delay
K_1= the time dependant rate constant

Using this model, rate of particulate passage can be calculated as the time dependant rate constant (K_1) * .59635, a number inherent to the one compartment model.

Forage Intake. An additional advantage of the one and two compartment models presented by Ellis et al. (1979) is that forage intake can be estimated from passage rate estimates if one assumes steady state kinetics. Krysl et al. (1985) compared fecal output estimated from total fecal collection and the one compartment model. Estimates of fecal output using ytterbium-labelled forages were not

significantly different from actual fecal outputs. In a similar trial, Vogel et al. (1984) compared fecal output estimates using total fecal collection and dysprosium-labelled wheat forage under grazing conditions. Again, fecal output estimated by the one compartment model was not significantly different from the actual values. Once fecal output is known, forage intake can be calculated as fecal output divided by the indigestibility of forage dry matter.

Oltjen et al. (1985) compared the one and two compartment models for steers grazing wheat pasture. Predicted fecal output estimates from the two compartment model tended to be more precise. However, they were less accurate because they tended to underestimate fecal output. In addition, when the one compartment model fit the data poorly, fecal output estimates tended to be overestimated.

The calculations to estimate forage intake from the one compartment model are as follows:

Fecal output (FO), kg/day= (Marker dose,g/Ko * 24) / 1000

Intake, kg/day= FO / Indigestibility of the grazed forage

Forage intake estimates from the two compartment model can be calculated as follows:

Tract Fill (UDMG), kg/day= (Marker Dose,g/ Ko)

Fecal Output, kg/day = UDMG * Ko/hour * 24 hours

Intake, kg/day = FO / Indigestibility of the grazed forage

Integration of Digestion and Passage. Several attempts have been made to combine both passage and digestion rates to determine the amount of feed actually degraded in the rumen, the amount of feed bypassing the rumen, and the voluntary intake of feedstuffs. In the simpliest sense, the proportion of potentially digestible dry matter in the rumen is equal to the rate of digestion (Kd) expressed as a proportion of the sum of the rates of passage (Kp) and Kd (Van Soest, 1982: Ellis et al.,1984). This value represents the theoretical value for the maximum amount of feed actually being digested in the rumen. Several more complex models have been proposed although only three will be discussed in length.

Waldo et al. (1972) proposed that the digestion of cellulose proceeds as if cellulose were of two definable components (i.e. potentially digestible and indigestible). The indigestible fraction, which is that component which could not be digested if held in the rumen for an indefinite period of time, can leave the rumen by passage alone. The digestible fraction can disappear by digestion as well as passage. Therefore, these researchers concluded that cellulose disappearance from the rumen could be described by the following differential equations:

$$\frac{dA}{dt} = -K_1A - K_2A \qquad \frac{dB}{dt} = -K_2B$$

where A= the amount of digestible cellulose present in the rumen
B= the amount of indigestible cellulose present in the rumen

t= time
K_1= the rate of digestion
K_2= the rate of passage

By solving these equations, the amount of cellulose remaining (f) at any time (t) is equal to:

$$f = ae^{-(K_1+K_2)} + be^{-K_2 t}$$

where a= the potentially digestible fraction which can disappear by digestion and passage

b= the indigestible fraction capable of leaving the rumen by passage alone

Using this model, these researchers were able to show that both rumen fill per unit of intake and the digestibility of cellulose could be mathematically derived.

Orskov and McDonald (1979) attempted to combine both passage and digestion rate estimates to determine the potential degradability (p) of a feedstuff. The effective degradability is assumed to represent the percent of the feed actually degraded in the rumen. The degradability of a feedstuff can be described by the following equation:

$$p = a + (bc/(c + k))\ (1-e^{-(c+k)t})$$

where a= the rapidly disappearing highly soluble fraction
b= that fraction other than fraction a that disappears at a constant fractional rate per unit of time
c= the fractional rate of digestion
k= the fractional rate of passage
t= time

As t increases, this equation reaches an asymptotic value of a + bc/(c+k). These researchers stated that the problem with this model is that measurement of disappearance from nylon bags in the rumen makes no allowance for the rate at

which particles pass out of the rumen. This can be seen for those feedstuffs that are slowly degraded or where passage rates are rapid.

Ellis (1978) attempted to quantify forage intake and utilization by describing cell wall digestion. According to Ellis, the diet is composed of highly digestible cell contents (CC) and the less digestible cell wall constituents (CWC). Of the CWC, a portion is indigestible (CWCi) and is excreted via the feces, and the remainder is digested (CWCd) at a uniform rate. However, some of the CWCd leaves the rumen by passage before digestion (UCWCd). These concepts are similar to those of Waldo et al. (1972).

Moreover, Ellis (1978) suggested that fill of undigested dry matter (UDMF) is a function of the dry matter excreted via the feces (UDMF), endogenous cell contents (ECC), microbial mass (MM), and rate of passage (Kp). Consequently, UDMF derived specifically from the forage alone equals (UDMF - (ECC + MM))/Kp. Thus, the fraction of intake which remains undigested is then essentially UDMF * Kp. This fraction can also be calculated as intake (I) * Kp/(Kp+Kd),the fraction of feed bypassing the rumen. Therefore, if both of these equations represent the fraction of intake that is undigested, they are equal (i.e., UDMF * Kp = I * Kp/(Kp+Kd). Hence, Ellis concluded that if voluntary intake is limited by the rates of digestion and passage, rearrangement of the previous equation estimates intake as:

$$I = UDMF * Kp/ (Kp/(Kp+Kd)).$$

Ellis stated that his model needs considerable refinement such as the identification of the site in the gastrointestinal tract where fill limits intake and quantification of the relationship between chemical and physical degradation of forage tissues.

In summary, all of the aforementioned researchers have emphasized the effects of rates of digestion and passage as factors limiting intake. Any procedure that alters these rates will eventually alter both the rate and extent of ruminal digestion and forage intake.

CHAPTER III

EFFECT OF SUPPLEMENTAL SILAGE ON PERFORMANCE OF STOCKER CATTLE GRAZING WHEAT PASTURE AND BERMUDAGRASS

Summary

A 3 year study was conducted to determine the effects of silage supplementation on weight gains and silage intake of steers grazing wheat pasture and bermudagrass. During the wheat pasture phase 240 fall-weaned steers with mean initial weights of 199 kg grazed wheat pasture and received no supplemental silage (treatment 1) or had ad libitum access to silage (treatments 2, 3 and 4). Stocking densities were approximately .86, .86, .65 and .43 hectares of wheat pasture per steer for treatments 1 to 4, respectively. During the bermudagrass phase 288 steers with mean initial weights of 356 kg followed a rotational grazing system in which cattle were rotated between paddocks until the available forage became limiting. At this point steers were given access to both pastures. Initial stocking densities were .32, .32, .23, and .15 hectares of bermudagrass per steer for treatments 1 to 4, respectively. Supplemental silage was fed only when the available forage

became limiting. On wheat pasture mean daily silage DM consumption for steers in treatments 2, 3 and 4 were .80, 1.22 and 1.72 kg DM/head /day, respectively. Average daily gains were .94, 1.03, 1.00 and .90 kg for steers in treatments 1 to 4, respectively. During the bermudagrass phase silage consumption ranged from 1.31 to 6.08 kg DM/head/day for steers in treatments 3 and 4. No silage was fed to steers of treatment 2 because bermudagrass never became limiting. Average daily gains were .60, .60, .60 and .63 kg for treatments 1 to 4, respectively. During both the wheat pasture and bermudagrass trials, the use of supplemental silage allowed stocking density to be doubled without decreasing stocker cattle performance.

Introduction

Rate of weight gain is of primary importance to the stocker cattle operator. Gains of cattle grazing wheat pasture and bermudagrass are potentially good. However, these gains may be decreased because of inadequate amounts of available forage. In addition, performance of cattle on wheat pasture may be limited because of snow and(or) ice cover. Supplementation on pasture therefore offers an alternative to increase daily gains of cattle and add stability to stocker cattle enterprises. Supplementation also serves as a means for increasing stocking densities. For example, if producers choose to graze-out wheat pasture rather than harvest a grain crop, only about 27% of the land

used during the fall and winter grazing period would be required for grazeout. Rather than purchase additional stocker cattle in the spring, the stocker cattle operator may choose to purchase cattle in the fall to take advantage of seasonal cattle markets and increase stocking density by supplementing cattle on pasture with silage. In addition, supplementation also provides a tool for improving the energy and(or) protein intake of cattle grazing lower quality forages. This may be the case for bermudagrass where forage quality deteriorates rapidly as the grazing season advances. Therefore, the objectives of this study were to investigate the effects of feeding silage on performance and silage intake of stocker cattle grazing wheat pasture and subsequently bermudagrass.

Experimental procedure

Wheat pasture

Ninety-six fall weaned Hereford and Brahman crossbred steers in year 1 (1981-82), ninety-six Hereford, Angus, and Hereford X Angus steers in year 2 (1982-83), and ninety-six Hereford, Hereford X Angus, and Limousin crossbred steers in year 3 (1983-84) were randomly allotted each year (within breed by weight) into 2 blocks of 48 steers each and randomly assigned to one of four treatments. Because of a shortage of wheat pasture in year 2, only 1 block of steers were used. Thus, a total of 5 replications with 48 steers

each were used on wheat pasture. Steers of treatment 1 served as the control and received no supplemental silage, whereas steers of treatments 2, 3, and 4 had ad libitum access to silage that was fed daily throughout the trial. In year 3, because of the large amounts of wheat forage initially on offer, steers were fed silage for only 68 days of the 105 day grazing trial. Wheat silage was used in year 1 and sorghum silage was used in years 2 and 3. Initial stocking rates were 1.16, 1.16, 1.54, and 2.33 steers per hectare for treatments 1 to 4, respectively. Nevertheless, stocking densities of treatments 2, 3, and 4 were equal to , one and one-half times greater than, and two times greater than that of steers in treatment 1, respectively. At the conclusion of each grazing trial steers of all treatments within a block were combined for the grazeout period and allowed .24 hectares per steer. During the grazeout period (approx. March 21 to May 23 each year) no supplemental silage was offered.

Initial, intermittant and final weights of the steers were measured after overnight shrinks without feed or water.

During periods of snow and(or) ice cover of wheat pasture steers of treatment 1 were fed old world bluestem hay. Hay was fed for 1 day in year 1, 9 days in year 2, and 9 days in year 3.

Silage consumption of steers was measured daily, and samples were taken weekly and composited across weeks within months for analyses. Samples were dried in a force air oven

at 65^{o}C and ground through a 1 mm mesh screen in a Wiley mill grinder. Samples were analyzed for dry matter, crude protein using the macro-Kjeldahl procedure (A.O.A.C., 1975), and in vitro dry matter digestibility by the Tilley and Terry (1963) procedure with urea (.5g/liter) added to 1 part strained rumen fluid: 1 part McDougall's buffer solution and a 24 h acid-pepsin digestion phase as modifications.

Forage availability was estimated throughout the wheat pasture grazing period by hand clipping 3 one-half square meter plots at selected times to coincide with major changes in climatic conditions each year. Terminal clippings were also taken to characterize the forage composition in which clippings were analyzed for dry matter, in vitro dry matter digestibility, and crude protein as previously described.

Data were analyzed statistically using the General Linear Model (GLM) Procedure of the Statistical Analysis System (SAS). The initial model for stocker weight gains included replication, treatment, replication X treatment interaction, breed, and breed X treatment interaction as sources of variation. This model was reduced when breed and the breed X treatment interaction were nonsignificant ($p>.13$). Consequently, the final model included replication, treatment, and replication X treatment interaction as sources of variation (appendix table XIII). This model was also used for statistical analysis of silage consumption data. Treatment was tested for significance by using the replication X treatment interaction as the error

term and the Type III sum of squares (SS3). Duncan's Multiple Range Test was used to identify treatments that were different.

Bermudagrass

The same steers used for the wheat pasture phase were subsequently grazed on bermudagrass each year. However, data from the first year were deleted due to a change in the method of supplementation. Consequently, an additional ninety-six Hereford and Limousin crossbred steers that averaged 346 kg were used for the 1985 grazing season (year 4). Initial stocking densities each year were approximately .32, .32, .23 and .15 hectares of bermudagrass per steer for treatments 1 to 4, respectively. Each trial was approximately 118 days in length (approx. May 22 to September 17 of each year). Steers of each treatment followed a rotational grazing system in which each pasture was divided by electrical fencing into two paddocks. Cattle grazed a single paddock until available bermudagrass became limiting, and were then rotated to the adjacent paddock until the available forage of both paddocks was low. At this point steers were given access to both paddocks. The objective of the rotational grazing system was to keep the available forage between 1 to 4 inches tall. If the available forage of the ungrazed paddocks became too abundant and the cattle could not maintain the pasture, excess forage of the ungrazed paddocks was harvested as hay.

When steers were rotated between paddocks, the amount of forage presented to the animals was estimated by hand clipping three one-half square meter plots. The forage composition was characterized using the forage availability samples where samples were composited across sampling days within months. Samples were analyzed for dry matter, in vitro dry matter digestibility, and crude protein as previously described.

Initial, intermittant and final weights of the steers were measured following overnight shrinks without feed and water. Sorghum silage was fed to steers of treatments 2, 3, and 4 only when available forage became limiting. Bermudagrass never became limiting for steers of treatment 2. Hence, no silage was fed. When silage was fed, silage consumption was measured daily and samples were taken weekly and composited across weeks within months for analyses. Samples were analyzed for dry matter, in vitro dry matter digestibility and crude protein as previously described.

All pastures were mowed each year following the initial grazing in the early summer to remove senescent cool season grasses. Additionally, all pastures were fertilized with nitrogen. Dates and rates of application of nitrogen fertilizer are shown by year in appendix table XIV.

Data were analyzed statistically using the same procedures and model as previously described.

Results and Discussion

Wheat pasture

Silage dry matter (DM) consumption, initial weight and stocker weight gains are presented in Table I while the composition of the silage used each year is shown in table III. The composition and availability of the wheat forage are shown in tables XV, XVI, and XVII for years 1, 2, and 3, respectively.

Silage DM consumption ranged from .20 to 3.95 kg DM/head/day, and increased ($p<.05$) as stocking density was increased. Steers would consume silage only when the available forage became limiting. Consequently, as the stocking density increased, the amount of wheat forage available to each steer was decreased causing an increase in silage DM consumption.

Average daily gains of steers among all treatments were similar ($p>.05$) indicating that the use of supplemental silage allowed gains of stocker cattle on wheat pasture to be maintained while stocking density was doubled. Feeding silage prior to grazeout did not affect ($p>.05$) their subsequent weight gains during the grazeout period. Stocker weight gains during this trial were excellent with treatment means ranging from .90 to 1.03 kg/head/day. For perspective, Mader et al. (1983) reported that weight gains

of steers grazing wheat pasture with and without a low quality roughage supplement averaged .79 kg/head/day. Similarly, stocker cattle weight gains in a study by Horn et al. (1981) were .55 kg/head/day for heifers that grazed wheat pasture, and .60 and .68 kg/head/day for heifers that grazed wheat pasture and were fed a pelleted supplement containing 0 or 100 mg monensin, respectively.

Bermudagrass

The composition of the bermudagrass is shown in tables XVIII, XIX, and XX for years 1, 2, and 3, respectively. The composition of the silage used each year is shown in table IV. Silage DM consumption of steers grazing bermudagrass during years 2, 3, and 4 are presented in Figures 1, 2 and 3, respectively. Supplemental silage was fed only when available forage became limiting each year. Consequently, times of feeding silage were not common each year, and were not analyzed statistically.

In year 2 (1983) silage supplementation began on June 30 for steers of treatment 4, and intake of silage increased rapidly from 1.36 to 5.00 kg DM/head/day on Aug. 24 afterwhich silage intakes were relatively constant until the end of the trial. Steers of treatment 3 were fed silage for 14 days (August 8 to 21) during which silage consumption averaged 3.86 kg DM daily.

Because of an extremely dry summer in year 3 (1984) silage supplementation began on June 4 and continued until

September 10. Silage consumption of steers of treatment 4 increased steadily from 2.27 to 6.08 kg DM/head/day as the amount of available forage decreased. Silage was fed for 6 days (September 5 to 10) to steers of treatment 3 in which silage consumption averaged 3.70 kg DM/head/day.

In year 4 (1985) silage supplementation began on July 12 and continued until September 9 for steers of treatment 4. Silage DM intakes for steers of treatment 4 averaged 3.73 kg DM/head/day. Silage supplementation began on August 9 for steers of treatment 3 and continued until September 12 in which silage DM intakes ranged from 3.00 to 4.81 kg DM/head/day. During the later stages of the trial steers of treatment 3 consumed more silage than did steers of treatment 4.

Initial weights and stocker weight gains of the steers are presented in Table II. Stocker weight gains across all treatments were similar ($p>.05$) and averaged .61 kg/head/day indicating that supplemental silage allow gains of stocker cattle to be maintained as stocking density is doubled. These gains in this study are similar to those of Oliver (1975) and Barnes et al. (1980) in which weight gains of stocker cattle averaged .66 and .58 kg/head/day, respectively.

TABLE I

SILAGE CONSUMPTION AND PERFORMANCE OF STEERS GRAZING WHEAT PASTURE

Treatment	1	2	3	4	SEM
Stocking Density, steers/hectare	1.16	1.16	1.54	2.33	
Number of steers	60	59*	59*	60	
Silage consumption (kg DM/head/day)					
Weekly range	---	.20-2.33	.40-3.09	.40-3.95	
Mean	---	.80[a]	1.22[b]	1.72[c]	.074
Grazing period					
December 18 to March 21, 93 days[d]					
Initial weight, kg	200[a]	199[a]	198[a]	197[a]	4.67
Final weight, kg	302[a]	300[a]	297[a]	285[a]	5.08
Daily gain, kg	.90[a]	1.03[a]	1.00[a]	.90[a]	.021
Grazeout(March 21 to May 23, 63 days[e])					
Initial weight, kg	302[a]	300[a]	297[a]	285[a]	5.08
Final weight, kg	359[a]	354[a]	350[a]	351[a]	6.32
Daily gain, kg	1.05[a]	.88[a]	.90[a]	1.08[a]	.099

* One steer died of respiratory disease in year 1 (1981-1982)
abc Means in the same row with different superscripts are different ($p<.05$)
d Number of days +/- 21
e Number of days +/- 7

TABLE II

PERFORMANCE OF STEERS GRAZING BERMUDAGRASS

Treatment	1	2	3	4	SEM
Stocking density, steers/hectare	3.13	3.13	4.35	6.67	
Number of steers	72	72	72	72	
Grazing period					
May 22 to September 17, 118 days[b]					
Initial weight, kg	353[a]	357[a]	356[a]	356[a]	3.65
Final weight, kg	424[a]	429[a]	427[a]	431[a]	4.01
Daily gain, kg	.60[a]	.60[a]	.60[a]	.63[a]	.015

a Means in a row with common superscripts are not different ($p>.05$)
b Number of days +/- 7

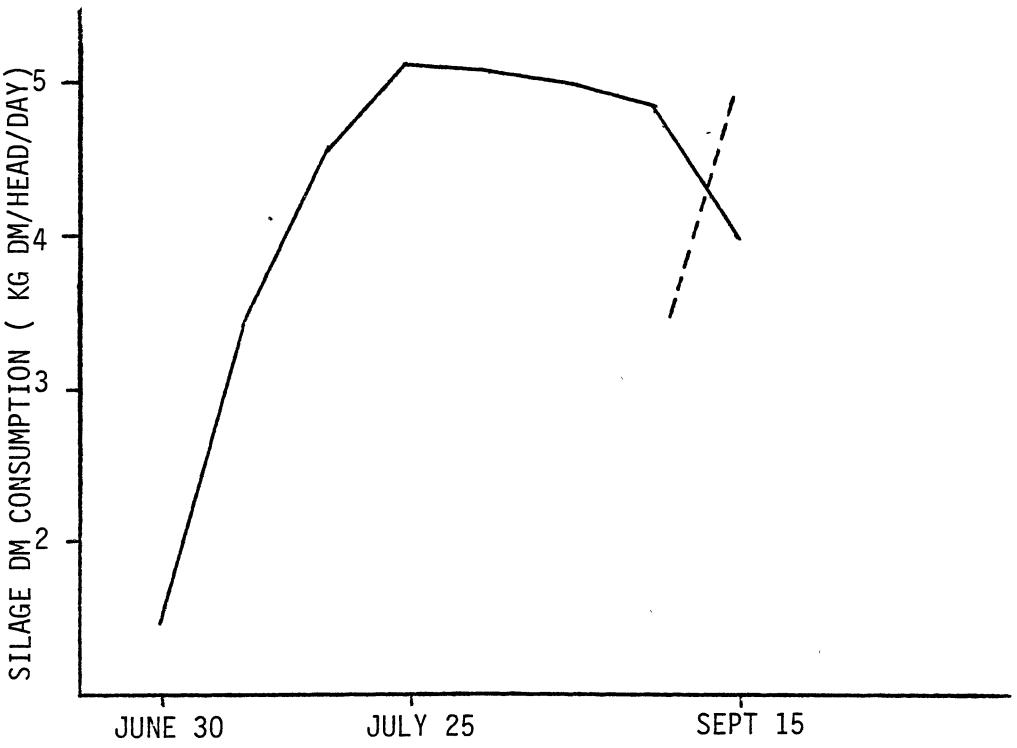

Figure 1. Silage DM Intakes of Steers Grazing Bermudagrass Year 2 (1983)

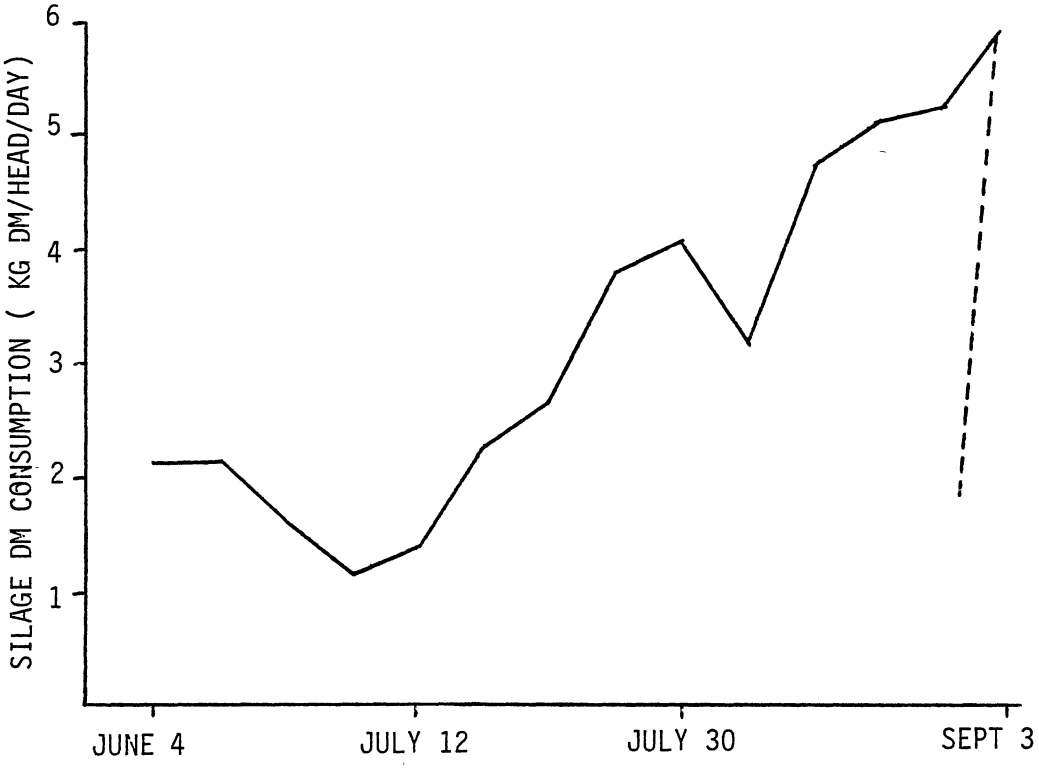

Figure 2. Silage DM Intakes of Steers Grazing Bermudagrass Year 3 (1984)

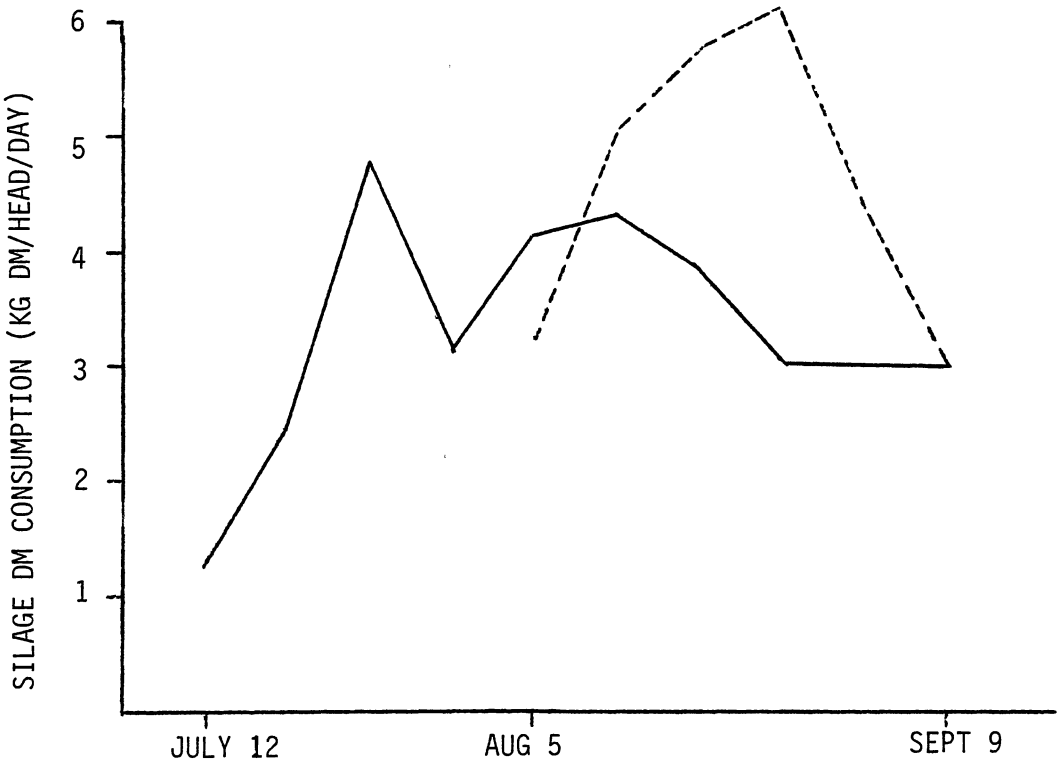

Figure 3. Silage DM Intakes of Steers Grazing Bermudagrass Year 4 (1985)

TABLE III

SILAGE COMPOSITION FOR WHEAT PASTURE GRAZING TRIALS

	CP*	IVDMD*	DM,%*
Wheat Silage (Year 1):	----- % of DM -----		
December 1981	9.48	50.62	35.10
January 1982	9.15	51.23	36.75
February 1982	9.07	51.00	33.18
March 1982	9.09	51.00	35.94
Mean Year 1	9.20	50.96	35.24
SEM	.096	.126	.766
Sorghum Silage (Year 2):			
January 1983	9.42	51.30	28.85
February 1983	7.99	54.65	25.62
March 1983	8.51	53.42	28.63
Mean Year 2	8.64	53.12	27.70
SEM	.412	.978	1.042
Sorghum Silage (Year 3):			
January 1984	10.02	49.29	27.07
February 1984	9.49	48.85	23.35
March 1984	9.07	47.42	23.20
Mean Year 3	9.53	48.42	24.54
SEM	.275	.543	1.270

* CP = Crude Protein; IVDMD = In Vitro Dry Matter Digestibility; DM = Dry Matter

TABLE IV

SILAGE COMPOSITION FOR BERMUDAGRASS GRAZING TRIALS

	CP*	IVDMD*	DM, %*
Sorghum Silage (Year 2):	-----% of DM ----		
June 1983	7.84	46.20	25.80
July 1983	7.89	45.70	26.13
August 1983	7.88	47.90	26.17
Mean Year 2	7.87	46.60	26.03
SEM	.015	.666	.117
Sorghum Silage (Year 3):			
June 1984	9.14	53.08	23.44
July 1984	9.40	52.97	26.33
August 1984	9.09	49.52	27.08
September 1984	9.18	47.30	27.00
Mean Year 3	9.20	50.72	25.96
SEM	.068	1.41	.858
Sorghum Silage (Year4):			
July 1985	8.99	56.56	25.58
August 1985	8.66	53.76	25.01
September 1985	8.60	48.32	26.28
Mean Year 4	8.75	52.88	25.62
SEM	.121	2.42	.367

* CP = Crude Protein; IVDMD = In Vitro Dry Matter Digestibility; DM = Dry Matter

CHAPTER IV

EFFECT OF SUPPLEMENTAL SILAGE ON FORAGE INTAKE, FLOW AND RUMINAL DIGESTION OF STOCKER CATTLE GRAZING WHEAT PASTURE AND BERMUDAGRASS

Summary

Twenty-four fall weaned steers were used in each of three years on wheat pasture and bermudagrass to determine effects of increasing amounts of supplemental silage on forage intake, flow, turnover, fill of undigested dry matter (UDM) in the gastrointestinal tract, and fecal output of steers grazing wheat and bermudagrass pastures. Steers were allotted to one of four treatments in a completely randomized experimental design in each trial, and steers were fed silage at 0, .35, .70, and 1.05 kg DM/100 kg body weight (BW) for treatments 1 to 4, respectively. In addition eight ruminally cannulated Hereford steers were alloted to one
of two treatments to determine effects of increasing silage on ruminal digestibility and rate of forage digestion. Steers of treatment 1 grazed wheat pasture and received no supplemental silage while steers of treatment 2 were

supplemented with .55 kg DM/100 kg BW. Forage intake and passage rate data were measured by feeding a pulse dosage of either ytterbium (Yb)-labeled wheat forage or bermudagrass followed by collection of fecal grab samples over a 4 day period. Fecal Yb concentrations were fitted to the one compartment model of Ellis et al. (1979). Rate and potential extent of forage digestion were determined in situ by the nylon bag technique. Data were fit to a nonlinear iterative equation to estimate the potentially digestible fraction and rate of forage digestion. Apparent extent of ruminal digestion was estimated from the equation of Orskov and McDonald (1979). Actual consumption of silage DM on wheat pasture was 0, .32, .60, and .78 kg/100 kg BW, whereas silage intakes on bermudagrass were 0, .34, .63, and .74 kg/100 kg body weight for treatments 1 to 4, respectively. As silage consumption increased, total DM intake increased over that of steers not fed silage, but at the expense of the basal forage. Both wheat and bermudagrass forage intake decreased linearly ($p<.10$) with increasing levels of silage. On wheat pasture both fill of UDM and fecal output increased linearly ($P<.05$) with increasing silage intake. Fecal output appeared to reach a plateau of approximately .87 kg/100 kg BW for steers fed higher levels of silage (i.e. treatments 3 and 4). From the in situ digestion the potential extent of DM and NDF digestion of wheat forage were not influenced by supplemental silage ($p>.05$). Yet, the ruminal degradability of the DM and NDF fractions were

higher ($p<.05$) where silage was fed. This was due in part to the increase, although nonsignificant ($p>.05$) in the rates of DM and NDF digestion. On bermudagrass, irregardless of the silage intake level, steers ate to a constant fill of approximately 1.36 kg/100 kg BW. Any differences in total DM intake at the higher intake levels of silage were due to the increased digestibility of total diet (i.e. bermudagrass + silage). Differences among treatments for flow and turnover of bermudagrass, and fill and fecal output of UDM were small and no significant trends were observed ($p>.10$). From the in situ digestion there was no apparent benefit from the supplemental silage. The potential extent of digestion, the rate of digestion, and the ruminal degradability of the DM and NDF fractions were not influenced ($p>.05$) by the addition of silage to the diet. Use of supplemental silage resulted in a decrease in basal forage intake although total forage intake increased. On wheat pasture the decrease in wheat forage intake was offset by an increase in wheat forage utilization while on bermudagrass the silage served as a substitute for bermudagrass with no apparent increase in bermudagrass utilization.

Introduction

The observed responses to supplementation on pasture have been well documented. In most cases, responses to supplementation can be expected when the pasture is of low

nutritive value, when the availability of pasture is low, or when some component of forage composition such as high water content limits intake (Davies, 1962;Davies and Lemcke,1977).

When animals are supplemented on pasture, questions arise as to what effect the supplement has on intake of the basal forage. Reported results are conflicting. Supplementation on pastures has resulted in positive associative effects and increased forage intake (Forbes et al., 1967; Umoh and Holmes, 1974). However, Lake et al. (1974) and Taylor and Wilkinson (1972) reported no effect of supplementation on forage intake. Consequently, if forage intake is not increased, animals may tend to substitute the basal forage for supplement. Yet, if there is a direct substitution (kg for kg) of supplement for forage, the overall energy status of the animal may be improved if the forage is of low nutritive value.

Therefore, the objectives of this study were to investigate effects of increasing amounts of supplemental silage on forage intake (wheat pasture and bermudagrass), flow and turnover of the basal forage, fill and fecal output of undigested dry matter in the gastrointestinal tract, ruminal degradability of the basal forage, and rate of forage digestion of steers grazing wheat pasture and bermudagrass.

Experimental Procedure

Wheat pasture

Cattle and Treatments. Twenty-four fall weaned Hereford and Hereford X Angus steers that averaged 279 kg in year 1 (1982), twenty-four Hereford and Hereford X Angus steers that averaged 230 kg in year 2 (1983), and twenty-four Hereford steers that averaged 259 kg in year 3 (1984) were blocked by weight within breed in years 1 and 2, and blocked by weight in year 3, and allotted to one of four treatments. Steers of all treatments grazed a single pasture each year. Steers of treatment 1 received no supplemental silage, while steers in treatments 2, 3, and 4 were supplemented with silage at .35, .70, and 1.05 kg DM/100 kg BW. In year 4 (1985) eight ruminally cannulated Hereford steers that averaged 320.7 kg were allotted to one of two treatments. Steers of treatment 1 served as the control and received no supplemental silage while steers of treatment 2 were supplemented with silage at .55 kg/100 kg BW. Wheat silage was used in year 1 whereas sorghum silage was used in years 2, 3 and 4.

Adaptation and Collection Periods. Four trials were conducted from Feb. 19 to March 6, 1982; March 4 to March 25, 1983; from Feb. 20 to March 9, 1984; and from March 1 to March 15, 1985. Each trial consisted of a 12-day adaptation period and a 4-day experimental period. During the adaptation periods of years 1 and 2, steers were removed

from wheat pasture at sunset and drylotted overnight. The following morning steers were fed silage in individual stalls and were allowed access to pasture after the silage was consumed. In years 3 and 4, steers were removed from pasture at sunset, immediately placed in individual feeding stalls and fed silage, and placed on pasture the following morning. Daily silage intakes were recorded. On the first day of the experimental periods, steers were fed 200 grams DM of ytterbium (Yb)-labelled wheat forage at 0800 hours in addition to their silage. In year 4, in addition to the Yb-labeled wheat forage, steers were fed approximately 200 grams of dysprosium (Dy)-labelled silage. The forages were labelled by the immersion technique as described by Mader et al. (1984) and Teeter et al. (1984) using .02 g Yb and Dy/g of forage DM for wheat pasture and silage, respectively. Fecal grab samples were subsequently collected from each steer at 0, 4, 8, 12, 24, 28, 32, 36, 48, 56, 72, 80, 96, and 104 hours post-dosage in year 1. In years 2 and 3 a 16 hour post-dosage collection time was added, whereas in year 4, 16 and 20 hour post-dosage collection times were added while the 96 and 104 hour post-dosage collection times were deleted for years 2, 3, and 4. Silage and wheat forage samples were collected daily, and were composited across days for analysis. Upon the completion of each trial, steers were weighed after a 15 to 17 hour shrink without feed and water.

In year 4 duplicate nylon bags containing approximately 3 grams of wheat forage DM or 4 grams of silage DM were ruminally incubated in each steer. Bags were incubated for 4, 8, 12, 19, 24, 36, 48, and 60 hours. When the incubation period was complete all bags were removed simultaneously. Bags were rinsed immediately after removal under running tap water manipulating the feed residues within the bags until the effluent was clear.

Analytical Procedures. All samples were dried in a force air oven at 55^{o}C and ground in a Wiley mill through a 1 mm mesh screen. Composited silage and wheat forage samples were analyzed for dry matter (DM), crude protein (CP) using the macro-Kjeldahl procedure (A.O.A.C., 1975), and in vitro dry matter digestibility (IVDMD) as outlined by Tilley and Terry (1963). The Tilley and Terry procedure was modified by adding urea (.5g/liter) to 1 part strained rumen fluid: 1 part McDougall's buffer solution and by decreasing the acid-pepsin digestion phase to 24 h. Approximately 1 gram of each fecal sample was ashed at 500^{o} C for 8 hours, digested in a solution of 1.5 N HNO_3 and 1.5 N HCL, and diluted with a 3.65% HCL solution (1.2M) containing 1000 ug K^{+}/per ml. Fecal ytterbium (Yb) and dysprosium (Dy) concentrations were determined by atomic absorption spectrophotometry using a nitrous-oxide acetylene flame. Residues from the nylon bags were analyzed for NDF content using the micro-digestion procedure as described by Waldern (1971) and Holechek and Vavra (1982). This procedure was

modified by deleting the sodium sulfite as suggested by Robertson and Van Soest (1981).

Calculations. Fecal Yb and Dy concentrations were fit to the one compartment model of Ellis et al. (1979).

$$Y = K_0 * T * e^{-k_1 T}$$

where Y= fecal marker concentration
Ko= initial concentration in the compartment
K_1= the time dependant rate constant
T= hour post dosage minus time delay

From these variables the following were calculated:

Fecal Output (FO), kg/day= (Marker dose,g/Ko)*24

Wheat Forage FO (WFO), kg/day= FO-[Silage DM Intake * Silage Indigestibility]

Wheat Forage DM Intake, kg/day= WFO/Indigestibility of wheat forage

Flow, %/h = .59635 * K_1;

Turnover,h = 1/Flow

Fill, kg = Marker dose,g/(Ko * K_1 * .59635)

The indigestibility of the wheat forage for all 4 years and the indigestibility of the silage used in years 1 and 2 were determined by IVDMD, whereas the indigestibility of the sorghum silage for years 3 and 4 were estimated in vivo using 6 steers in digestion trials in which steers were fed silage at 1.30 kg DM/100 kg BW.

Dry matter(DM) and NDF disappearance estimates from the residues during the in situ digestion were fit by a nonlinear iterative equation to estimate potential degradability (p) where :

$$p = a + b(1-e^{-c(t-T)})$$

where a= the highly soluble rapidly disappearing fraction

b= that fraction other than fraction a that disappears at a constant fractional rate of time
c= rate of digestion
t= time
T= lag time before digestion begins.

Incorporation of the lag time, Tau (T), led to high standard errors for estimated parameters. Consequently, the lag time was eliminated which reduced the standard errors for the constants a, b, and c. Therefore, potential degradability (p) was estimated as:

$$p = a + b(1-e^{-ct})$$

Using the fitted constants (i.e. a,b and c) the effective ruminal degradability (RD) for DM and NDF was estimated from the equation of Orskov and McDonald (1979) where:

$$RD = a + bc/(c+k)$$

The rate constant k represents rate of passage and was obtained from the forage intake and passage rate data based on the fecal excretion curves. When the nonlinear iterative equation estimated fraction a to be less than 0, lag time (T) was determined as T= -log((a/b)+1)/c. Consequently, ruminal degradability where fraction a was less than 0 was calculated as:

$$RD=(a+b)(c/c+k)e^{-kT}$$

Statistical Analysis of Data. Data were analyzed by least squares analysis of variance using a General Linear Model (GLM) procedure of the Statistical Analysis System (Helwig and Council, 1979) for a completely randomized experimental design. The statistical model for analysis included treatment, year, and treatment X year interaction

as sources of variation using the type II sum of squares. Duncan's New Multiple Range Test was used to detect differences among treatment means. In addition, orthogonal contrasts were conducted to test for linear, quadratic, and cubic effects of increasing silage intake. The statistical model for analysis of ruminal degradability included treatment, forage type, and treatment X forage type interaction as sources of variation.

Bermudagrass

Cattle and treatments. The same steers used for the wheat pasture study were used on bermudagrass. At the beginning of each trial, the steers averaged 400, 369, 362, and 361 kg for years 1, 2, 3, and 4, respectively. Steers were assigned to the same treatments as described in the "wheat pasture" experimental procedure. However, corn silage was used in place of wheat silage in the first year.

Adaptation and collection periods. Four trials were conducted from July 7 to July 20, 1982; from July 25 to Aug. 5, 1983; from July 13 to Aug. 3,1984; and from July 17 to August 1, 1985 in the same manner as outlined in the experimental procedure for the wheat pasture trials with the following differences: 1) steers were fed approximately 235 grams of ytterbium (Yb)-labelled bermudagrass, 2) the 96 and 104 hour post-dosage samples were deleted for all 4 years, 3) a 16 hour post-dosage collection time was added in years

2,3, and 4, and 4) a 20 hour post-dosage collection time was added in year 4.

Calculations. Percent DM and NDF disappearance data from the in situ digestion were fit to the equation $p=a+b(1-e^{-ct})$ as previously described in the "wheat pasture" experimental procedure. In addition because the standard errors for potential degradability were extremely high data were also fit to an additional equation to attempt to estimate the potentially digestible fraction with greater precision. The corresponding equation to estimate potential degradability (p) was:

$$p=b(1-e^{-ct})$$

where b=the potentially digestible fraction
c=rate of digestion
t=time

However, estimation of the potentially digestible fraction in this manner was unsuccessful because of the lack of fit of data to the equation. Thus, the original equation was used.

All analytical procedures and statistical analysis were conducted in a similar manner as described in the "wheat pasture" experimental procedure.

Results and Discussion

Composition of silage and forage during the forage intake trials on wheat pasture and bermudagrass is shown in tables V and VI, respectively.

Wheat Pasture

Forage intake and passage rate data for wheat pasture are presented in table VII for years 1,2, and 3 and in table VIII for year 4. During the first three years silage DM intakes for steers in treatments 2, 3 and 4 were .32, .60 and .78 kg/100 kg BW and were slightly lower than anticipated. As silage intake increased the amount of wheat forage consumed decreased linearly ($p<.10$) from 2.67 kg/100 kg BW for steers of treatment 1 to 2.20 kg/100 kg BW for steers of treatment 4 indicating that steers were substituting silage for wheat forage (figure 4). However, this was not a direct kg for kg substitution. Consequently, steers fed silage consumed more total forage than those steers of treatment 1. Total forage intakes for steers of treatments 1 to 4 were 2.67, 2.80, 2.89, and 2.98 kg/100 kg BW, respectively (table VII).

Flow (%/h) and turnover (h) of wheat forage in addition to fill (% of BW) and fecal output (% of BW) of undigested dry matter (UDM) in the gastrointestinal tract are presented in figure 5. Data relevant to flow and turnover for steers of treatment 3 in the first year did not fit observed trends and was deleted. Nevertheless, turnover decreased ($p<.10$) and flow increased ($p<.05$) linearly with increasing amounts of silage. Yet, differences among treatment means were small (4.70%) and differences in wheat forage utilization among treatments would not be expected. This is supported

by Varga and Prigge (1982) who demonstrated that digestibility of alfalfa and orchardgrass was not influenced ($p>.05$) as rate of passage increased 5.3 to 6.6 %/h. Both fill and fecal output of undigested residues in the gastrointestinal tract increased as steers increased their silage intakes. Fill of UDM increased linearly ($p<.05$) from .47 to .63 kg/100 kg BW, whereas fecal output increased linearly ($p<.05$) from .64 to .90 kg/100 kg BW. Although fecal output did exhibit a linear increase, fecal output appeared to reach an upper limit of approximately .87 kg/100 kg BW for steers of treatments 3 and 4. This is consistent with data of Conrad et al. (1964) who conducted trials to determine voluntary intake on lactating dairy cows fed rations of varying digestibility. In these studies voluntary intake appeared to vary to yield a fecal output of .94 kg OM/ 100 kg BW. Consequently, forage intake may have been limited by fecal output more so than by fill of UDM in the gastrointestinal tract.

In year 4 all forage intake and passage rate data were slightly lower than that observed for years 1,2, and 3. Nevertheless, the same trends were observed (table VIII). As silage DM intakes increased from 0 kg/100 kg BW for steers of treatment 1 to .55 kg/100 kg BW for steers of treatment 2 the amount of wheat forage consumed by steers of treatment 2 decreased by .6 kg when compared with steers of treatment 1, although the total amount of forage consumed was similar for steers of both treatments ($p>.05$). This

indicated that steers were substituting silage for wheat forage. Contrary to years 1,2, and 3, there was a tendency for flow and turnover of wheat forage to decrease and increase, respectively as the amount of supplemental silage fed increased. Yet, the treatment differences were not significant ($p>.05$). Consequently, treatment differences would not be expected in forage digestibility as previously mentioned by Varga and Prigge (1982). Both fill and fecal output also increased as the level of supplemental silage increased. This may possibly be due to the decrease in the digestibility of the total diet compared to that of wheat forage alone.

Data from the in situ digestion trial (table IX) indicated that the potentially digestible fractions of DM and NDF of wheat forage were not influenced by the addition of silage to the diet ($p>.05$). Approximately 95 % of wheat forage DM and 66 % of wheat forage NDF were potentially digestible by steers of both treatments. This is contrary to Mertens and Loften (1980) who indicated that the potential extent of digestion of fescue, alfalfa, and orchardgrass was decreased by the addition of corn and wheat starch to the diet. Moreover, these researchers noted that digestion lag was increased as the percent of starch increased in the diet. Yet, in this study there was no apparent delay before digestion began by feeding supplemental silage on pasture. Rather, digestion lag for the cell wall fraction of wheat forage was reduced from

12.63 h for steers of treatment 1 to 9.07 h for steers of treatment 2 ($p<.05$). Both rates of DM and NDF digestion (%/h) tended to increase ($p>.05$) when silage was added to the diet. As the amount of supplemental silage increased, rate of DM digestion increased from 8.49 to 12.34 %/h and rate of NDF digestion increased from 8.04 to 11.26 %/h. Thus, because rate of digestion increased and rate of passage decreased with the addition of silage to the diet the extent of ruminal digestion of DM and NDF was significantly increased ($p<.05$). Approximately 63.07 % of the potentially digestible fraction of wheat forage DM was digested in the rumen of steers fed silage while only 52.52 % was digested in steers that grazed wheat forage and were fed no supplemental silage. In a similar manner, there was a 49% increase in digestion of the cell wall fraction where steers were fed silage. The increase in wheat forage utilization may have been the result of increased cellulose digestibility. Arias et al. (1951) demonstrated that cellulose digestibility in vitro was enhanced when small amounts of available carbohydrates were added to the diet.

With the addition of silage to the diet the potentially digestible fraction of silage DM and NDF was significantly increased ($p<.05$) for steers fed silage. Yet, the rates of DM and NDF digestion of the potentially digestible fractions tended to be higher, although nonsignificantly ($p>.05$), for steers of treatment 1. Consequently, the extent of ruminal degradability of silage DM and NDF was similar for steers of

both treatments.

Bermudagrass

Forage intake and passage rate data for bermudagrass in years 1, 2, and 3 are shown in table X and in table XI for year 4. Silage DM intakes for steers of treatments 2, 3 and 4 were .34, .63 and .74 kg/100 kg BW. With increasing amounts of supplemental silage, bermudagrass forage intake decreased linearly ($p<.01$) from 2.17 kg/100 kg BW for steers of treatment 1 to 1.70 kg/100 kg BW for steers of treatment 4 (figure 6). However, total forage intake increased linearly ($p<.05$) from 2.17 to 2.44 kg/100 kg BW. Although the steers substituted silage for bermudagrass, the overall effect of feeding silage was to increase the total amount of forage consumed.

Flow (%/h) and turnover (h) of bermudagrass in addition to fill (% of BW) and fecal output (% of BW) of UDM in the gastrointestinal tract are presented in figure 7. Regardless of the level of intake or the amount of silage consumed neither flow nor turnover of bermudagrass was significantly influenced ($p>.05$). Flow ranged from 3.72 to 3.90 %/h whereas turnover, the reciprocal of flow, ranged from 26.3 to 27.6 h. Thus, it would be logical to assume that bermudagrass forage utilization would be similar for all treatments since digestibility of the fibrous fraction is dependant upon ruminal retention (Grovum, 1977). Fill and fecal output of undigested residues were similar among

treatments, and no significant trends were observed. Fill and fecal output for steers of all treatments were approximately 1.36 kg/100 kg BW and 1.23 kg/100 kg BW per day, respectively. These data suggest that both fill and fecal output may limit the amount of bermudagrass consumed. The observed differences in total intake for steers of each treatment may have been due to the increased digestibility of the total diet over that of bermudagrass alone. This is supported by Conrad et al. (1964) who proposed that if voluntary intake is controlled by gut fill, increasing the digestibility of the ration will cause an increase in voluntary intake.

In year 4, as the level of supplemental silage increased bermudagrass forage intake decreased ($p>.05$) while total forage intake increased from 2.35 kg DM/100 kg BW for steers of treatment 1 to 2.69 kg/100 BW for steers of treatment 2 (table XI). Yet, this difference was not significant ($p>.05$). Flow and turnover of bermudagrass were not influenced by supplemental silage ($p>.05$) although flow and turnover were lower and higher, respectively for steers of treatment 2. Moreover, fill and fecal output were higher for steers fed silage. Fill increased significantly ($p<.05$) from 1.12 % of BW for steers of treatment 1 to 1.49 % of BW for steers of treatment 2 while fecal output increased nonsignificantly ($p>.05$) from 1.05 % of BW for steers of treatment 1 to 1.21 % of BW for steers of treatment 2. The

significant increase in fill can be attributed to the increase in total forage intake.

Data from the in situ digestion on bermudagrass are presented in table XII. During the course of the collection period, all 60 h and some of the 48 h bags were lost. Therefore, the potential extent of digestion and the digestion rate constants are based on 48 h of incubation. Data from Smith et al. (1972) indicated that digestion of forages is not complete by 72 h. Consequently, the estimates of the potentially digestible fraction and ruminal degradability were lower than anticipated with greater variability. Nevertheless, as the amount of supplemental silage increased, neither the rates of DM and NDF digestion nor digestion lag were influenced by supplemental silage ($p>.05$). However, the potentially digestible fractions of bermudagrass DM and NDF were decreased nonsignificantly ($p>.05$) by 8.2 and 45.9 %, respectively. Therefore, because there was no difference in digestion rates and passsage rates were similar, ruminal degradability of DM and NDF were similar for steers of both treatments ($p>.05$).

With the addition of silage to the diet, neither the rates of digestion, digestion lag, nor the potentially digestible fractions of silage DM and NDF were influenced ($p>.05$). However, the potentially digestible fraction of silage DM was increased nonsignificantly ($p>.05$) by 6% while the potentially digestible fraction of silage NDF was decreased by 15 %. This relationship between increasing the

potential digestibility of the DM fraction and decreasing the digestibility of the NDF fraction can not be explained and may be artificial in this data set due to the large variance. Data from Varga and Hoover (1983) indicated that DM and NDF disappearance tended to parallel (r=.74). Nevertheless, ruminal degradability of silage DM was increased by 16 % whereas ruminal degradability of silage NDF was increased by 14 % for steers fed silage.

In summary supplemental silage on wheat pasture and bermudagrass allowed for stocking densities to be doubled without decreasing cattle performance. Both wheat forage and bermudagrass intakes decreased as the amount of supplemental silage increased. On wheat pasture fill and fecal output increased linearly as the level of silage increased though it appeared that steers would eat until fecal output was approximately .87 kg/100 kg BW. Use of supplemental silage resulted in an increase in wheat forage utilization by increasing rate of digestion and ruminal degrability of wheat forage DM and NDF. Conseqently, the increase in wheat forage utilization allowed for stocking densities to be doubled without decreasing cattle performance. On bermudagrass, steers ate to a constant fill of 1.36 kg/100 kg BW. There appeared to be no increase in bermudagrass utilization when silage was fed. Consequently, increases in total DM intake for steers of each treatment were the result of increased digestibility of the total diet over that of bermudagrass alone. On bermudagrass use of

supplemental silage resulted in the substitution of silage for bermudagrass which allowed for stocking densities to be doubled.

TABLE V

SILAGE AND FORAGE COMPOSITION DURING FORAGE INTAKE TRIALS ON WHEAT PASTURE

Feedstuff	Availability	CP*	IVDMD*	DM,%*	N
	kg DM/hectare	-- % of DM --			
Year 1:					
Wheat Silage		9.44	50.73	36.68	8
Wheat Forage	543	27.25	74.90	25.80	5
Year 2:					
Sorghum Silage		8.64	56.38	27.92	8
Wheat Forage	2329	30.19	77.80	16.13	7
Year 3:					
Sorghum Silage		9.74	50.00	25.44	8
Wheat Forage	1810	24.33	75.22	29.70	4
Year 4:					
Sorghum Silage		8.35	56.65	20.14	12
Wheat Forage	837	30.25	80.50	17.26	6
SEM	183	.187	2.308	.917	

* CP = Crude Protein; IVDMD = In Vitro Dry Matter Digestibility; DM = Dry Matter

TABLE VI

SILAGE AND FORAGE COMPOSITION DURING FORAGE INTAKE TRIALS ON BERMUDAGRASS

Feedstuff	Availability	CP*	IVDMD*	DM,%*	N
	kg DM/hectare	-- % of DM --			
Year 1:					
Corn Silage		10.79	56.20	33.70	4
Bermudagrass	3608	10.59	47.60	42.81	5
Year 2:					
Sorghum Silage		8.30	46.53	27.27	8
Bermudagrass	2544	10.79	39.90	34.63	4
Year 3:					
Sorghum Silage		10.36	63.70	29.01	6
Bermudagrass	2232	10.82	46.47	41.05	4
Year 4:					
Sorghum Silage		8.23	50.67	23.81	6
Bermudagrass	2357	10.32	54.05	44.51	5
SEM	370	.423	1.265	1.054	

* CP = Crude Protein; IVDMD = In Vitro Dry Matter Digestibility; DM = Dry Matter

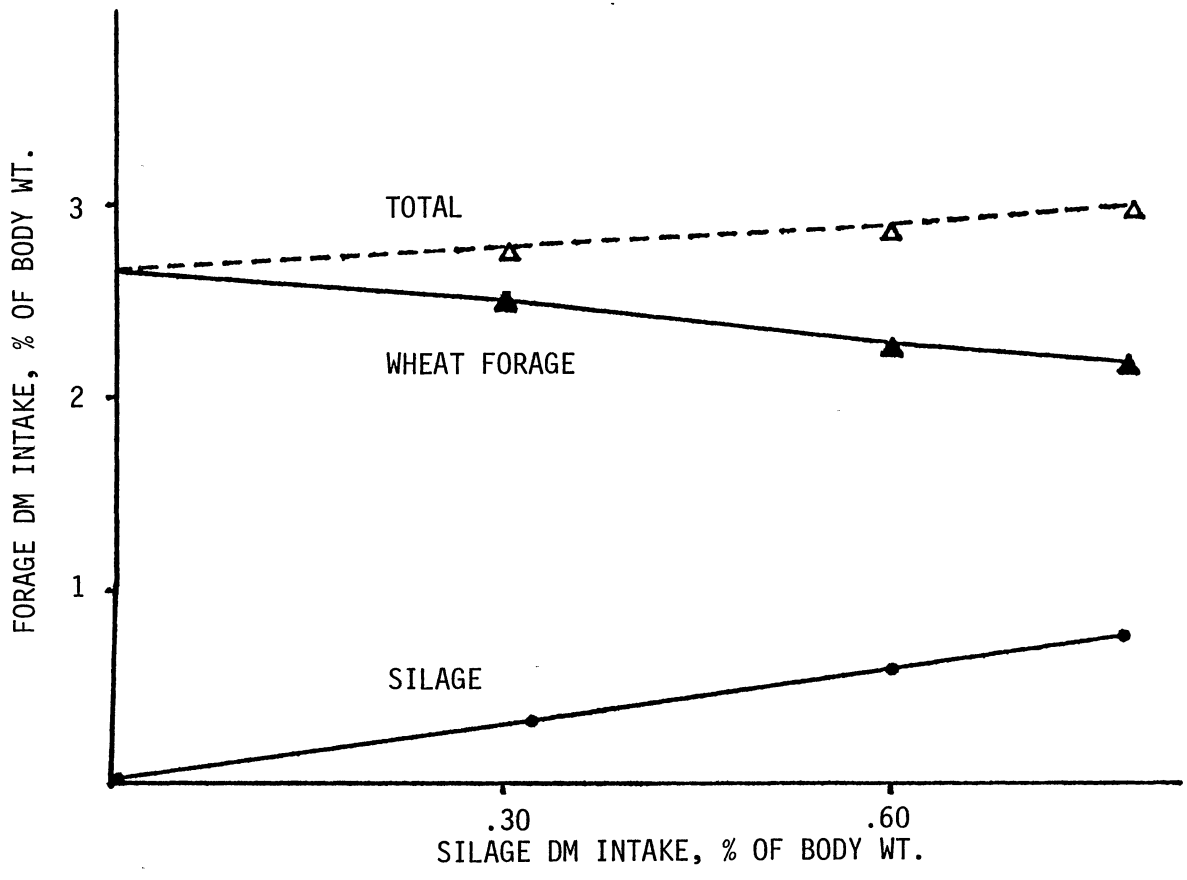

Figure 4. Forage DM Intake of Steers Grazing Wheat Pasture. Years 1, 2 and 3

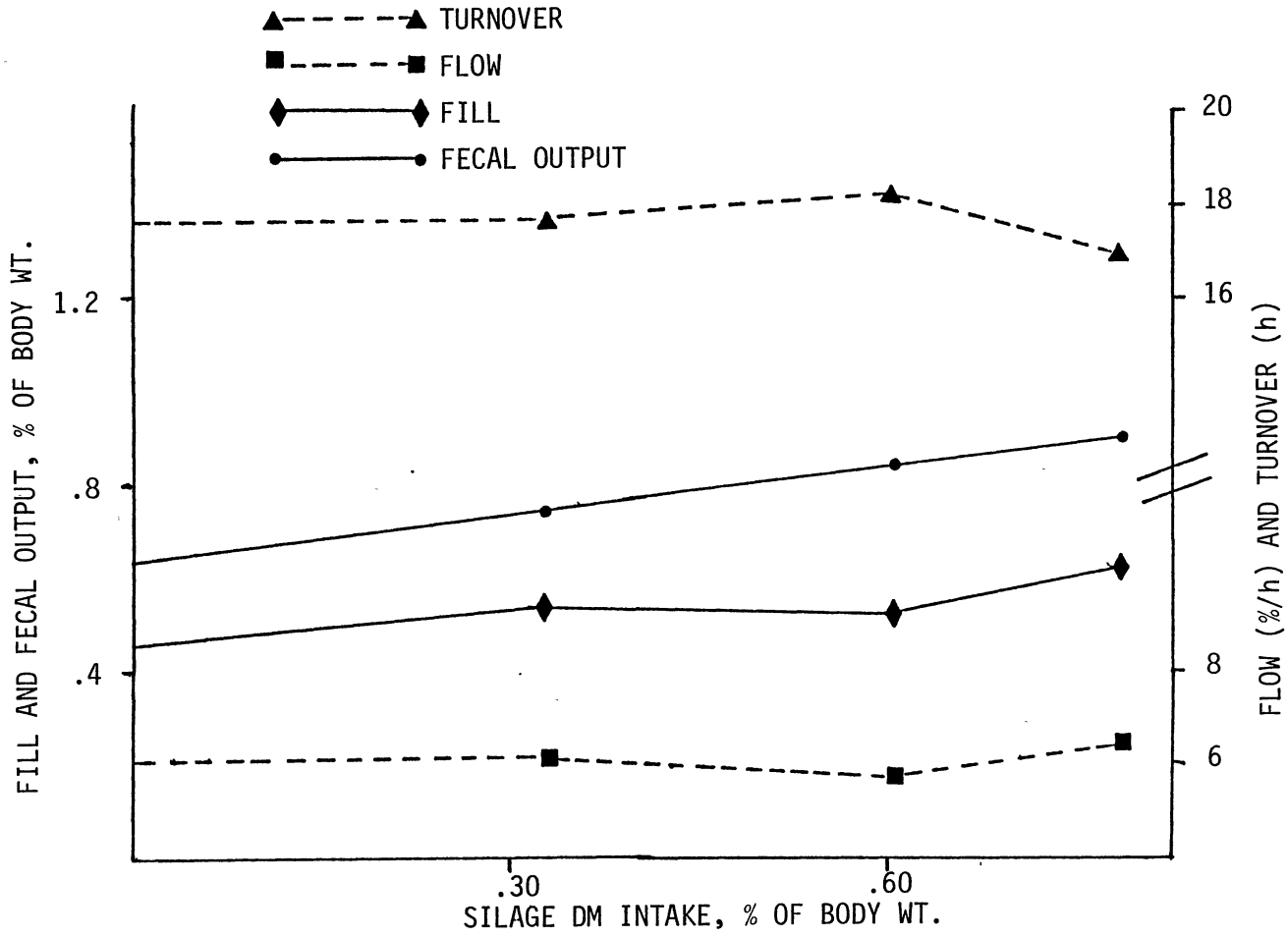

Figure 5. Fill and Fecal Output of the Gastrointestinal Tract and Flow and Turnover of Wheat Forage. Years 1, 2 and 3

TABLE VII

FORAGE INTAKE, FLOW, DIGESTIVE TRACT FILL, AND FECAL OUTPUT OF STEERS FED SILAGE ON WHEAT PASTURE (Years 1, 2 and 3)

Treatment	1	2	3	4	SEM	O.S.L of Trends*		
Number of Steers	18	17	17(11)**	16		L	Q	C
Silage DM Intake, %BW	.00[a]	.32[b]	.60[c]	.78[d]	.026			
Wheat Forage Intake, %BW	2.67[a]	2.48[a]	2.30[c]	2.20[a]	.130	.102	.995	.952
Total Forage Intake, %BW	2.67[a]	2.80[a]	2.89[a]	2.98[a]	.129	.282	.988	.938
Flow, %/h	6.07[a]	6.09[a]	5.68[a]	6.36[a]	.197	.034	.725	.945
Turnover, h	17.59[a]	17.59[a]	18.18[a]	16.86[a]	.518	.073	.784	.959
Fill, %BW	.47[a]	.54[b]	.52[ab]	.63[c]	.021	.023	.953	.459
Fecal Output, %BW	.64[a]	.75[b]	.84[c]	.90[c]	.032	.006	.917	.997

*O.S.L = Observed Significance Levels
L= Linear Q= Quadratic C= Cubic
** Only 11 steers were used for calculating flow and turnover of wheat forage
acbdMeans in the same row with different superscripts are different (P<.05)

TABLE VIII

FORAGE INTAKE, FLOW, DIGESTIVE TRACT FILL, AND FECAL OUTPUT OF STEERS GRAZING WHEAT PASTURE (Year 4)

Treatment Number of Steers	1 4	2 4	SEM
Silage DM Intake, %BW	.00[a]	.55[b]	.021
Wheat Forage Intake, %BW	2.27[a]	1.67[a]	.241
Total Forage Intake, %BW	2.27[a]	2.22[a]	.233
Wheat Flow, %/h	6.57[a]	5.78[a]	.732
Wheat Turnover, h	16.24[a]	17.51[a]	1.849
Fill, %BW	.30[a]	.42[a]	.056
Fecal Output, %BW	.44[a]	.57[a]	.044
Silage Flow, %/h	5.17[a]	4.86[a]	.600
Silage Turnover, h	20.46[a]	21.01[a]	.861

ab Means in a row with different superscripts are different ($P<.05$)

TABLE IX

RUMINAL DIGESTION OF WHEAT FORAGE AND SILAGE OF STEERS ON WHEAT PASTURE (Year 4)

Treatment	1	2	SEM
Silage DM Intake, %BW	0	.55	
Wheat Forage			
DM			
Potentially Digestible, %	95.24[a]	95.38[a]	4.22
Digestion Rate, %/h	8.49[a]	12.34[a]	1.63
Digestion Lag, h	.769[a]	.519[a]	.82
Ruminal Degradability,%	52.52[a]	63.07[b]	2.11
NDF			
Potentially Digestible, %	66.06[a]	66.04[a]	4.22
Digestion Rate, %/h	8.04[a]	11.26[b]	1.59
Digestion Lag, h	12.63[a]	9.07[b]	.95
Ruminal Degradability, %	16.71[a]	24.87[b]	2.20
Sorghum Silage			
DM			
Potentially Digestible, %	46.07[a]	69.53[b]	.42
Digestion Rate, %/h	6.53[a]	4.00[a]	1.63
Ruminal Degradability, %	29.93[a]	33.22[a]	2.11
NDF			
Potentially Digestible, %	23.53[a]	51.07[b]	4.99
Digestion Rate, %/h	7.08[a]	4.08[a]	1.58
Digestion Lag, h	11.00[a]	10.77[a]	.95
Ruminal Degradability, %	7.78[a]	11.92[a]	2.20

ab Means in a row with different superscripts are different ($p<.05$)

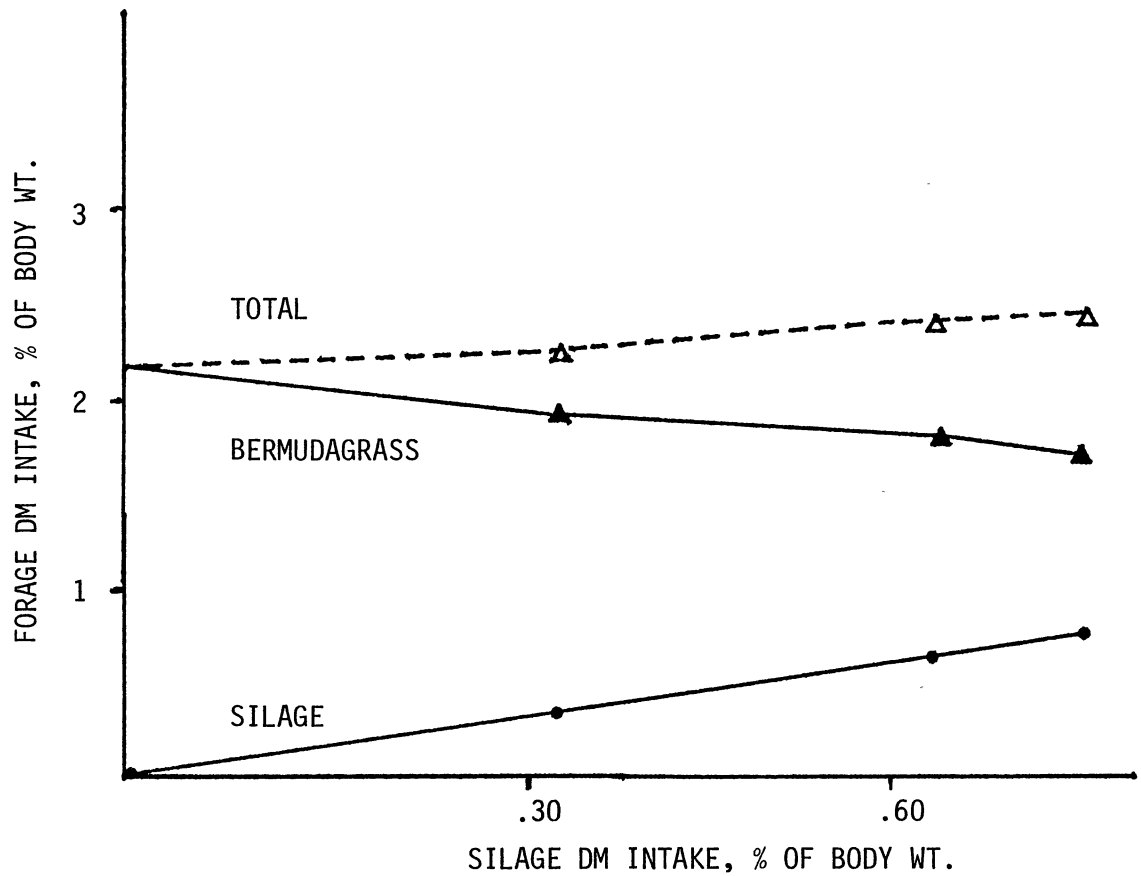

Figure 6. Forage DM Intakes of Steers Grazing Bermudagrass Years 1, 2 and 3

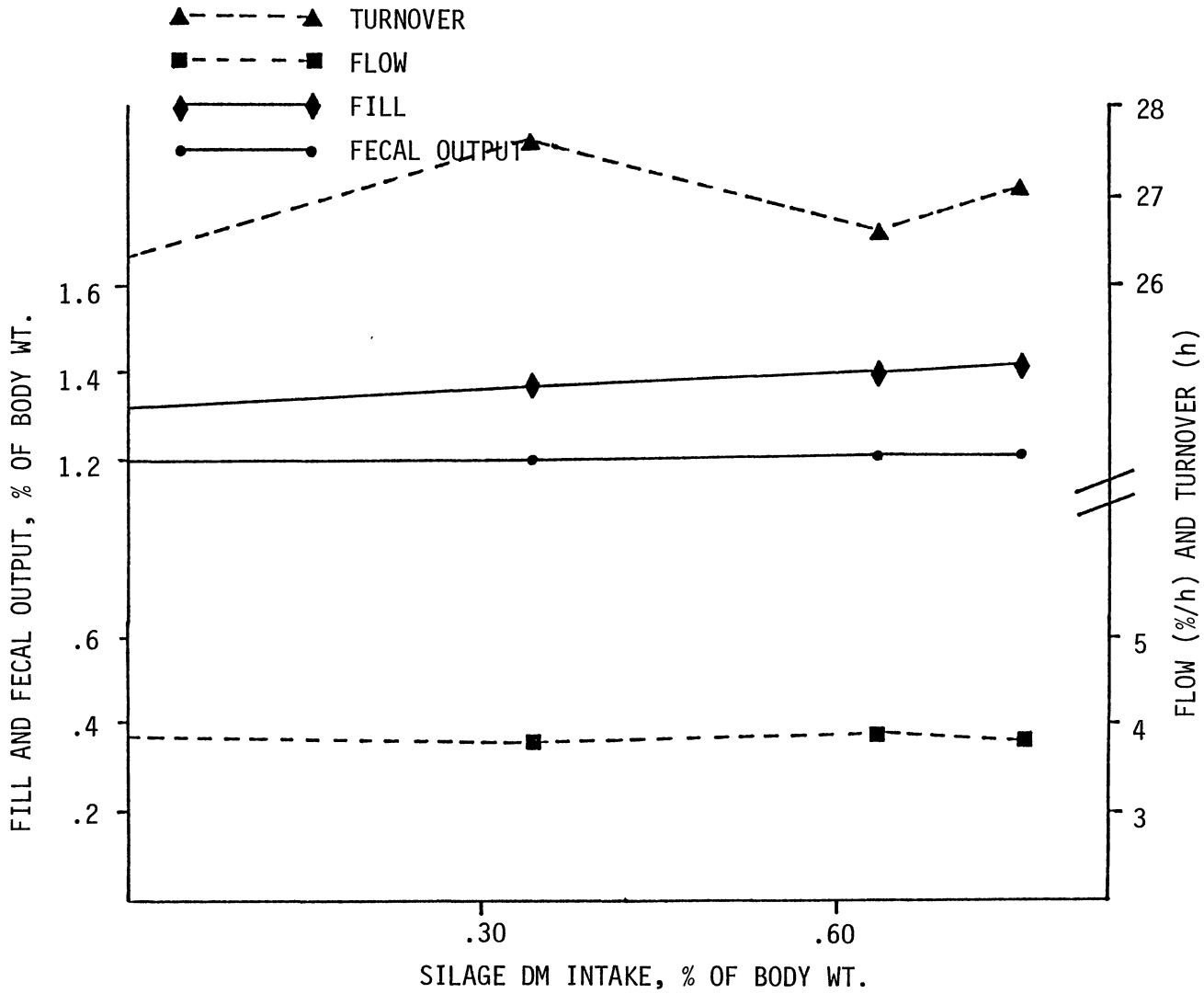

Figure 7. Fill and Fecal Output of the Gastrointestinal Tract and Flow and Turnover of Bermudagrass. Years 1, 2 and 3

TABLE X

FORAGE INTAKE, FLOW, DIGESTIVE TRACT FILL, AND FECAL OUTPUT OF STEERS FED SILAGE ON BERMUDAGRASS (Years 1, 2 and 3)

Treatment	1	2	3	4	SEM	O.S.L. of Trends*		
Number of Steers	18	17	16	16		L	Q	C
Silage DM Intake, %BW	.00[a]	.34[b]	.63[c]	.74[d]	.018			
Bermudagrass Forage Intake %BW	2.17[a]	1.90[b]	1.78[b]	1.70[b]	.090	.005	.658	.855
Total Forage Intake, %BW	2.17[a]	2.24[a]	2.41[a]	2.44[a]	.087	.034	.649	.859
Flow, %/h	3.91[a]	3.72[a]	3.90[a]	3.84[a]	.110	.936	.366	.202
Turnover, h	26.34[a]	27.66[a]	26.66[a]	27.08[a]	.786	.782	.327	.330
Fill, %BW	1.32[a]	1.37[a]	1.39[a]	1.43[a]	.176	.186	.902	.594
Fecal Output, %BW	1.20[a]	1.19[a]	1.26[a]	1.27[a]	.048	.149	.472	.812

*O.S.L.= Observed Significance Levels
L= Linear Q= Quadratic C= Cubic
abcdMeans in the same row with different superscripts are different ($p<.05$)

TABLE XI

FORAGE INTAKE, FLOW, DIGESTIVE TRACT FILL, AND FECAL OUTPUT OF STEERS GRAZING BERMUDAGRASS (Year 4)

Treatment Number of Steers	1 4	2 4	SEM
Silage DM Intake, %BW	.00[a]	.44[b]	.025
Bermudagrass Forage Intake, %BW	2.35[a]	2.26[a]	.102
Total Forage Intake, %BW	2.35[a]	2.69[a]	.116
Bermudagrass Flow, %/h	3.92[a]	3.42[a]	.169
Bermudagrass Turnover, h	25.60[a]	29.45[a]	1.334
Fill, %BW	1.12[a]	1.49[b]	.097
Fecal Output, %BW	1.05[a]	1.21[a]	.052
Silage Flow, %/h	4.61[a]	3.61[a]	.385
Silage Turnover, h	21.68[a]	27.69[a]	2.590

ab Means in a row with different superscripts are different ($p<.05$)

TABLE XII

RUMINAL DIGESTION OF BERMUDAGRASS AND SILAGE OF STEERS ON BERMUDAGRASS (Year 4)

Treatment	1	2	SEM
Silage DM Intake, %BW	0	.44	
Bermudagrass			
DM			
Potentially Digestible, %	70.20[a]	64.36[a]	10.28
Digestion Rate, %/h	2.22[a]	2.12[a]	.67
Digestion Lag, h	4.06[a]	3.16[a]	.71
Ruminal Digestion, %	17.48[a]	18.48[a]	1.76
NDF			
Potentially Digestible, %	64.63[a]	44.30[a]	8.86
Digestion Rate, %/h	2.96[a]	3.62[a]	.92
Digestion Lag, h	5.99[a]	7.33[a]	.48
Ruminal Digestion, %	16.95[a]	17.50[a]	1.38
Sorghum Silage			
DM			
Potentially Digestible, %	64.52[a]	74.20[a]	10.28
Digestion Rate, %/h	3.98[a]	3.39[a]	.67
Digestion Lag, h	.33[a]	.55[a]	1.42
Ruminal Digestion, %	31.34[a]	36.31[a]	1.75
NDF			
Potentially Digestible, %	72.30[a]	68.19[a]	8.64
Digestion Rate, %/h	3.21[a]	3.52[a]	.90
Digestion Lag, h	1.50[a]	1.45[b]	.55
Ruminal Digestion, h	30.44[a]	34.80[b]	1.35

ab Means in a row with different superscripts are different ($p<.05$)

LITERATURE CITED

Adolph, E.F. 1947. Urges to eat and drink in rats. Am. J. Physiol. 151:110.

Akin, D.E. and D. Burdick. 1975. Percentage of tissue types in tropical and temperate grass leaf blades and degradation of tissues by rumen microorganisms. Crop Sci. 15:661.

Akin, D.E., D.Burdick, and G.E.Michaels. 1974. Rumen bacterial interrelationships with plant tissue degradation revealed by transmission electron microscopy. Appl. Micro. 33:1149.

A.O.A.C. 1975. Official methods of Analysis (12th ed.). Assoc. of Official Analytical Chemists, Washington D.C.

Arias, C., W. Burroughs, P. Gerlaugh, and R.M. Bethke. 1951. The influence of different amounts and sources of energy upon in vitro urea utilization by rumen microorganisms. J. Anim. Sci. 10:683.

Bae, D.H., J.G. Welch, and A.M. Smith. 1979. Forage intake and rumination by sheep. J. Anim. Sci. 49:1292.

Bae, D.H., J.G. Welch, and A.M. Smith. 1981. Efficiency of mastication in relation to hay intake by cattle. J. Anim. Sci. 52:1371.

Balch, C.C. and R.C. Campling. 1965. Rate of passage of digesta through the digestive tract. Physiology of digestion in the ruminant. Butterworth's, Washington D.C.

Barnes, K.C., J.D. Netherton, T.L. Evicks, G.W. Horn, and W.E. McMurphy. 1980. Performance of steers grazed on bermudagrass: A cooperative field trial. Ok. Agr. Exp. Sta. Res. Rep. MP 107:72.

Baumgardt, B.R. 1970. Control of feed intake in the regulation of energy balance. In Phillipson, A.T. (Ed.). Physiology of Digestion and Metabolism in the Ruminant. pp. 226-253.

Bhattacharya, A.N. and R.G. Warner. 1968. Effect of propionate and citrate on depressed feed intake after

intraruminal injection of acetate in dairy cattle. J. Dairy. Sci. 51:1091.

Blaxter, K.L., F.W. Wainman, and R.S. Wilson. 1961. The regulation of food intake by sheep. Anim. Prod. 3:51

Campling, R.C., M. Freer, and C.C. Balch. 1961. Factors affecting the voluntary intake of food by cows. 2. The relationship between the voluntary intake of roughages, the amount of digesta in the reticulo-rumen and the rate of disappearance. Brit. J. Nut. 15:531.

Chai, K., P.M. Kennedy, and L.P. Mulligan. 1984. Reduction in particle size during rumination in cattle. Can. J. Anim. Sci. 64:339 (Abstr.).

Conrad, H.R., A.D. Pratt, and J.W. Hibbs. 1964. Regulation of feed intake in dairy cows. I. Change in importance of physical and physiological factors with increasing digestibility. J. Dairy Sci. 47:54.

Crampton, E.W. 1957. Interrelationships between digestible nutrient content, voluntary dry matter intake and the overall feeding value of forages. J. Anim. Sci. 16:546.

Davies, H.L. 1962. Intake studies in sheep involving high fluid intake. Proc. Aust. Soc. Anim. Prod. 4:167.

Davies, H.L. and B.G. Lemcke. 1977. Studies in the supplementation of grazing frieson steers in the central coast area of New South Wales. Aust. J. Exp. Agric. Anim. Husb. 17:545.

Deswysen, A.G. and H.J. Ehrlein. 1981. Silage intake, rumination and psuedo-rumination activity in sheep studied by radiography and jaw movement recordings. Brit. J. Nut. 46:327.

Dulphy, J.P., B. Remond, and M. Theriez. 1980. Ingestive behavior and related activities in ruminants. Digestive Physiology and Metabolism in Ruminants. A.V.I. Publishing Westport Conn. pp. 103-122.

Egan, A.R. 1965. Nutritional studies and intake regulation in sheep. II. The influence of sustained duodenal infusions of casein or urea upon voluntary intake of low protien roughages by sheep. Aust. J. Agr. Res. 16:451.

Ehle, F.R and M.R. Murphy. 1982. In situ particle size reduction and the effect of particle size on degradation of crude protein and dry matter in the rumen of dairy steers. J. Dairy Sci. 65:963.

Elder, W.C. 1967. Winter grazing small grains in Oklahoma. O.K. Agric. Exp. Sta. Bull. B-654.

Ellis, W.C. 1978. Determinants of grazed forage intake and digestibility. J. Dairy Sci. 61:1828.

Ellis, W.C., J.H. Matis, and J.C. Lascano. 1979. Quantitating ruminal turnover. Fed. Proc. 38:2702.

Ellis, W.C., J.H. Matis, K.R. Pond, C.R. Lascano, and J.P. Telford. 1984a. Dietary influences on flow rate and digestive capacity. Herbivore Nutrition, Science Press Craighall, South Africa pp.269-293.

Ellis, W.C. and J.P. Telford. 1984b. Forage and grazing effects on intake and utilization of annual ryegrass by cattle. National Wheat Pasture Symposium Proceedings Ok. St. Univ. M.P. 115 pp. 223-234.

el-Shazly, K., B.A. Dehority, and R.R. Johnson. 1961. Effects of starch on the digestion of cellulose in vitro and in vivo by rumen microorganisms. J. Anim. Sci. 20:268.

Evans, E.W., G.R. Pearce, J. Burnett, and S.L. Pillinger. 1973. Changes in some physical characteristics of the digesta in the reticulo-rumen of cows fed once daily. Brit. J. Nut. 29:357.

Forbes, T.J., A.M. Raven, J.H.D. Irwin, and K.L. Robinson. 1967. The utilization of grass fed indoors to young beef cattle, with or without supplementary barley. J. Brit. Grasl. Soc. 22:158.

Ford, M.J. 1984. Supplementation of wheat pasture stocker cattle with silage. M.S. Thesis. Library, Ok. St. Univ.

Gill, J., R.C. Campling, and D.R. Westgarth. 1966. A study of chewing during eating in the cow. Brit. J. Nut. 20:13.

Gill, S.S., H.R. Conrad, and H.A. Hibbs. 1969. Relative rate of in vitro cellulose disappearance as a possible estimator of digestible dry matter intake. J. Dairy Sci. 52:1687.

Gordon, J.G. 1958. The act of rumination. J. Ag. Sci. 50:34.

Grovum, W.L. and V.J. Williams. 1973. Rate of passage of digesta in sheep. 4. Passage of marker through the alimentary tract and the biological relevance of

rate-constants derived from the changes in concentration of marker in feces. Brit. J. Nut. 30:313.

Grovum, W.L. 1977. Rate of passage of digesta in sheep. 6. The effect of level of food intake on mathematical predictions of the kinetics of digesta in the reticulo-rumen and intestines. Brit. J. Nut. 38:425.

Hodgson, H.J. 1967. The importance of forages in livestock production in the United States. Forage: Economics/Quality. Amer. Soc. Agron. Spec. Pub. No. 13.

Holechek, J.L. and M. Vavra. 1982. Comparison of micro- and macro- digestion methods for fiber analysis. J. Range Manage. 35:799.

Horn, G.W., T.L. Mader, S.L. Armbruster, and R.R. Frahm. 1981. Effect of monensin on ruminal fermentation, forage intake and weight gains of wheat pasture stocker cattle. J. Anim. Sci. 52:447.

Krysl, F.J., F.T. McCollum, and M.L. Galyean. 1985. Estimation of fecal output and particulate passage rate with a pulse dose of Ytterbium-labelled forage. J. Range Manage. 38:180.

Lake, R.P., D.C. Clanton, and J.F. Karn. 1974. Intake, digestibility and nitrogen utilization of steers consuming irrigated pasture as influenced by limited energy supplementation. J. Anim. Sci. 38:1291.

Lee, J.A. and G.R. Pearce. 1984. The effectiveness of chewing during eating on particle size reduction of roughages by cattle. Aust. J. Agric. Res. 35:609.

Lofgreen, P.A. and R.G. Warner. 1972. Relationship of dietary caloric density and certain blood metabolites to voluntary feed intake in mature wethers. J. Anim. Sci. 35:1239.

Mader, T.L., G.W. Horn, W.A. Phillips, and R.W. McNew. 1983. Low quality roughages for steers grazing wheat pasture. I. Effect on weight gains and bloat. J. Anim. Sci. 56:1021.

Mader, T.L., R.G. Teeter, and G.W. Horn. 1984. Comparison of forage labelling techniques for conducting passage rate studies. J. Anim. Sci. 58:208.

McDougall, E.I. 1948. Studies on ruminal saliva. I. The composition and output of sheep's saliva. Biochem J. 43:49.

Mertens, D.R. 1977. Dietary fiber components: relationship to the rate and extent of ruminal digestion. Fed. Proc. 36:187.

Mertens, D.R. and J.R. Loften. 1980. The effect of starch on forage fiber digestion kinetics in vitro. J. Dairy Sci. 63:1437.

Miller, B.G. and R.B. Muntifering. 1985. Effect of forage: concentrate ratio on kinetics of forage fiber digestion in vivo. J. Dairy Sci. 68:40.

Minson, D.J. 1982. Effect of chemical and physical compostion of herbage upon intake. In: J.B. Hacher (ed.) Nutritional Limits to Animal Production from Pastures. (Symposium) Brisbane, Aust. Commonwealth Agric. Bureau, Slouth U.K. pp.167-182.

Mosely, G. 1981. Herbage quality and physical breakdown in the foregut of sheep. Proc. N.Z. Soc. Anim. Proc. 41:142. (Abstr.).

Mosely, G. and J.R. Jones. 1984. The physical digestion of perennial ryegrass and white clover in the foregut of sheep. Brit. J. Nut. 52:384.

Mudgal, V.D., R.M. Dixon, P.M. Kennedy, and L.P. Milligan. 1982. Effect of two levels of intake on retention times of liquid, particle and microbial markers in the rumen of sheep. J. Anim. Sci. 54:1051.

Murphy, M.R. and J.M. Nicoletti. 1984. Potential reduction of forage and rumen digesta particle size by microbial action. J. Dairy Sci. 67:1221.

Newton, J.E. and N.E. Young. 1974. The performance and intake of weaned lambs grazing S24 perennial ryegrass, with and without supplementation. Anim. Prod. 18:191.

Oliver, W.M. 1975. Effect of monensin on gains of steers grazed on coastal bermudagrass. J. Anim. Sci. 41:999.

Oltjen, J.W., G.W. Horn, and T.L. Mader. 1985. Comparison of one and two compartment models for prediction of fecal output of cattle grazing wheat pasture. Proc. 18th Rumen Function Conference. Chicago.

Orskov, E.R. and I. McDonald. 1979. The estimation of protein degradability in the rumen from incubation measurements weighted according to rate of passage. J. Agric. Sci. 92:499.

Owens, F.N. and H.R. Isaacson. 1977. Ruminal microbial yields: factors influencing synthesis and bypass. Fed Proc. 36:198.

Pearce, G.R. 1965. Rumination in sheep. II. The circadian pattern of rumination. Aust. J. Agric. Res. 16:635.

Pearce, G.R. and R.J. Moir. 1964. Rumination in sheep. I. The influence of rumination and grinding upon the passage and digestion of foods. Aust. J. Agric. Res. 15:635.

Poppi, D.P. 1979. Voluntary intake of leaf and stem fractions of tropical forages offered to cattle and sheep. Phd dissertation. Univ. of Queensland.

Poppi, D.P. and B.W. Norton. 1980. The validity of the critical size theory for particles leaving the rumen. J. Agric. Sci. 94:275.

Poppi, D.P., D.J. Minson, and J.H. Ternouth. 1981. Studies of cattle and sheep eating leaf and stem fractions of grasses. II. Factors controlling the retention of feed in the reticulo-rumen. Aust. J. Agric. Res. 32:99.

Poppi, D.P., D.J. Minson, and J.H. Ternouth. 1981. Studies of cattle and sheep eating leaf and stem fractions of grasses. III. The retention time in the rumen of large particles. Aust. J. Agric. Res. 32:123.

Pond, K.R., W.C. Ellis, and D.E. Akin. 1984. Ingestive mastication and fragmentation of forages. J. Anim. Sci. 58:1567.

Reid, C.S.W., M.J. Ulyatt, and J.A. Monroe. 1977. The physical breakdown of feed during digestion in the ruminant. Proc. N.Z. Soc. Anim. Proc. 37:173.

Robertson, J.B., and P.J. Van Soest. 1981. In: The Analysis of Dietary Fiber. W.P.T. Jones and O. Theander, eds. Marcell Dekker, New York.

Robles, A.Y., R.L. Belyea, and F.A. Martz. 1981. Intake, digestibility, ruminal characteristics and rate of passage of alfalfa diets fed to sheep. J. Anim. Sci. 53:774.

Shaver, R.D., A.J. Nytes, L.D. Satter, and N.A. Jorgensen. 1985. Influence of forage physical form and feed intake level on particle size of masticates, ruminal digesta and feces of dairy cows. J. Anim. Sci. 61(Supp.1):480.

Shipley, R.A. and R.E. Clark. 1972. Tracer methods for in vivo kinetics. New York: Academics pp. 1-20.

Simkins, K.L., J.W. Suttle, and B.R. Baumgardt. 1965. Regulation of food intake in ruminants. 4. Effects of acetate, propionate, butryate and glucose on voluntary food intake in dairy cattle. J. Dairy Sci. 46:1635.

Smith, L.W., H.K. Goering, and C.H.Gorden. 1972. Relationships of forage compositions with rates of cell wall digestion and indigestibility of cell walls. J. Dairy Sci. 55:1140.

Smith, L.W., H.K. Goering, D.R. Waldo, and C.H. Gordon. 1971. In vitro digestion rates of forage cell wall components. J. Dairy Sci. 54:71.

Taylor, J.C. and J.M. Wilkenson. 1972. The influence of level of concentrate feeding on the voluntary intake of grass and on live weight gain by cattle. Anim. Prod. 14:85.

Teeter, R.G., F.N. Owens, and T.L. Mader. 1984. Ytterbium Chloride as a marker for particulate matter in the rumen. J. Anim. Sci. 58:465.

Thorton, R.F. and D.J. Minson. 1973. The relationship between voluntary intake and mean apparent retention time in the rumen. Aust. J. Agric. Res. 24:889.

Thye, F.W. and R.G. Warner. 1969. Relationship of various blood metabolites to voluntary feed intake in lactating ewes. J. Dairy Sci. 52:908 (Abstr.).

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

Troelson, J.E. and J.B. Campbell. 1968. Voluntary consumption of forage by sheep and its relation to the size and shape of particles in the digestive tract. Anim. Prod. 10:289.

Ulyatt, M.J. and C.S.W. Reid. 1982. Effects of chewing during eating on particle size reduction and subsequent fermentation in sheep. Proc. N.Z. Soc. Anim. Prod. 42:159. (Abstr.).

Ulyatt, M.J., R.L. Baldwin, and L.J. Koong. 1976. The basis of nutritive value- a modelling approach. Proc. N.Z. Soc. Anim. Prod. 37:140.

Ulyatt, M.J., K.L. Blaxter, and I. McDonald. 1967. The relationship between the apparent digestibility of

roughages in the rumen and lower gut of sheep, the volume of fluid, and voluntary feed intake. Anim. Prod. 9:463.

Umoh, J.E. and W. Holmes. 1974. The influence of type and level of supplementary feed on intake and performance of beef cattle on pasture. J. Brit. Grasl. Soc. 29:301.

Utley, P.R., R.S. Lowrey, and W.C. McCormick. 1973. Corn silage and corn silage plus small grain pastures for finishing steers. J. Anim. Sci. 36:423.

Van Soest, P.J. 1982. Nutritional Ecology of the Ruminant. O and B Books, Corvallis,Or.

Varga, G.A. and E.C. Prigge. 1982. Influence of forage species and level of intake on ruminal turnover rates. J. Anim. Sci. 55:1498.

Varga, G.A. and W.H. Hoover. 1983. Rate and extent of neutral detergent fiber degradation of feedstuffs in situ. J. Dairy Sci. 66:2109.

Vogel, G.J., J. Zorrillo-Rios, G.W. Horn, R.W. McNew, and K.B. Poling. 1985. Comparison of external markers for estimating fecal output of cattle grazing wheat pasture. Ok. Agr. Exp. Sta. Res. Rep. MP 117:155.

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

Waldo, D.R., L.W. Smith, and E.L. Cox. 1972. Model of cellulose disappearance from the rumen. J. Dairy Sci. 55:125.

Welch, J.G. 1982. Rumination, particle size and passage from the rumen. J. Anim. Sci. 54:885.

Welch, J.G. and A.M. Smith. 1969. Effect of varying amounts of forage intake on rumination. J. Anim. Sci. 28:827.

Welch, J.G. and A.M. Smith. 1971. Physical stimulation of rumination activity. J. Anim. Sci. 33:1118.

Weston, R.H. and J.P. Hogan. 1967. The digestion of chopped and ground roughages by sheep. I. The movement of digesta through the stomach. Aust. J. Agric. Res. 18:789.

Wilkins, R.J. 1969. The potential digestibility of cellulose in forage and feces. J. Agr. Sci. 73:57.

Wise, M.B., R.W. Haven, B.R. Harkins, and E.R. Barrick. 1968. Finishing beef cattle on all concentrate diets. J. Anim. Sci. 27:1449.

APPENDIXES

TABLE XIII

STATISTICAL MODEL FOR WEIGHT GAIN ANALYSIS OF STEERS GRAZING WHEAT PASTURE AND BERMUDAGRASS

	Source of Variation	Degrees of Freedom
Wheat Pasture		
	Replication	4
	Treatment	3
	Replication X Treatment	12
Bermudagrass		
	Replication	5
	Treatment	3
	Replication X Treatment	15

TABLE XIV

DATES AND RATES OF NITROGEN FERTILIZER APPLICATION ON BERMUDAGRASS

	Date	Type of fertilizer	Amount, kg/ha.
Year 2 (1983)			
	May 12	Ammonium Nitrate	56.1
	July 14	Ammonium Nitrate	56.1
Year 3 (1984)			
	May 8	Urea	56.1
	June 18	Urea	56.1
	August 8	Urea	56.1
Year 4 (1985)			
	April 25	Urea	56.1
	June 12	Urea	56.1

TABLE XV

WHEAT FORAGE AVAILABILITIES AND COMPOSITION
(GRAZING TRIAL YEAR 1)

DATE		AVAILABILITY		CP*	IVDMD*	DM,%*
		kg DM/head	kg DM/ hectare	--- % of DM ---		
December 23,1981						
Treatment	1	1205	1465	26.62	78.63	25.48
	2	1355	1387	28.03	81.00	23.97
	3	869	1236	26.47	79.30	24.61
	4	479	1335	26.30	80.57	24.28
January 25, 1982						
Treatment	1	493	607	22.12	76.24	42.87
	2	470	479	23.32	75.70	41.43
	3	254	364	20.87	72.34	42.72
	4	48	134	21.68	72.84	41.77
March 1, 1982						
Treatment	1	255	305	25.57	72.50	27.91
	2	499	515	28.57	74.23	27.57
	3	125	176	25.33	66.93	28.96
	4	45	123	27.74	69.63	24.81
March 24, 1982						
Treatment	1	737	895	24.71	72.07	20.59
	2	1131	1140	26.44	71.04	18.88
	3	397	566	27.13	71.70	18.25
	4	126	357	27.63	73.40	18.34

* CP = Crude Protein; IVDMD = In Vitro Dry Matter Digestibility; DM = Dry Matter

TABLE XVI

WHEAT FORAGE AVAILABILITIES AND COMPOSITION
(GRAZING TRIAL YEAR 2)

DATE	AVAILABILITY		CP*	IVDMD*	DM,%*
	kg DM/head	kg DM/ hectare	--- % of DM ---		
January 13, 1983					
Treatment 1	545	437	N.A.	N.A.	N.A.
2	764	755	N.A.	N.A.	N.A.
3	493	522	N.A.	N.A.	N.A.
4	288	305	N.A.	N.A.	N.A.
February 17, 1983					
Treatment 1	1012	811	23.21	72.87	33.10
2	938	927	26.11	74.86	29.75
3	698	900	27.19	73.65	28.96
4	623	659	22.50	72.50	33.46
March 17, 1983					
Treatment 1	1482	1187	28.77	75.87	20.17
2	1388	1372	30.93	74.43	19.36
3	1060	1366	29.91	74.22	19.23
4	960	1017	27.82	76.48	22.28

* CP = Crude Protein; IVDMD = In Vitro Dry Matter Digestibility; DM = Dry Matter

TABLE XVII

WHEAT FORAGE AVAILABILITY AND COMPOSITION
(GRAZING TRIAL YEAR 3)

Date	Availability		CP*	IVDMD*	DM,%*
	kg DM/head	kg DM/ hectare	---% of DM ---		
December 7, 1983					
Treatment 1	397	437	N.A.	N.A.	N.A.
2	504	555	N.A.	N.A.	N.A.
3	306	448	N.A.	N.A.	N.A.
4	273	603	N.A.	N.A.	N.A.
January 3, 1984					
Treatment 1	326	359	N.A.	N.A.	N.A.
2	433	477	N.A.	N.A.	N.A.
3	309	453	N.A.	N.A.	N.A.
4	193	428	N.A.	N.A.	N.A.
February 1, 1984					
Treatment 1	200	220	22.05	76.14	36.59
2	307	338	22.39	76.51	37.06
3	213	312	23.29	78.50	34.96
4	82	183	24.32	74.80	30.27
March 15, 1984					
Treatment 1	412	453	25.56	76.25	33.03
2	428	483	26.32	75.66	28.65
3	404	592	23.07	76.14	29.61
4	168	373	27.45	72.12	31.59
March 22, 1984					
Treatment 1	443	488	24.67	81.16	25.03
2	866	954	25.07	81.95	21.80
3	570	833	26.06	80.92	23.02
4	155	345	25.94	78.56	23.83

* CP = Crude Protein; IVDMD = In Vitro Dry Matter Digestibility; DM = Dry Matter

TABLE XVIII

BERMUDAGRASS COMPOSITION (GRAZING TRIAL YEAR 2)

DATE		CP*	IVDMD*	DM,%*
June 1983		--- % of DM ---		
	Treatment 1	N.A.	N.A.	34.26
	2	N.A.	N.A.	37.15
	3	N.A.	N.A.	31.43
	4	N.A.	N.A.	36.49
July 1983				
	Treatment 1	13.07	47.21	37.09
	2	14.74	47.99	42.20
	3	12.49	46.83	37.15
	4	13.98	47.21	38.12
August 1983				
	Treatment 1	9.82	42.20	34.83
	2	9.89	44.00	46.75
	3	9.55	47.07	37.25
	4	N.A.	N.A.	N.A.
September 1983				
	Treatment 1	8.12	41.20	39.42
	2	7.04	41.40	39.55
	3	7.17	42.50	36.75
	4	8.63	43.27	46.29

* CP = Crude Protein; IVDMD = In Vitro Dry Matter Digestibility; DM = Dry Matter

TABLE XIX

BERMUDAGRASS COMPOSITION (GRAZING TRIAL YEAR 3)

DATE		CP*	IVDMD*	DM,%*
		--- % of DM ---		
June 1984				
Treatment	1	16.05	55.49	29.89
	2	17.52	56.13	31.15
	3	15.74	54.15	31.36
	4	N.A.	N.A.	35.54
July 1984				
Treatment	1	12.43	52.04	29.74
	2	12.63	53.03	34.45
	3	14.55	56.82	29.88
	4	14.13	50.98	36.32
August 1984				
Treatment	1	11.15	46.56	41.16
	2	7.48	46.19	47.89
	3	10.20	50.12	42.15
	4	11.39	54.08	44.95
September 1984				
Treatment	1	10.54	42.95	42.58
	2	10.20	40.18	47.72
	3	9.00	46.69	44.55
	4	11.02	43.15	42.65

* CP = Crude Protein; IVDMD = In Vitro Dry Matter Digestibility; DM = Dry Matter

TABLE XX

BERMUDAGRASS COMPOSITION (GRAZING TRIAL YEAR 4)

DATE		CP*	IVDMD*	DM,%*
		--- % of DM ---		
May 1985				
Treatment	1	14.73	58.45	29.30
	2	16.75	62.90	29.72
	3	12.56	57.49	22.93
	4	13.65	62.41	29.31
June 1985				
Treatment	1	11.12	52.34	33.68
	2	16.10	54.79	30.12
	3	10.91	54.84	28.13
	4	15.67	57.18	31.14
July 1985				
Treatment	1	10.30	42.18	42.51
	2	11.04	45.14	39.28
	3	12.45	59.47	34.19
	4	12.08	59.83	39.04
August 1985				
Treatment	1	10.88	51.88	38.10
	2	8.67	45.00	42.61
	3	9.78	50.38	40.96
	4	N.A.	N.A.	N.A.

* CP = Crude Protein; IVDMD = In Vitro Dry Matter Digestibility; DM = Dry Matter

VITA

Gary John Vogel

Candidate for the Degree of

Master of Science

Thesis: INFLUENCE OF SUPPLEMENTAL SILAGE ON FORAGE INTAKE AND UTILIZATION AND PERFORMANCE OF STOCKER CATTLE GRAZING WHEAT PASTURE AND BERMUDAGRASS

Major Field: Animal Science

Biographical:

Personal Data: Born in Marengo, Iowa, December 30, 1961. Married Gerri LeAnne Hughes, August 6, 1983.

Education: Graduated from Hereford High School, Hereford, Texas in May 1980; transferred from Clarendon Junior College, Clarendon, Texas in May, 1981; received Bachelor of Science degree in Animal Production from Texas Tech University, Lubbock, Texas in December, 1983; completed the requirements for the Master of Science degree in Animal Science at Oklahoma State University, Stillwater, Oklahoma in December, 1985.

Professional Experience: Co-owner Blue Ribbon Cattle Company, Hereford, Texas, 1974-1985; worked on family cattle ranch, 1974-1981; livestock sales Hereford Cattle Commission, summer, 1983; Graduate Assistant at Oklahoma State University, 1983-1985.

Professional Organizations: American Society of Animal Science.