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INFLUENCE OF INHERENT DIFFERENCES AND PRODUCTION STATUS
ON INTAKE AND DIGESTIBILITY OF NUTRIENTS
IN BEEF CATTLE

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ABSTRACT

A total of 59 beef cattle were used in investigations relating inherent and production differences to intake and digestibility of nutrients. Twelve lactating cows in a total-collection digestion trial, 24 cows in 3 successive acid-insoluble ash indicator-ratio digestion trials (trials 1, 2 and 3) and 23 yearling steers in another indicator-ratio digestion trial were fed mainly grass hay, grass silage and corn silage, respectively. The data were analyzed by the method of linear multiple regression.

The cows in the total-collection digestion trial offered the orchard-grass timothy hay (OGTH) consumed 1.6 kg more ($P < .10$) dry matter than those cows fed the tall-fescue-timothy hay (TFTH). More neutral detergent fiber (14.6%, $P < .001$), acid detergent fiber (14.7%, $P < .01$), hemicellulose (9.4%, $P < .01$), cellulose (21.7%, $P < .001$) and crude protein (12.5%, $P < .01$) were digested by the cows fed TFTH than those cows fed the OGTH. Cow weight was positively related to the digestibility of dry matter, neutral detergent fiber, neutral detergent solubles, acid detergent fiber and crude protein and the respective regression coefficients were .07% ($P < .05$), .06% ($P < .10$), .10% ($P < .05$), .04% and .10% ($P < .10$). Calf age accounted for about 29% ($P < .05$) of the variation in digestibility of the dry matter and for about 5% ($P < .05$) of the variation in digestibility of the neutral detergent fiber by their dams.

In the 3 successive indicator-ratio digestion trials the daily dry matter intake was higher in the pregnant than in the nonpregnant

cows by about 2.0 kg ($P < .05$) in a 66-day (range, 25 to 89 days) pregnancy (trial 2) and by about 1.5 kg ($P < .01$) in a 108-day (range, 67 to 131 days) pregnancy (trial 3). Stage of gestation did not affect nutrient intake at 34 days (range, 25 to 48 days) post-conception (trial 1). However, as pregnancy advanced to 66 (trial 2) and 108 days (trial 3) a 1-day increase in the length of gestation was associated with a 40-g decrease in daily dry matter intake in trial 2 and a 30-g decrease in trial 3. The nonpregnant cows digested 3.9% more ($P < .05$) of the neutral detergent fiber and 4.3% more ($P < .01$) of the hemicellulose in trial 2 but .73% less ($P < .05$) of the hemicellulose in trial 3. In trial 2 a 1-day increase in the age of the in situ developing fetus caused a rise in digestibility of neutral detergent fiber and hemicellulose of .12% ($P < .10$) and .19% ($P < .01$), respectively. However, in trial 3, a 1-day increase in the age of the in situ developing fetus caused a reduction of .19% ($P < .05$) in the digestibility of hemicellulose. In trial 1, the cow whose milk production was higher by 1 kg digested significantly more of the dry matter (3.0%, $P < .05$), neutral detergent fiber (3.3%, $P < .05$), acid detergent fiber (3.6%, $P < .05$), hemicellulose (3.5%, $P < .001$) and cellulose (3.0%, $P < .05$).

The study with the yearling steers revealed that the steer with a 1-kg greater metabolic size consumed about 110 g more dry matter ($P < .001$) than the lighter steer. A comparison in nutrient digestibility among Angus (A), Hereford (H), A x H and H x A steers revealed that nutrient digestibility was similar in A, H and H x A. However, the A x H steer as compared to the A steers digested

significantly less ($P < .05$) of the dry matter (7.8%), neutral detergent fiber (10.8%), neutral detergent solubles (6.4%), acid detergent fiber (10.3%), hemicellulose (12.0%) and cellulose (8.6%).

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CHAPTER I

INTRODUCTION

The performance of a variety of physiological functions in beef cattle causes wide difference in their nutrient requirements. Ruminant nutritionists have expended a considerable effort to study the nutrient composition of a vast variety of feeds and their utilization by the animal.

The amount of a feed that animals voluntarily consume has also received considerable research attention. This voluntary consumption or ration intake is not only influenced by ration characteristics but also by the physiological state of the animal such as maintenance, growth, gain, gestation and lactation.

However, it is believed that independent of intake, differences in animals due to chronological age, breed and differences in production do not cause a measurable variation in nutrient digestibility. As such, nutrient digestibility values within an animal species are freely interchanged without consideration for inherent and individual differences in animals. However, there are some indications that these differences are too big to be ignored.

One of the reasons why past researchers were unable to see these individual animal differences was because of limitation in degrees of freedom used in most of the conventional energy balance trials. As of now, the total-collection digestion trial is the best procedure we have for the determination of nutrient digestibility.

Unfortunately, the method is both labor and capital intensive. Because of these factors, in almost all of the total-collection digestion studies the best minimum number of animals is used.

Also, the latin-square design was widely used in many of the digestion trials. This statistical design enables the effective evaluation of the variations due to dietary treatments. But, at the same time, it effectively eliminates other sources of variations and thus prevents the realization of magnitude of the influence of individual animal differences on digestibility.

Also, due to lack of consistency among investigators, residual error terms become unnecessarily inflated, causing the influences of individual differences on digestibility to be statistically non-significant. For instance, Schneider and Lucas (1950) compiled a total of 4,629 individual digestion trials to study the relative importance of certain sources of variation in nutrition. They noted that 20 to 40% of the within-feed variation was due to researchers.

In the present study, an attempt was made to minimize conceivable sources of errors by using relatively larger numbers of animals (60 beef cattle) and by following strict sampling, processing and laboratory analysis procedures.

The main objectives of this study were to supply basic data relating animal inherent and production differences to nutrient digestibility in beef cattle.

CHAPTER II

LITERATURE REVIEW

Ration Constituents Influencing Animal Performance

Factors Affecting Voluntary Intake

Physical and physiological factors regulating intake in ruminants have been reviewed by different workers (Conrad, 1966; Forbes, 1970a; Warner et al., 1971; Bergen, 1972). Studies by Conrad et al. (1964), Forbes (1970a) and Purser and Moir (1966a) showed that on high-fiber diets, the physical capacity of the gastrointestinal tract had a significant and positive relationship with the quantity of forage voluntarily consumed.

One of the factors limiting volume of the rumen is the abdominal fat. Amount of abdominal fat was negatively correlated to rumen content (Forbes, 1968b).

Warner et al. (1971) indicated, in a review, that of diets containing below 2.5 k cal/g digestible energy (65% energy digestibility) intake is controlled by the physical limitation of rumen volume while above this energy concentration it is controlled by the chemostatic mechanisms which in turn are regulated by physiological nutrient requirements of the animal (Forbes, 1970a).

Chemostatic regulation of feed intake is controlled by blood metabolites (Conrad, 1966; Baumgardt, 1970; Forbes, 1970a; Warner et al., 1971). When sheep were fed a high energy ration, there was a rise in plasma volatile fatty acids and a decline in free fatty

acids (Warner et al., 1971). Further, they noted that an exchange of blood from "satiated" sheep with blood of "hungry" sheep in a cross-circulation experiment resulted in a subsequent depression of voluntary feed intake by the hungry sheep.

The level of glucose in the blood affects intake by nonruminants and this is mediated through the ventromedial hypothalamic nuclei (Conrad, 1966). Volatile fatty acids in ruminants were expected to play a role similar to that played by glucose in nonruminants (McCullough, 1959). Later works (Conrad, 1966; Forbes, 1970a) showed that infusion of acetate affected intake in ruminants. Thye et al. (1970) reported that in ewes fed a pelleted ration composed of 45% concentrate and 55% roughage, blood acetate, propionate and glucose levels were poorly related to feed intake. However, butyrate and free fatty acids were negatively correlated to subsequent voluntary feed intake.

Intake Variables Influencing Digestibility

There is a general understanding among nutritionists that the level of dry matter intake influences digestibility of nutrients in ruminants. In spite of the voluminous work published, there is no complete agreement on the direction of the relationship between intake and digestibility. Hale et al. (1939) reported that the level of intake had a positive relationship with digestion of crude fiber in dairy cows fed alfalfa hay in amounts of 0, 20 or 30% of the total ration. Later McCullough (1959) reported a correlation of 0.51 between intake and digestibility of dry matter. Recent

work with sheep and cattle (Blaxter et al., 1961; Stehr and Kirchgessner, 1976) confirmed that digestibility increased as a result of higher plane of nutrition.

Anderson et al. (1959) studied the influences of fresh green forage and hay intake on digestibility and concluded that in steers the level of intake did not affect digestibility. The same conclusions were made by Gill et al. (1978) from data obtained from beef cows fed grass silage, by Greenhalgh and Runcie (1962) from data obtained from grazing dairy cows and by Watson et al. (1935) from data obtained from Shorthorn steers fed a ration of mixed clover and grass hay at levels of 2.5, 4.5, 6.0 and 9.0 kilograms per day.

In contrast, a large number of workers have reported a significant and negative relationship between intake and digestibility of nutrients (Mitchell, 1942; Reid and Hinks, 1962) and the relationship becomes apparent at above-maintenance levels of feeding (Moe et al., 1963). In a study where non-lactating and lactating cows producing 54.4 kg milk/day were fed rations made up of concentrates and either an early-cut hay or a late-cut hay, they noted that as intake level was increased from 1 x maintenance to 6 x maintenance the relative total digestible nutrient of the ration declined by 23% from that of the 1 x maintenance level.

The possible reasons for the negative relation of intake and digestibility, above-maintenance levels of intake, have been reported by Blaxter and McGraham (1966) and Alexander and Hentges (1962). They noted a faster rate of passage of ingesta through the fore-stomach with increased intake and Moore (1964) stated

that an increase in rate of passage caused a decrease in digestibility.

In a series of studies with Angus steers ranging in age between 25 and 33 months, Forbes et al. (1928) concluded that in ruminants the proportion of ration digested decreased at an increasing rate as the amount of ration ingested daily increased. Brody (1945) reported that above maintenance, digestibility of rations tended to decrease with feed intake in accordance with the principle of diminishing increments. Therefore, the seemingly contrasting results relating intake to digestibility in ruminants reported by a large number of workers appeared to fit well with the concept of a dynamic relationship between intake and digestibility.

Animal Variables Affecting Intake and Digestibility of Ration Constituents

Condition of Animal

Condition in this study denotes the overall degree of fatness of cattle. It can be estimated by visual appraisal or by the use of ultrasonic fat measuring devices (Klosterman et al., 1968). Condition can also be estimated from the ratio of weight to height of an animal. It is known that the height at withers in cattle is influenced less by nutritional condition than other linear measurements partly because the animal attains more than 50% of its height at birth and reaches its maximum height before it is 10 months old (Brody, 1945). This makes the height measurement a good reference point.

Brody (1945) compared the weight to height ratio differences of cattle from Nebraska and Missouri and concluded that the ratio was higher in the Nebraska cattle because of the better plane of nutrition resulting in better condition of the Nebraska cattle as compared to Missouri cattle. Klosterman et al. (1968) noted that weight alone cannot describe condition very well. In their study, Charolais cows were taller at the hooks than Hereford cows. However, there was no difference between the breeds in weight-to-height ratio. From this study they concluded that weight-to-height ratios can be used to best describe condition of cows which are widely different in type and size. Klosterman et al. (1968) reported a significant correlation of .89 between condition score and the weight-to-height ratio.

The relationship between condition of the animal and its nutrient utilization was determined in a study with mature Angus and Charolais cows by Klosterman et al. (1979). They reported that voluntary forage intake of cows was positively related to condition of the animal. Results from a recent study by Houpt (1977) showed that the correlation between nutrient intake and condition is not always positive. If an animal is starved and supplied feed free choice, it will eat more than it did before the fast and rapidly regain the weight lost. In contrast, if an animal is force-fed, it gains weight but when force feeding is terminated, it eats less than pre-force feeding until its body weight returned to the normal level. Gill et al. (1978) studied the relationship between condition of the animal and nutrient digestion and reported that condition of

the animal was negatively correlated (-0.67) with apparent protein digestibility.

It appears that easily obtainable physical measurements like weight, wither height and the ratio between the two, with repeatability of .89, .94 and .85, respectively (Williams et al., 1979b), can be used to assess influences of condition of an animal on nutrient utilization.

Lactation Status of the Animal

In a study reported by Williams et al. (1979a), milk production estimates of Hereford cows were obtained by the weigh-suckle-weigh method at intervals of 4, 8 and 16 hours. The milk production estimates in kg/hour for the intervals of 4, 8 and 16 hours were 9.2, 7.6 and 5.9, respectively. However, the correlation between milk production estimates for 4-, 8- and 16-hour separation of calf and average daily gain were .27, .46 and .45, respectively.

Stage of lactation has an effect on intake. From parturition to peak milk production, the dairy cow does not consume enough energy for maintenance and milk production, i.e., she mobilizes body fat. The level of intake increases within a few days after parturition and reaches its peak 6 to 10 weeks thereafter; more specifically, Brown et al. (1977) reported that the peak in milk production is reached in 7 weeks and the peak in dry matter intake is reached 13 weeks post partum. Gaskins and Anderson (1980) conducted a long-time study of the change in daily milk production in Angus-Hereford, Jersey-Angus and Simmental-Angus cows and concluded that milk production peaked in about 8 weeks time and then decreased at

an increasing rate with an average decline of -0.0238 kg/day. However, research by Moe et al. (1965), Brown et al. (1977), Houpt (1977) and Knox (1979) indicated that the rate of decline in intake was less than that in rate of decline in lactation. During mid and late lactation, cows consumed energy above maintenance requirements, thus replacing the body stores of fat lost during the early stages of lactation.

Although intake directly affects digestibility, the author is not aware of studies relating stage of lactation with digestibility independent of intake. Gill et al. (1978) reported a positive and significant correlation in beef cows between digestibility by the cow and average daily gain (ADG) of their calves. The correlation coefficients between calf ADG and digestibility of dry matter, acid detergent fiber and gross energy in the dam were .46, .60 and .41, respectively.

Age of Animal

The earliest study relating age and nutrient utilization was conducted by workers in New Mexico (Christensen and Simpson, 1914; Christensen et al., 1916). From a series of experiments with Hereford steers fed alfalfa hay with and without sorghum meal, they concluded that digestion of the proximate constituents was not different among yearlings, 2-year and 3-year old steers. Later, Schneider et al. (1953) reported studies of an indicator digestion trial with pasture forage using 3 age groups of sheep: lambs, yearlings and adult rams. They concluded that dry matter digestion was not significantly influenced by age of sheep. In contrast, in a series of well-designed

studies involving a large number of sheep ranging in age between 1 to 4 years, Raymond et al. (1954) concluded that there was a 1 percentage unit increase in dry matter digestibility for each year increase in age of the sheep.

There are data giving indirect evidences about the relationship between age and nutrient utilization of an animal. Thomas et al. (1961) reported that rumen motility increased with age. A Russian worker, Demchenko (1967), studied the metabolism of feed in growing cattle and reported that methane loss increased with advance in age. However, in Ayrshire steers ranging in age between 15 to 35 weeks, age of the animal had no effect on methane production but retention of nitrogen was more efficient in the younger animals (Blaxter and McGraham, 1966). In a study where a group of ewes ranging in age between 20 months and 10 years were used, the older ewes had higher levels of plasma acetate than the younger sheep (Koenig et al., 1980). Hansard (1954) studied the effect of age, ranging between 10 days to 190 months, on true digestibility of radiocalcium in Hereford cattle and concluded that fecal excretion of radiocalcium increased with an increase in age.

Stage of Gestation

Forbes (1970a) reviewed a substantial number of studies with both cows and ewes, showing that intake of animals is influenced by the stage of pregnancy. Most studies were conducted during the last trimester of pregnancy. During that time, it was noted that dry matter intake declined significantly (Moodie and Robertson, 1961; Reid and Hinks, 1962; Forbes et al., 1967; Forbes, 1970b; Friend,

1971; Sykes and Field, 1972; Gill et al., 1978). This depression of intake in late gestation could not be prevented by increasing energy density of the ration (Curran et al., 1967). In another study, 4-year-old Cheviot ewes in late gestation were housed individually and were given free access to either a protein concentrate or a carbohydrate concentrate and excellent quality chopped hay (Gordon and Tribe, 1951). All of the ewes decreased their intake significantly during the last few weeks of pregnancy.

What causes the reduction in intake during the last stages of gestation? One factor is a decrease in volume of the gastrointestinal tract (GI) due to advancing pregnancy. In a sow 110 days pregnant, the contents of the stomach and alimentary tract were smaller than that of an open sow kept on the same ration for 110 days (Keap and Lodge, 1967). In a study of ewes ranging in pregnancy between 72 and 144 days, there was a negative relationship between volume of rumen contents and volume of uterus plus abdominal fat (Forbes, 1968a; Forbes, 1969; Forbes, 1970b).

However, Forbes (1970b) suggested that besides the physical factor (reduction in size of GI tract), there is also a metabolic factor for the reduction in intake of the pregnant animal. The existence of this metabolic factor was suggested because in heifers fed a concentrate ration, intake declined during the last 3 months of pregnancy. The chemical changes, both hormonal and free-fatty acids, taking place to reduce intake in pregnant animals are not fully understood. There is evidence that feed intake is depressed when large amounts of estrogen is administered in the presence of

progesterone, a situation similar to that in late gestation (Forbes, 1970b; Muir et al., 1972).

Heaney and Lodge (1973) noted that plasma free-fatty acid levels were 790 and 260 U equiv/l for pregnant and nonpregnant cows, respectively. Thye et al. (1970) reported a negative correlation between plasma free-fatty acid content and voluntary intake. Thus, the reduced intake in late pregnancy is also partly due to high free-fatty acid content in the plasma which results from a rapid mobilization of fat deposits. It appears that high plasma free-fatty acids cause reduction of intake and not vice versa. In the pregnant animal, high free-fatty acid levels could not be altered by feed allowance approaching free choice. Thus the maternal tissue mobilization could be the normal feature of late pregnancy as a result of hormonal changes (Sykes and Field, 1972).

Pregnancy has a marked influence on digestibility of nutrients. The rate of passage of food through the digestive system of Merino ewes in late pregnancy (Graham and Williams, 1962) was high. In these studies the mean retention time decreased by 1 to 1 1/2 hours per 100-g increase of estimated weight of concepta. A study with pregnant Holstein cows showed that digestibility of gross energy was less by pregnant than by non-pregnant cows (Flatt et al., 1967d) and the digestibility declined further in advanced pregnancy. Also, crude protein digestibility decreased with advancing pregnancy (Gill et al., 1978).

Breed of Animal

Few attempts have been made to determine heritabilities of digestive abilities within types of cattle (Warwick and Cobb, 1974). It is, however, generally accepted that large differences exist among and within breeds in feed capacity and appetite. As a result, most research efforts were directed towards comparing intake within British breeds or between British breeds and zebu types of cattle. Bogart and England (1971) and Lusby et al. (1976) fed chopped alfalfa hay to Hereford, Hereford x Holstein and Holstein cows and concluded that dry matter intake per unit body weight was significantly influenced by cow breed. Studies comparing nutrient intake by European breeds and zebu-type cattle showed that the former consumed significantly more ration than the latter (Phillips et al., 1960; Warwick and Cobb, 1974). In a study where 11 Shorthorn x Hereford (SH), 12 Africander x SH (AX) and 11 Brahman x SH (BX) were used, Vercoe and Frisch (1973) reported that the SH steers had a higher intake than the BX and AX steers. In a similar study, Vercoe (1970) concluded that the digestible energy intake between 50% Brahman x 25% Hereford x 25% Shorthorn (BX) and 50% Shorthorn x 50% Hereford (SH) was not significantly different.

Nutrient digestibility difference among types of cattle have been reported by Washburn et al. (1948). They obtained data from "Compact" and conventional types of Shorthorn steers and concluded that digestibility of dry matter and nitrogen was not different between the 2 groups of cattle. Dickinson et al. (1969) using data from 57 Ayrshire, 68 Brown Swiss and 57 Holstein cows, concluded that

feed efficiencies (100 x gross energy in milk, gross energy in feed) were 54.3, 60.3 and 62.0%, respectively, and were significantly different. A comparison in digestibility among Brahman, Brahman x Short-horn, Africander x Hereford and Hereford steers, revealed that Herefords digested significantly less than the other breeds. Analysis of covariance showed that steers with Brahman and Africander breeding were not significantly different, but the Herefords were significantly ($P < .01$) displaced from the pooled results of the other breeds (Robinson and Stewart, 1968). From statistical analyses of data obtained from both U.S.A. and Australia, Moran and Vercoe (1972) concluded that the true digestion of nitrogen in zebu types was slightly higher than in the British breeds, 88.63 and 87.94%, respectively. Swett et al. (1961) collected data from Sindi x Jersey crosses, Jersey and Holstein and confirmed that increasing the proportion of Sindi inheritance caused a reduction in the size of the digestive system. Hungate et al. (1960) studied the fermentation rate of rumen contents from zebu and European type cattle and showed that fermentation was significantly higher in zebus.

Acid-Insoluble Ash as Internal Indicator

Kotb and Luckey (1972) made an extensive review of the use of indicators, both internal and external, in digestibility studies and concluded that compared to the conventional total collection they provide the advantage of cheapness because a quantitative measurement of consumed feed or feces need not be made. There are two types of indicators (Maynard et al., 1979). The external indicators, example

chromic oxide, must be added to the feed while the internal indicators are the natural components of the feed offered to the animal. In the present study, 2N HCl insoluble ash was used (AIA). AIA is similar to insoluble silicious compounds (Van Keulen and Young, 1977). Silica is a component of plant cell walls probably serving as a binding surfact (Van Soest and Robertson, 1978). Because AIA is a component of the feed, it is a good example of an internal indicator.

One of the desirable features of an indicator is that it should not be digestible by the animal so that the ratio of the percentage indicator in the feed to that in the feces represents the undigested fraction of the dry matter in the feed. Recovery (percentage of the indicator consumed recovered in the feces) for AIA was 95.8% with sheep (Van Keulen and Young, 1977), between 98.9 and 101.2% with steers (Thonney et al., 1979), between 98 and 108% when refusal AIA was included and 91 to 121% without the refusal AIA with sheep (Block et al., 1980). In all cases, the calculated recovery was not significantly different from 100%.

Another criterion of a good indicator is that the rate of excretion of the indicator should not fluctuate with time. From fecal samples collected from steers at an interval of 4 hours for 1 day (Thonney et al., 1980), from sheep at an interval of 2 hours for 1 day (Van Keulen and Young, 1977) or from pigs at an interval of 2 hours for 3 days (McCarthy et al., 1977), they concluded that the time of the day fecal samples were taken did not contribute significantly to the variability in the calculation of nutrient digestibility by the AIA method.

A large number of workers have compared digestion coefficients calculated from silica ratios with coefficients obtained from total-collection digestion trials (Gallup and Kuhlman, 1931; Gallup and Kuhlman, 1936; Mitchell, 1942; Gallup et al., 1945) and reported that the values obtained were similar but not always consistent. Recently, researchers comparing digestion coefficients by the two methods showed consistently good agreement. With steers fed mixed grass hay and 0, 20, 40, 60 and 80% concentrate, digestibility of the rations as determined by AIA was not significantly different from the total collection (Thonney et al., 1979). When sheep and dairy cows were used the correlation coefficients for the total collection vs AIA digestibility determinations in wethers fed corn green chop or cows fed hay were .96 and .95, respectively (Block et al., 1980). AIA using 2N HCl accurately determined digestibility of dry matter in sheep (Van Keulen and Young, 1977). Dry matter digestibility determined by total collection and AIA indicator were 60.9 and 59.4, respectively and were highly correlated ($r=.98$). Similar results were obtained with swine (McCarthy et al., 1974 and 1977) and with broilers (Vogtmann et al., 1975). However, when pigs were fed concentrate ration plus .5% celite and .5% chromic oxide, the values for digestibility from total collection and AIA were, energy: 86.3 and 84.8%, and nitrogen: 86.0 and 84.6%, respectively, and the difference between the means was significant (McCarthy et al., 1974). The data indicated the care one must take to avoid contamination or addition of certain interfering substances to the sample. According to one of the earliest studies

(Gallup et al., 1945), a 10% error in silica determination would produce an error of about 5.0, 2.5 and 1.0 percentage units in coefficients of 50, 75 and 90, respectively.

CHAPTER III

INFLUENCES OF ANIMAL AND RATION VARIABLES ON NUTRIENT INTAKE AND DIGESTIBILITY IN COWS AT EARLY LACTATION

Summary

The objective was to relate animal differences and ration variables to intake and digestibility of nutrients in 12 Angus cows. The cows were fed either tall fescue-timothy hay (TFTH) or orchard grass-timothy hay (OGTH) in a total-collection digestion trial. All of the cows were in their early lactation and were nursing calves whose average age was 33 days. The cows' weight ranged between 363 and 465 kg with a mean weight of about 400 kg. The data were analyzed by the method of multiple linear regression. The cows offered the OGTH and TFTH consumed 8.6 and 7.0 kg, respectively, dry matter daily. Apparent dry matter digestibility by cows fed OGTH was 57.6% and by cows fed TFTH was 62.1%. The cows offered OGTH consumed 1.6 kg more ($P < .10$) dry matter than the cows fed TFTH. More of the dry matter (2.8%), neutral detergent fiber (14.6%, $P < .001$), acid detergent fiber (14.7%, $P < .01$), hemicellulose (9.4%, $P < .01$), cellulose (21.7%, $P < .001$) and crude protein (12.5%, $P < .01$) were digested by cows fed TFTH than by cows fed OGTH. Increasing the intake of a specific nutrient had a significant negative influence on its digestibility. Increasing intake by 1 kg more depressed the digestibility of neutral detergent solubles by 7.2% ($P < .10$) and of the crude protein by 14.8%. A 1 kg weight advantage of the cows was

positively related to the digestibility of dry matter, neutral detergent fiber, neutral detergent solubles, acid detergent fiber and crude protein and the respective regression coefficients were .07% ($P < .05$), .06% ($P < .10$), .10% ($P < .05$), .04% and .10% ($P < .10$).

Age of calf had a positive influence on the digestibility of nutrients by their dams and it accounted for about 29% ($P < .05$) of the variation in dry matter digestibility and for about 5% ($P < .05$) of the variation in neutral detergent fiber digestibility.

(Key words: Ration Constituents and Intake, Ration Constituents and Digestibility, Nutrient Intake and Digestibility, Cow Weight and Digestibility, Calf Age and Digestibility.)

Introduction

Generally it is assumed that digestibility is not strongly related to physical and production parameters in beef cattle. Warwick and Cobb (1974) reviewed the very scanty data relating inherent differences in beef cattle with differences in nutrient digestibility. They concluded that the variation in digestive ability is too small to warrant its use as a basis for selection. Since then, some investigators have shown that structurally large cows (taller at withers, longer and wider at the hooks and with a deeper heart girth) had larger rumen capacities than did structurally smaller cows (Nutt et al., 1980). Purser and Moir (1966b) noted that rumen volume and dry matter digestibility were positively related. However, Gill et al. (1978) reported that the relationship between cow size and apparent crude protein digestibility was negative and significant ($r = -.71$).

The objectives of this study were to supply more data relating cow structural size with digestibility and to investigate the possible relationship between calf age and cow nutrient digestibility.

Materials and Methods

Management of Experimental Animals

A total-collection digestion trial was conducted with 12 lactating open Angus cows for a 7-day preliminary period and a 7-day sample collection period. The cows were weighed and randomly divided into 2 groups before they were placed in metabolism crates for the feeding of one of the experimental hays. The crates were designed to effectively restrain the cows while at the same time giving free access for nursing the calves.

Six cows were fed hay which was predominantly orchard grass (Dactylis glomerata) and some timothy (Phleum pratense) (OGTH) while the other 6 cows were fed hay which contained mainly tall fescue (Festuca arundinacea) and some timothy (TFTH). The field from which the second hay was harvested had been heavily fertilized with nitrogen, potassium and phosphorus at the rate of 113, 228 and 170 kg per ha, respectively. In addition, the cows were fed a total of 0.5 kg per head per day of chromic oxide carrier pellets, one half at 8 a.m. and the other half at 4 p.m. preceding watering and feeding of the hay. The nutrient composition of the hay is given in Table 1. The cows in both groups were fed their respective rations (modified ad libitum) and had access to water twice daily. Before the start of fecal collection, a catheter was inserted into the neck of the bladder

Table 1. Components of Ration Fed to Cows (Percent Dry Basis)

Item	Hay		Chromium oxide carrier pellets
	Orchard grass- timothy	Tall fescue- timothy	
Dry matter	92.14	92.66	90.39
Neutral detergent fiber	65.47	74.92	47.91
Neutral detergent solubles	34.53	25.08	52.09
Acid detergent fiber	35.45	39.37	30.25
Hemicellulose	30.02	33.55	17.66
Cellulose	30.00	35.60	22.99
Crude protein	7.20	12.62	14.93
Lignin	5.45	3.77	7.26
Acid-insoluble ash	1.14	0.89	10.59

to guide urine from the cows into plastic jars to avoid contamination of feces by urine.

Sampling Feces

Daily voided feces by each cow were weighed at 4 p.m. and the weight was recorded. The feces were thoroughly mixed and a 10% aliquot sample was taken and stored in plastic bags labeled with animal number and date of collection. All of the fecal samples were stored at -20 C until they were mixed and processed for laboratory analysis.

Sample Preparation

Both the feed and refusal composite samples were ground, as fed in a Wiley mill fitted with 1 mm screen. Representative samples were stored in glass jars labeled with type of sample, animal number and date of collection. The composite of each day's fecal sample for each cow was weighed while fresh and reweighed at the end of 3 days of drying in a 50 C oven and 3 days of air equilibration to determine the percent air equilibrated dry matter (percent AEDM). The total dry matter content was determined from the product of percent AEDM and residual percent DM obtained after the same fecal sample was dried at 100 C.

Laboratory Analysis

The representative feed, refusal and fecal samples were analyzed for dry matter (DM) and crude protein (CP) by AOAC (1975) methods and neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (lignin) by the method of Van Soest (1963).

Additional ration constituents were calculated from the following relationships:

Neutral detergent solubles, % (%NDS) = $100 - \% \text{NDF}$

Hemicellulose, % (%HCL) = $\% \text{NDF} - \% \text{ADF}$

Cellulose, % (%CL) = $\% \text{ADF} - \% \text{Lignin}$

Digestion coefficients were calculated by conventional methods.

Intake and digestibility values are given in Table A-1.

Animal Variables

During the course of the study, measurements were made of the cows and of the calves. The age of the animals in days was the period between date calved and the last day of the collection period. The weight in kg of cows or calves was the mean of weights at the start and end of the digestion trial. Height of the animal in cm represented the vertical length measurement of the animal at the withers. Condition of the animal was estimated from the ratio of weight in kg to height in cm of the animal. Milk production by the cows was estimated from weight differences in calves before and after nursing (weigh-suckle-weigh method) twice daily during the trial period after separating the calves for 12 hours. The weight difference on the first and last days of the digestion trial was used to determine the average daily gain of the calves. Cow and calf parameters are given in Tables A-2 and A-3.

Statistical Analysis

The data were analyzed by the method of multiple linear regression (SAS, 1979). Partial regression coefficients and partial

coefficients of determination were used to determine the direction and strength of relationships between dependent and independent variables in the multiple regression models. The influences of several animal variables on nutrient intake and on digestibility were tested using analysis of variance. The independent variables were cow age, cow height, cow weight-to-height ratio and calf average daily gain. Independent variables whose relationship to either intake or to digestibility were not significant ($P > .10$) were deleted from the model. From the final models, least squares means were calculated for the class variables. The following models were selected:

Intake = Intercept, calf age and hay type

Digestibility = Intercept, nutrient intake, cow weight,
calf age and hay type.

Results and Discussion

Relation of Ration Constituents and Nutrient Intake

The analysis of variance of the relation between ration components and nutrient intake is given in Table 2. The total components of the model accounted for 35% of the variation in dry matter consumed by the cows. Of the total variation, 93% ($R^2 = .33$) was due to hay type. Least square means of nutrient intake of the cows are given in Table 3. The cows fed orchard grass-timothy hay (OGTH) consumed about 1.6 kg more ($P < .10$) dry matter (8.62 vs. 6.98) per day than cows fed the tall fescue-timothy hay (TFTH). Reid and Jung (1965) reported that there was a significant and positive

Table 2. Analyses of Variance of Nutrient Intake of Cows in the Total-Collection Digestion Trial.

Source	Intake, kg/head/day ^a							
	DF	DM	NDF	NDS	ADF	HCL	CL	CP
Calf age, days	1	1.03	.66	.04	.26	.15	.16	.03
Hay type ^b	1	7.87 ⁺	.47	4.54***	.43	.05	.02	.15*
Residual	9	1.72	.91	.13	.18	.21	.21	.02
R ²		.35	.11	.80	.27	.08	.08	.57

⁺P<.10; *P<.05; **P<.01; ***P<.001.

^aDM (dry matter); NDF (neutral detergent fiber); NDS (neutral detergent solubles); ADF (acid detergent fiber); HCL (hemicellulose); CL (cellulose); CP (crude protein).

^bOrchard grass or tall fescue and timothy.

Table 3. Coefficients of Partial Regression and Least Square Means for Nutrient Intake of Cows in the Total-Collection Digestion Trial.

Source	Intake, kg/head/day					
	DM	NDF	NDS	ADF	HCL	CP
Intercept	5.65	3.97	1.67	1.93	1.91	1.82
Calf age, days	.04	.03	.01	.02	.02	.02
Hay type ^b						
Orchard grass-timothy	⁺ 8.62	5.53	*** 3.19	2.98	2.54	2.42
Tall fescue-timothy	6.98	5.03	1.94	2.60	2.41	2.34
						.67
						.90

⁺p<.10; *p<.05; **p<.01; ***p<.001.

^aDM (dry matter); NDF (neutral detergent fiber); NDS (neutral detergent solubles); ADF (acid detergent fiber); HCL (hemicellulose); CL (cellulose); CP (crude protein).

^bAsterisks above a mean indicate level of significance for the class effects.

correlation of .62 between ration acid insoluble lignin and voluntary intake and a negative correlation of .69 between ration cell-wall constituents and voluntary intake. Van Soest (1963) suggested that the relatively high intake levels of legumes as compared to grasses may be due to the fact that legumes have a low cell-wall content which is highly lignified, while grasses contain a high cell-wall fraction which is less lignified. In the present study, the OGTH contained 65.5% cell-wall and 5.5% acid-insoluble lignin while the TPTH had 74.9% cell-wall and 3.8% acid-insoluble lignin. Hence, the cell-wall level in the OGTH was lower but was more highly liquified than the cell-wall fraction in the TPTH. This might be part of the reason why the cows consumed more OGTH. Also, there is an indication that heavy nitrogen fertilization depresses intake. Reid and Jung (1965) reported that dry matter intake was depressed significantly in sheep fed tall fescue hay heavily fertilized with nitrogen (510 kg/ha) which was the case with the TPTH fed to the cows in the present experiment and might have contributed to higher intake of the OGTH in the present study.

Relation of Ration Constituents and Digestibility

The influences of ration components on nutrient digestibility is given in Table 4. The cows fed the TPTH digested more of the neutral-detergent fiber (14.6%, $P < .001$) and crude protein (12.5%, $P < .01$) than cows fed the OGTH (Table 5). The TPTH had 13.0% crude protein while the OGTH contained only 7.0% crude protein. There is an indication for a positive association between the level of crude protein in the ration and the digestibility of fibrous fractions of a

Table 4. Analyses of Variance of Nutrient Digestibility of Cows in the Total-Collection Digestion Trial.

Source	DF	Digestibility, % ^a						
		DM	NDF	NDS	ADF	HCL	CL	CP
Intake, kg/head/day	1	5.89		56.61 ⁺	6.42	6.17	22.22	31.92
Cow weight, kg.	1	41.99*	30.63 ⁺	80.97*	12.62	21.91	32.61	76.77 ⁺
Calf age, days	1	46.92*	39.78*	47.21 ⁺	102.55 ⁺	18.92	21.25	76.11 ⁺
Hay type ^b	1	14.56	578.0***	458.75***	481.66**	248.74**	1351.61***	227.75**
Residual	7	5.98	6.35	10.77	23.28	11.17	9.27	14.17
R ²		.74	.94	.94	.85	.81	.96	.80

⁺P<.10; *P<.05; **P<.01; ***P<.001.

^aDM (dry matter); NDF (neutral detergent fiber); NDS (neutral detergent solubles); ADF (acid detergent fiber); HCL (hemicellulose); CL (cellulose); CP (crude protein).

^bOrchard grass or tall fescue and timothy.

Table 5. Coefficients of Partial Regression and Least Square Means for Nutrient Digestibility of Cows in the Total-Collection Digestion Trial.

Source	Digestibility, % ^a						
	DM	NDF	NDS	ADF	HCL	CL	CP
Intercept	29.92	33.39	10.07	25.34	61.76	25.16	15.69
Intake, kg/head/day	-.64	-.01	-7.16 ⁺	-2.07	-1.82	3.57	-14.77
Cow weight, kg	.07*	.06 ⁺	.10*	.04	.06	.06	.10 ⁺
Calf age, days	.32*	.30*	.32 ⁺	.49 ⁺	.20	.22	.43 ⁺
Hay type ^b							
Orchard grass-timothy	58.47	** ⁺	** ⁺	**	**	**	**
Tall fescue-timothy	61.27	53.17	70.41	36.92	74.86	44.55	44.10
		67.75	41.86	51.61	84.23	66.26	56.56

⁺P<.10; *P<.05; **P<.01; ***P<.001.

^aDM (dry matter); NDF (neutral detergent fiber); NDS (neutral detergent solubles); ADF (acid detergent fiber); HCL (hemicellulose); CL (cellulose); CP (crude protein).

^bAsterisks above a mean indicate level of significance for the class effects.

ration. Schneider and Flatt (1975) reviewed about 50 factors influencing digestibility and concluded that more protein in the feed increased the digestibility of fiber in the feed by supplying the nutrients essential for proper growth and activity of microorganisms in the rumen. However, the digestibility of neutral detergent solubles (comprising predominantly sugars, starch, pectin, protein and lipids, Van Soest and Robertson, 1978) was lower by 28.6% ($P < .001$) in the cows fed the OGTH. The neutral detergent solubles content of the OGTH (34.5%) was higher by 9.4% than in the TFTH (25.1%). In the section where they reviewed the level of intake of soluble carbohydrates on digestibility, Schneider and Flatt (1975) concluded that rumen microorganisms utilize the readily available carbohydrates instead of attacking the fibrous fractions in ration containing relatively more soluble carbohydrates. This could be the reason why more of the neutral detergent solubles and less of the neutral detergent fiber of the OGTH and not of the TFTH were digested.

Relation of Nutrient Intake and Digestibility

There was a significant relationship between intake and digestibility of the neutral detergent solubles, cellulose and crude protein fractions of the hay (Table 4). The negative regression coefficients between the intake of a specific nutrient and its digestibility were 7.2% ($P < .10$) for neutral detergent solubles and 14.8% for crude protein (Table 5). These results are in agreement with the data reported by Brody (1945) and Moe et al. (1963) who stated that in ruminants the proportion of digested ration decreased as the amount of ration ingested increased. This relationship is

assumed to be due to a more rapid passage of the ingesta through the gastro-intestinal tract when intake is increased, causing a reduction in the rate of fermentation and digestion (Blaxter and McGraham, 1956).

Relation of Cow Weight and Digestibility

The cows' weight ranged between 363 and 465 kg with a mean weight of about 400 kg. Cow weight differences accounted for 25.8% of the variation in digestibility of dry matter (Table 4). The cow having a 100 kg more weight advantage digested 7% more ($P < .05$) of the dry matter, 6% more ($P < .10$) of the neutral-detergent fiber, 10% more ($P < .05$) of the neutral detergent solubles and 10% more ($P < .10$) of the crude protein (Table 5). Gill et al. (1978) noted a significant but second degree relationship between cow weight and crude protein digestibility. Nutt et al. (1980) observed that the cow with a 1 kg weight advantage had a 60 ml more rumen capacity. Purser and Moir (1966b) reported a positive relationship between rumen volume and the digestibility of dry matter.

In this study, cow height (range, 108.7 to 122.4 cm and mean 114.0 cm) did not have a measurable effect on nutrient digestibility. But cow weight was positively related to nutrient digestibility and the relationship was statistically significant. Hence, irrespective of height, the fat cows were probably more efficient digestors of most of the nutrients. However, Hogan et al. (1967), Forbes (1969) and Nutt et al. (1980) reported that abdominal fat and rumen capacity are negatively correlated because reduction in rumen capacity increases the turnover rate of the ingesta (Graham and Williams,

1962) and this depresses digestibility. Since nutrient digestibility was enhanced in this study, this relationship is not directly applicable.

Relation of Calf Age and Digestibility by Cows

The calves' age ranged between 22 and 46 days with a mean age of 33.3 days. The nutrient digestibility of cows was significantly related to age difference in the calves (Table 4). Calf age accounted for 28.9% of the variation in digestibility of the dry matter but for about 5.0% of the variation in the digestibility of the neutral-detergent fiber and both of the partial coefficients of determination values were statistically significant ($P < .05$). The correlation between calf age and cow daily milk yield was low ($r = .23$) and milk production did not significantly affect nutrient digestibility in this study. Hence, the significant relationship between calf age and dam nutrient digestibility was not due to the difference in the daily milk yield.

However, it is known that suckling increases the levels of oxytocin in the peripheral blood of the cow (Schmidt, 1971). Hence, it could be that the older calf might have been less dependent on the dam and had suckled for a shorter time each day than the younger calves. This might have caused a relative decline in the oxytocin titer in the blood of the cow with the older calf. It is known that oxytocin causes faster contraction of not only the udder myoepithelial cells but also of the smooth muscles in the uterus (McDonald, 1975) and possibly the smooth muscle in the gastro-intestinal tract (GI). Hence, the GI smooth muscles in the cows nursing the older calves

might have contracted less and for a shorter period of time, causing a slower turnover of ingesta by the cows with older calves. This might have caused the nutrients to be digested more in the cows with older calves than in the cows with younger calves.



CHAPTER IV

INFLUENCE OF ANIMAL AND RATION VARIABLES ON NUTRIENT INTAKE AND DIGESTIBILITY IN COWS AT MID TO LATE LACTATION

Summary

The main objectives of the study were to investigate the possible influences of animal physiological and inherent differences on intake and digestibility of nutrients using acid-insoluble ash as the internal indicator for the determination of nutrient digestion coefficients. Three successive indicator-ratio digestion trials were conducted with 24 cows each in trials 1 and 2 and 23 cows in trial 3. The cows in all of the trials were fed mainly grass silage ad libitum. Metabolic size in kg was 97.3 for the cows in trial 1, 96.4 for the cows in trial 2 and 95.8 for the cows in trial 3. There were 16 pregnant cows and 8 nonpregnant cows in trial 2 and 20 pregnant and 3 nonpregnant cows in trial 3. The cows were pregnant for 34, 66 and 108 days during trials 1, 2 and 3, respectively. All of the cows were lactating during the conduction of the trials and they produced 6.9 kg during trial 1, 6.4 kg during trial 2 and 3.5 kg during trial 3. The influence of metabolic size on intake was significant in only the first indicator-ratio digestion trial. In trial 1, a kg difference in metabolic size was associated with a .06 kg rise ($P < .10$) in dry matter intake.

A comparison of nutrient intake difference between pregnant and nonpregnant cows showed that pregnancy status did not affect the daily nutrient intake in trial 1 but the daily dry matter intake was higher in the pregnant than in the nonpregnant cows by about 2.0 kg ($P < .05$) in trial 2 and by about 1.5 kg ($P < .01$) in trial 3. A study of the influence of stage of gestation on nutrient intake revealed that at 34 days (range, 25 to 48 days) post conception (trial 1), stage of gestation did not affect nutrient intake. However, as pregnancy advanced to 66 (range, 25 to 89 days, trial 2) and 108 days (range, 67 to 131 days, trial 3), a 1-day increase in the length of gestation was associated with a 40-g decrease in trial 2 and a 30-g decrease in trial 3 in the daily dry matter intake. Difference in metabolic size had a positive influence on nutrient digestibility in trial 3. In the same trial, metabolic size accounted for about 11% ($P < .10$) of the variation in digestibility of dry matter, neutral detergent fiber and cellulose. Pregnancy status had a significant influence on digestibility only in trials 2 and 3. The nonpregnant cows digested 3.9 percentage unit more ($P < .05$) of the hemicellulose in trial 3. Digestibility of neutral fiber in the 66-days pregnant cows (trial 3) and digestibility of hemicellulose was significantly affected by stage of pregnancy in both the 66-days (trial 2) and 108-days pregnant cows (trial 3). In trial 2, a 1-day increase in the age of the in situ developing fetus caused a rise in digestibility of neutral-detergent fiber and hemicellulose of .12% ($P < .10$) and 19% ($P < .01$), respectively. However, as pregnancy advanced to 108 days (trial 3) digestibility of most of the nutrients was depressed.

In trial 3, a 1-day increase in the age of the in situ developing fetus caused a reduction of .19% ($P < .05$) in the digestibility of hemicellulose.

The relation between daily milk yield and nutrient digestibility was significant only in the cows lactating for 146 days (trial 1) and not in the cows lactating for 187 days (trial 2) or 229 days (trial 3). In trial 1 the cow whose milk production was higher than that of the average cow by 1 kg digested significantly more of the dry matter (3.0%, $P < .05$), neutral-detergent fiber (3.3%, $P < .05$), acid detergent fiber (3.6, $P < .05$), hemicellulose (3.5%, $P < .001$) and cellulose (3.0%, $P < .05$). The daily nutrient intake had a depressing effect on the digestibility of nutrients. In trials 2 and 3 the cow consuming 1 kg more dry matter daily had the digestibility of the dry matter depressed by 1.3% ($P < .10$) and by 2.4% ($P < .05$), respectively.

(Key words: Metabolic Size on Intake or Digestibility, Pregnancy Status on Intake or Digestibility, Stage of Gestation on Intake or Digestibility, Milk Production and Digestibility, Nutrient Intake and Digestibility.)

Introduction

There is an acute shortage of data showing the possibility of an influence of the earlier stages of pregnancy on nutrient intake and digestibility. Studies by Forbes (1970a) and by Sykes and Field (1972) with pregnant ewes showed that nutrient intake increased up to week 18 of pregnancy (last trimester) but declined thereafter. Also, the very limited results from studies relating pregnancy and

nutrient digestibility indicated that pregnancy depressed digestibility in the last trimester of pregnancy (Flatt et al., 1967; Gill et al., 1978). The relation of digestibility to rate of milk production has not been studied. However, Gill et al. (1978) observed a positive correlation of 0.46 ($P < .05$), 0.60 ($P < .01$) and 0.41 ($P < .05$) between calf average daily gain, a proxy of milk production, and dry matter, acid detergent fiber and gross energy digestion of their dams, respectively. The objectives of this study were to identify possible relationships between production and animal differences on intake and digestibility of nutrients in beef cows.

Materials and Methods

Management of Experimental Animals

A total of 24 lactating cows and their steer calves were used in a completely random design. These same cows were used in 3 successive indicator digestion trials, interspersed throughout 1 lactation. There were 12 Angus and 12 Hereford cows, one half of which were nursing their steer calves sired by bulls of their own breed while the remaining one half were nursing their steer calves sired by bulls of the other breed. The cow-calf pairs were assigned to a 2 x 12 meter individual feeding and loafing pen starting on 4/16/79 and remained there until 10/16/79. The pens had concrete floors and were partially under an open shed. Each pen had an automatic waterer, a large feeding stall equipped with a gate at the rear for the cow and a small creep feeding stall for the steer calf. Each day the cow-calf pairs were placed in their pens at about 7 a.m.

and were turned out at around 5 p.m. to loafing areas, each accommodating 12 cow-calf pairs for an overnight stay.

In a previous study, calves were seen sharing feed offered to the dams (Gill et al., 1978). Prior to the present study, the calves consumed about 2 to 4 kg silage daily. To avoid this, the doors behind the cow feeding gates were closed during the 4-day adjustment and 6-day sample collection until they were turned out at 5 p.m.

Feeding Procedure

Throughout the overall trial and the digestion trials, the cows were fed a measured modified ad libitum amount of grass silage composed of timothy (Phleum pratense) and orchard grass (Dactylis glomerata) along with alfalfa (Medicago sativa) pellets. During the 3 digestion trials, covering the periods 6/2/79 to 6/12/79 (trial 1), 7/15/79 to 7/25/79 (trial 2) and 9/15/79 to 9/25/79 (trial 3), the amount of silage offered was adjusted so that the daily refusal was less than 10% of the amount offered. The alfalfa pellets were fed top-dressed over the silage. The pellets were fed in a constant ratio to the silage, i.e., about 10% of the previous day's consumption of silage.

Daily representative feed samples were taken before feeding and representative refusal samples at 4 p.m. the same day. Both the feed and refusal samples were deposited in plastic bags labeled with cow number and sampling date. The bags were sealed and stored at -20 C until drying. Nutrient composition of the ration is given in Table 6.

Table 6. Components of Ration Fed to Cows (Trials 1, 2 and 3, Percent Dry Basis)

Items	Grass silage			Alfalfa pellets		
	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
Dry matter	29.94	37.71	20.03	90.20	89.27	92.98
Neutral detergent fiber	73.40	74.22	59.19	48.33	51.88	47.21
Neutral detergent solubles	26.60	25.78	40.81	51.67	48.12	52.79
Acid detergent fiber	49.88	47.34	43.48	36.94	35.06	33.62
Hemicellulose	23.52	26.88	15.71	11.39	16.82	13.59
Cellulose	42.13	39.01	33.51	28.82	26.82	25.54
Crude protein	9.34	10.84	15.85	19.93	23.52	19.69
Lignin	7.75	8.33	9.97	8.12	8.24	8.08
Acid-insoluble ash	1.39	1.32	1.09	3.04	1.58	1.83

Sampling Feces

During each of the 3 digestion trials, fecal samples were collected for 6 days. To obtain the samples, a gloved hand was inserted into the rectum and all available feces was scooped out into plastic bags identified with animal number, hour and date of collection. Fecal sampling was alternated between mornings and afternoons so that 3 morning (8 a.m.) and 3 afternoon (4 p.m.) samples were collected from each animal. The fecal samples were stored at -20 C until they were processed for laboratory analyses.

Laboratory Procedure

The feed, refusal and fecal samples from the 3 trials were weighed into clean preweighed aluminum pans and dried for 3 days at 50 C and air equilibrated for 3 days. All of the samples were ground in a Wiley mill using a 20-mesh (1 mm) screen and stored in plastic bags labeled with type of sample, animal number, date and hour of collection. For each animal equal and representative a.m. fecal samples were composited into one composite sample and all of the p.m. samples into another sample. Also, equal percentages of every day's offered feed, on air-equilibrated dry matter (AEDM) basis, were composited into one sample. Similarly, the refusal from each animal was composited on AEDM basis by mixing equal percentages from each day's refusal into one composite representative sample for each animal.

Laboratory Analyses

The representative feed, refusal and fecal samples were analyzed for dry matter (DM) and crude protein (CP) (AOAC, 1975); neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (Lignin) (Van Soest, 1963); and 2N-acid insoluble ash (AIA) (Van Keulen and Young, 1977). Additional ration constituents were calculated from the following relationships:

Neutral detergent soluble, % (%NDS) = $100 - \%NDF$

Hemicellulose, % (%HCL) = $\%NDF - \%ADF$

Cellulose, % (%CL) = $\%ADF - \%Lignin$

Preliminary studies with the AIA laboratory analysis of Van Keulen and Young (1977) revealed that the procedure as described in their publication was not in sufficient detail and therefore unsatisfactory because the error between some duplicate samples was unacceptable, sometimes approaching 80%. However, due to the following additional refinement steps, the error between duplicate samples was reduced to below 1%. Procedure of the previous workers, with the added refinement steps underlined, is as follows:

1. Grind sample to pass 1 mm screen.
2. Wash 50 ml porcelain crucibles with distilled water and ash at 600 C for 3 hours. Before putting the crucibles in the furnace, make sure that it is free of dust or ash.
3. Transfer the crucibles into clean desiccators and cool them for 4 hours.
4. Weigh the empty crucibles and record the weight (We).

5. Weigh a 2-gram or a 3-gram feed sample into the 50 ml crucible.
 - a. Each sample is analyzed in triplicate.
 - b. Take extra care when getting the sample and transferring it into crucibles. Make sure that the sample in all the 3 crucibles is a representative sample, otherwise all the effort will be worthless.
6. Dry the samples at 135 C for 2 hours or at 105 C for 10 hours in still air ovens.
7. Cool in a clean desiccator for 4 hours and reweigh the crucible with the contents (Ws). Be careful when opening spout on the desiccator otherwise some of the samples can fly away causing error.
8. Ash the sample for 10 hours at 450 C. The furnace must be made free from sand, ash or any other particles before the samples are placed in it.
9. Do not put the ashed samples in a desiccator at this stage! If further analysis is to be delayed, the crucibles can be kept outside but must be covered with clean paper to keep out the laboratory dust. If the ash sample is stored for a considerable length of time, wetting the ash with some drops of 2N HCl prevents loss of ash due to flying away because of air movement in the laboratory.
10. The ash is transferred to a 600 ml Berzelius beaker (without spout). It is always good to wet the ash with 2N HCl before transferring to the beaker and the wet ash

is transferred into the beaker with a wash bottle filled with 2N HCl. More 2N HCl must be added to raise the liquid volume to 100 ml in the beaker.

11. The mixture is boiled for 5 minutes.
12. The hot hydrolysate is filtered through Whatman No. 41 paper, using a porcelain Buchner funnel with inside measurement of 91 mm by 46 mm diameter and depth, respectively. But the whole inside filtering surface of the Buchner funnel must be covered with the filter paper. In this study, this was achieved by first forming a cylinder from the 15 cm (diameter) filter paper by folding it down on the bottom of an empty 600 ml Berzelius beaker before fitting it into the funnel.
13. The hydrolysate is then washed free of acid with hot distilled water at 85 to 100 C.
14. The filter paper with ash is transferred back into the original crucible and ashed for 10 hours at 450 C (see item 8).
15. The crucible with content is cooled in a desiccator for 4 hours (see item 7 for modification).
16. Weigh the crucible with its content (Wf).
17. Percent acid-insoluble ash is calculated according to the following equation:

$$\text{AIA, \%} = \frac{W_f - W_e}{W_s} \times 100$$

Determination of Digestion Coefficients

The laboratory analysis results were used to determine the apparent digestion coefficients of DM, NDF, NDS, ADF, HCL, CL and CP by the AIA-ratio technique using the formulas of Schneider and Flatt (1975).

$$\begin{array}{l} \text{Digestion coefficient} \\ \text{of dry matter, \%} \end{array} = 100 - 100 \frac{\begin{array}{l} \% \text{ indicator in the dry} \\ \text{matter of the feed (offered)} \end{array}}{\begin{array}{l} \% \text{ indicator in the dry} \\ \text{matter of the feces} \end{array}}$$

$$\begin{array}{l} \text{Digestion coefficient} \\ \text{of nutrient, \%} \end{array} = 100 - 100 \frac{\begin{array}{l} \% \text{ indicator in} \\ \text{the feed (offered)} \end{array}}{\begin{array}{l} \% \text{ indicator in} \\ \text{the feces} \end{array}} \times \frac{\begin{array}{l} \% \text{ nutrient in} \\ \text{the feces} \end{array}}{\begin{array}{l} \% \text{ nutrient in} \\ \text{the feed} \end{array}}$$

Animal Variables

During the course of the study, measurements were made of the cows and of the steer calves. The age of the animals in days was the period between date calved and the last day of the collection period for the respective trial. The weight, in kg, was the mean of weights at the start and end of the respective digestion trial and metabolic size represented $W_{\text{kg}}^{.75}$. Height of the animal in cm represented the vertical length measurement of the animal at the withers. Condition of the animal was estimated from the ratio of weight in kg to height in cm of the animal. Milk production by cows was estimated from weight differences in calves before and after nursing (weigh-suckle-weight) once during the trial period after separating the calves from the cows for 12 hours in trials, 1, 2 and 3. When the 12-hour milk production record was multiplied by 2, it resulted in the daily

milk yield of the cows. The gestation length in days was back-calculated from the date of the next calving.

In order to obtain daily weight gains of calves during a longer period, the overall trial was divided into 3 parts which included time before, during and after the digestion trial. Following are the dates from which average daily weight gain was calculated.

<u>Trial</u>	<u>Interval</u>	<u>Days</u>
1	4/16/79 to 6/12/79	58
2	6/13/79 to 7/25/79	44
3	7/26/79 to 9/05/79	43

Statistical Analysis

The data were analyzed by the method of multiple linear regression (SAS, 1979). Partial regression coefficients and partial coefficients of determination were used to determine the direction and the strength of relationship. Partial coefficients of determination values were computed by dividing the partial sum of squares by the corrected total sum of squares. Initially, weight to height ratio, age of the animal, weight of the animal, height of the animal, milk production, calf average daily gain and breed of cow were also included in the model as independent variables and daily nutrient intake or digestibility as dependent variables. However, to guard the model from over-parameterization the independent variables found to have no effect ($P > .10$) were deleted. Least square means for the class variables were calculated from the best fitting final models. The final models used were:

Trial 1

Intake = Intercept, metabolic size, pregnancy status and gestation (pregnancy).

Digestibility = Intercept, nutrient intake, metabolic size, pregnancy status and gestation (pregnancy).

Trial 2

Intake = Intercept, metabolic size, pregnancy status and gestation (pregnancy).

Digestibility = Intercept, nutrient intake, metabolic size, milk production, pregnancy status and gestation (pregnancy).

Trial 3

Intake = Intercept, metabolic size, age of cows, pregnancy status and gestation (pregnancy).

Digestibility = Intercept, nutrient intake, pregnancy status and gestation (pregnancy).

Results and Discussion

Relation of Metabolic Size and Nutrient Intake

The relationship between nutrient intake and animal parameters was studied. This relationship was similar in dry matter intake and intake of most nutrients (Tables A-15 to A-24), the only exception being intake of hemicellulose. Therefore, only dry matter and hemicellulose intake in relation to animal parameters will be discussed. During trials 1, 2 and 3, metabolic size of cows and

standard error in kg were 97.3 ± 1.8 , 96.4 ± 1.8 and 95.8 ± 1.8 , respectively. The analysis of variance of the relation between metabolic size and dry matter intake is given in Table 7. In trials 1, 2 and 3, all components of the models accounted for 16, 32 and 43% of the variation in dry matter intake of the cows, respectively. Of the total variation, 75% in trial 1, 10% in trial 2 and .6% in trial 3 of the variation in dry matter intake were accounted for by the difference in metabolic size. Coefficients of partial regression relating metabolic size with the daily dry matter intake are presented in Table 8. In trial 1, a 1 kg increase in metabolic size was associated with a .06 kg rise ($P < .10$) in dry matter intake. However, while the positive relation persisted, the influence of metabolic size on intake was not statistically significant in trial 2 and the relationship was negative in trial 3. Cows in the 3 successive trials varied in physiological status (pregnancy and lactation) as well as in metabolic size. At advanced stages of pregnancy (trial 3), the magnitude of the effect of metabolic size on DM intake decreased while the effect of stage of pregnancy increased. However, metabolic size also changed during the successive trials. Metabolic size of the cows in trial 1 decreased in the successive trials by .89 kg in trial 2 and by an additional 0.6 kg in trial 3. This is probably an indication that mature beef cows must attain a metabolic size of at least 97.3 kg before the relationship between intake and metabolic size becomes positive and statistically significant. Trimberger et al. (1963) studied factors affecting appetite in 129 Guernsey cows. They concluded that, in the cows with an average

Table 7. Analyses of Variance of Dry Matter Intake and Digestibility of Cows in the Indicator-Ratio Digestion Trial.

Source	Intake, kg/head/day						Digestibility, %					
	Trial 1 DF	Trial 1 MS	Trial 2 DF	Trial 2 MS	Trial 3 DF	Trial 3 MS	Trial 1 DF	Trial 1 MS	Trial 2 DF	Trial 2 MS	Trial 3 DF	Trial 3 MS
Intake, kg/head/day							1	19.32	1	86.30 ⁺	1	95.14*
Metabolic size, kg	1	6.45 ⁺	1	2.02	1	.03	1	30.19	1	11.55	1	52.68 ⁺
Milk production, kg/day							1	155.93*				
Age, years					1	1.28						
Pregnancy status ^a	1	.94	1	19.50*	1	8.82**	1	41.22	1	51.45	1	.45
Gestation (pregnancy) ^b	1	1.12	1	8.77 ⁺	1	4.82*	1	21.15	1	40.02	1	9.46
Residual	20	2.30	20	2.65	18	.87	18	30.66	19	28.87	18	15.75
R ²		.16		.32		.43		.35		.38		.42

⁺p<.10; *p<.05; **p<.01.

^apregnant versus open.

^bstage of gestation in days.

Table 8. Coefficients of Partial Regression and Least Square Means for Dry Matter Intake and Digestibility of Cows in the Indicator-Ratio Digestion Trial.

Source	Intake, kg/head/day			Digestibility, %		
	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
Intercept	1.40	7.30	10.98	66.99	80.25	76.82
Intake, kg/head/day				-0.65	-1.28 ⁺	-2.36 [*]
Metabolic size, kg	.06 ⁺	.04	-0.01	-0.14	-0.09	0.20 ⁺
Milk production, kg/day				2.95 [*]		
Age, years			0.11			
Pregnancy status ^a						
Open	8.57	6.42 [*]	7.14 ^{**}	65.98	69.30	75.35
Pregnant	8.60	8.37	8.63	63.29	67.17	71.51
Gestation (pregnancy) ^b	.03	-0.04 ⁺	-0.03 [*]	0.16	0.08	-0.04

⁺p<.10; *p<.05; **p<.01.

^aAsterisks above a mean indicate level of significance for the class effects.

^bStage of gestation in days.

metabolic size of about 103.0 kg, the correlation between dry matter intake and metabolic weight was positive ($r=.49$). The partial correlation coefficient between dry matter intake and metabolic size was positive in trial 1 but was lower by .15 than the correlation coefficient for the Guernsey cows.

Relation of Pregnancy Status and Nutrient Intake

There were 16 pregnant and 8 nonpregnant cows in trial 1, 20 pregnant and 4 nonpregnant cows in trial 2 and 20 pregnant and 3 nonpregnant cows in trial 3. The nutrient intake for pregnant and nonpregnant cows is given in Tables A-15 to A-24. There was no difference in dry matter intake between the pregnant and nonpregnant cows in trial 1, but in trials 2 and 3, pregnancy status accounted for 25.1% and 22.0%, respectively, of the variation in dry matter consumed by the cows (Table 7). The daily dry matter intake was higher in the pregnant than in the nonpregnant cows by 2.0 kg/day ($P<.05$) in trial 2 and by 1.5 kg/day ($P<.01$) in trial 3 (Table 8).

Brown (1966) concluded that pregnant cows consumed more silage than nonpregnant cows. Forbes (1970b) reported that single-bearing ewes ate more dry matter than nonpregnant ewes. These findings are in agreement with the data reported for the cows in trials 2 and 3. However, there was no significant difference in intake between the pregnant and the nonpregnant cows in trial 1. The cows were pregnant for 34, 66 and 108 days during the conduction of trials 1, 2 and 3, respectively. Hence, it is conceivable that the in situ developing fetus does not exert pressure for additional intake by the dam on or before 34 but after 66 days of pregnancy.

Relation of Stage of Gestation and Nutrient Intake

The stage of gestation range for trials 1, 2 and 3 was 25 to 48 days, 25 to 89 days and 67 to 131 days, respectively. At an average 34 days post-conception (trial 1), stage of gestation did not significantly influence nutrient intake (Table 7). However, as pregnancy advanced to an average of 66 days (trial 2) and 108 days (trial 3), there was a significantly negative influence on nutrient intake (Table 8). A 1-day increase in the length of gestation was associated with a 40-g decrease ($P < .10$) in trial 2 and a 30-g drop ($P < .05$) in trial 3 in the daily dry matter intake. Similar relationships were reported by Gordon and Tribe (1951), Reid and Hinks (1962) and Forbes (1970a,b) in ewes; by Friend (1971) in sows; and by Moodie and Robertson (1961) and Currant et al. (1967) in cows. All of their studies had been conducted because it was known that the enlargement of the pregnant uterus reduces the content of the gastro-intestinal tract.

However, it is important to note that cows in trials 2 and 3 were in their first and second trimester of pregnancy, respectively. In these early stages of gestation the size of the pregnant uterus probably has some effect on gastro-intestinal fill. The additional factor for the decrease in intake with advancing pregnancy even in early gestation might be hormonal changes in the dam.

Effect of administered hormone on ration intake was reported by Andrews et al. (1949). When they subcutaneously implanted lambs with 10 or 25 mg of stilbestrol or 10 mg of testosterone, the wether lambs consumed less feed than control wether lambs. In contrast to this observation, Clegg and Cole (1954) showed that subcutaneous

implanation of a 12-mg stilbestrol capsule caused an increase in feed intake. However, Forbes (1970a) and Muir et al. (1972) reported that when a large amount of progesterone was given together with estrogen to open ewes and heifers, respectively (a physiological state similar to pregnancy), it reduced intake.

Although it is clear that at 66 and 108 days of gestation the pregnant cows consumed more dry matter than the nonpregnant cows, an advance in pregnancy from 66 to 108 days caused a progressive decline in dry matter intake.

Relation of Metabolic Size and Digestibility

The digestibility of dry matter was significantly ($P < .10$) affected by metabolic size difference in trial 3. Metabolic size accounted for 10.8% of the digestibility of dry matter in trial 3 (Table 7). The cow in trial 3 with a 1 kg metabolic size advantage digested .20 percentage unit more ($P < .10$) dry matter (Table 8). During this trial (trial 3), the average metabolic size of the cows was 95.8 kg. This value was lower than metabolic size value of the cows in trial 1 by 1.5 kg and of the cows in trial 2 by .59 kg. Metabolic size did not significantly affect dry matter digestibility in trials 1 and 2. Hence, it seems that beef cows become efficient digesters of dry matter when they are at a lower metabolic size than when at a higher metabolic size.

Relation of Pregnancy Status and Digestibility

The relationship between nutrient digestibility and animal parameters was studied. This relationship was similar in dry matter digestibility and digestibility of most nutrients (Tables A-15 to A-24), the only exception being digestibility of hemicellulose. Therefore, only dry matter and hemicellulose digestibility in relation to animal parameters will be discussed.

In all of the trials, the nonpregnant cows digested more of the dry matter (Table 8) than the pregnant cows. Pregnancy status accounted for 31.1% of the variation in digestibility of hemicellulose in trial 2, but for 19.1% of the digestibility of hemicellulose in trial 3 (Table 9). The nonpregnant cows digested 4.3 percentage units more ($P < .01$) of the hemicellulose in trial 2, but 0.73 percentage unit less ($P < .05$) of the hemicellulose in trial 3 (Table 10). It is not clear why digestibility of hemicellulose was enhanced in the nonpregnant cows in trial 2 but depressed in trial 3. The nonpregnant cows in trial 2 consumed 0.45 kg less ($P < .05$) hemicellulose. However, the amount of hemicellulose consumed by the cows in trial 3 was not significantly affected by pregnancy status of cows. Nevertheless, the pregnant cows digested about .73 percentage unit more ($P < .05$) of the hemicellulose than the nonpregnant cows. There are data indicating an inverse relationship between dry matter intake and digestibility (Brody, 1945; Forbes et al., 1928; Moe et al., 1963). The nonpregnant cows in trial 2 consumed less hemicellulose than the pregnant cows. Hence, the nutrient digestibility might have been enhanced in the nonpregnant cows in trial 3 due to the difference

Table 9. Analyses of Variance of Hemicellulose Intake and Digestibility of Cows in the Indicator-Ratio Digestion Trial.

Source	Intake, kg/head/day						Digestibility, %					
	Trial 1 DF	Trial 1 MS	Trial 2 DF	Trial 2 MS	Trial 3 DF	Trial 3 MS	Trial 1 DF	Trial 1 MS	Trial 2 DF	Trial 2 MS	Trial 3 DF	Trial 3 MS
Intake, kg/head/day							1	60.84 [†]	1	11.16	1	173.53*
Metabolic size, kg.	1	.25	1	.12	1	.01	1	.45	1	27.89	1	71.89
Milk production, kg/day							1	221.52***				
Age, years					1	.03						
Pregnancy status ^a	1	.03	1	1.07*	1	.21	1	15.44	1	248.61**	1	165.24*
Gestation (pregnancy) ^b	1	.04	1	.49 [†]	1	.11*	1	2.69	1	203.87**	1	185.13*
Residual	20	.09	20	.16	18	.02	18	14.53	19	17.17	18	32.50
R ²		.16		.30		.44		.59		.59		.32

[†]P<.10; *P<.05; **P<.01; ***P<.001.

^aPregnant versus open.

^bStage of gestation in days.

Table 10. Coefficients of Partial Regression and Least Square Means for Hemicellulose Intake and Digestibility of Cows in the Indicator-Ratio Digestion Trial.

Source	Intake, kg/head/day			Digestibility, %		
	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
Intercept	0.34	1.77	1.75	74.17	88.91	107.85
Intake, kg/head/day				-5.83 [†]	-1.88	-21.09 [*]
Metabolic size, kg	0.01	0.01		-0.02	-0.13	0.24
Milk production, kg				3.52***		
Age, years			-0.02			
Pregnancy status ^a						
Open	1.75	1.60 [*]	1.08	79.30	88.95 ^{**}	81.54 [*]
Pregnant	1.78	2.05	1.32	76.25	84.64	82.27
Gestation (pregnancy)	0.01	-0.01 [†]	-0.01 [*]	0.06	0.19**	-0.19 [*]

[†]p<.10; *p<.05; **p<.01; ***p<.001.

^aAsterisks above a mean indicate level of significance for the class effects.

in the daily nutrient intake rather than due to the pregnancy status of the cows. However, in trial 3 there was no difference in hemicellulose intake between the two groups of cows and the nutrient fraction was digested more by the pregnant and less by the nonpregnant cows. Also, in the model relating animal parameters to nutrient digestibility, nutrient intake was included as one of the independent variables and its influence was held constant during the evaluation of the influences of pregnancy status on nutrient digestibility.

Relation of Stage of Gestation and Digestibility

There were 16 pregnant cows in trial 1 and 20 pregnant cows in each of trials 2 and 3. During trials 1 and 2, the cows were in their first trimester and during trial 3 they were in their second trimester of pregnancy. The relation between stage of pregnancy and digestibility of specific nutrients is presented in Tables A-15 to A-24. Digestibility of hemicellulose in the 66 days (trial 2) and 108 days (trial 3) pregnant cows was significantly affected by stage of pregnancy. In trial 2 a 1-day increase in the age of the in situ developing fetus caused a rise in digestibility of hemicellulose of .19% ($P < .01$) (Table 10). However, as pregnancy advanced to 108 days (trial 3), digestibility of hemicellulose was depressed. In trial 3, a 1-day increase in the age of the in situ developing fetus caused a reduction of .19% ($P < .05$) in the digestibility of hemicellulose. Decreases in digestibility with increasing length of gestation were also noted by Flatt et al. (1967) and Gill et al. (1978). The depression in digestibility of hemicellulose by the cows in trial 3 was probably partly due to the enlargement of the

pregnant uterus causing decreased gastro-intestinal fill resulting in increased passage of digesta which is known to depress digestibility. In ewes ranging in pregnancy between 72 and 114 days (third trimester), there was a negative relationship between the volume of the rumen content and volume of the uterus (Forbes, 1968a, 1969). Graham and Williams (1962) reported that retention time of food in the digestive system of ewes fell by 1 to 1 1/2 hours per 100 g increase of the estimated weight of the concepta and that an increase in the rate of passage depressed digestibility. The cows in trial 3 were pregnant for an average of 108 days (i.e., second trimester) during the conduction of that trial. Hence, negative relationship between the gravid uterus and digestibility probably starts as early as the fourth month of pregnancy in the beef cows.

Relation of Daily Milk Yield and Digestibility

The average of the amount of milk produced by the cows was 6.9 kg (trial 1), 6.4 kg (trial 2) and 3.5 kg daily (trial 3). These values are comparable to the values reported by Boggs et al. (1980). All of the cows were nursing calves during all trials and they were lactating for an average of about 146 days in trial 1, 187 days in trial 2 and 229 days in trial 3. The analysis of variance relating lactation and nutrient digestibility is given in Tables 7 and 9, pages 48 and 54, respectively. In trial 1, milk production accounted for 18.4% of the variation in the digestibility of dry matter and for 35.1% of the variation in the digestibility of hemicellulose. In the same trial (trial 1), the cow whose daily milk production was higher by 1 kg, digested significantly more (3.0%, $P < .05$) of the dry

matter and hemicellulose (3.52%, $P < .001$). During trial 1, the cows produced about 7 kg of milk per day. This amount was higher than the amount of the daily milk yield of the cows in trials 2 and 3 by .50 kg and 3.5 kg, respectively. Also, the cows were lactating for 146, 187 and 229 days during trials 1, 2 and 3, respectively. Hence, the data indicate that efficiency of nutrients digestibility is regulated by both the stage of lactation and the daily milk yield.

Relation of Daily Nutrient Intake and Digestibility

During trials 1, 2 and 3 the cows consumed, respectively, 8.6 kg, 8.0 kg and 8.4 kg dry matter daily. The relation between dry matter intake and digestibility is present in Table 7, page 48. About 10.0% variation in the digestibility of dry matter in trial 3 and about 19.5% of the variation in digestibility of dry matter in trial 4 were accounted for by the level of the daily dry matter intake. The study showed that dry matter digestibility was depressed by the daily intake of the nutrient in all of the successive indicator-ratio digestion trials. In trials 2 and 3, the cow consuming 1 kg more dry matter daily had the digestibility of the dry matter depressed by 1.3% ($P < .10$) and 2.4% ($P < .05$), respectively (Table 8, page 49). This result is in agreement with data reported by Mitchell (1942) and Reid and Hinks (1962).

The underlying causes of the negative correlation between intake and digestibility were investigated by some researchers. Graham and Williams (1962) measured the rate of passage of feed through the digestive system of Merino ewes and concluded that the

mean retention time fell by 3 hours per 100 g of increase of feed intake. Moore (1964) reported that an increase in rate of passage caused a decrease in digestibility.



CHAPTER V

INFLUENCES OF ANIMAL AND RATION VARIABLES ON NUTRIENT INTAKE AND DIGESTIBILITY IN YEARLING STEERS

Summary

Acid-insoluble ash was the internal digestibility indicator used in an investigation relating inherent animal differences to intake and digestibility of nutrients. The trial was conducted with 23 yearling steers comprising 6 Angus (A), 5 Hereford (H) and 12 crosses of which 6 were A x H (Angus sire and Hereford dam) while the remaining 6 were H x A (Hereford sire and Angus dam). They were fed mainly corn silage for an adjustment period of 4 and sample collection period of 6 days. The relation between metabolic size and nutrient intake showed that about 49% of the variation in dry matter intake was due to difference in metabolic size. A steer with a 1 kg advantage in metabolic weight consumed about 110 g more dry matter ($P < .001$) than a lighter steer. There was an indication of an inverse relationship between the daily intake of a specific nutrient and its digestibility. A comparison in nutrient digestibility among Angus (A), Hereford (H), A x H and H x A revealed that nutrient digestibility was similar in A, H and H x A. However, the A x H steers, as compared to the A steers, digested significantly less ($P < .05$) of the dry matter (7.8%), neutral detergent fiber (10.8%), neutral detergent solubles (6.4%), acid detergent fiber (10.3%), hemicellulose (12.0%) and cellulose (8.6%).

(Key Words: Metabolic Weight and Intake, Nutrient Intake and Digestibility, Breed and Digestibility.)

Introduction

It is assumed that there is no substantial difference in nutrient intake and digestibility among beef cattle of the British type (Washburn et al., 1948; Warwick and Cobb, 1974). However, it has been amply demonstrated that the Bos indicus cattle (zebu type) consume less dry matter than the Bos taurus (British type) cattle (Howes et al., 1963; Warwick and Cobb, 1974). A comparison of the nutrient digestibility between these two types revealed that high-fiber rations were digested better by the zebu types while the lower fiber rations were digested better by the British types of cattle (Schneider and Flatt, 1975). The objective of this study was to determine the nutrient intake and digestibility differences between yearling steers of Angus, Hereford breed and their two-way crosses.

Materials and Methods

Management of Experimental Animals

A total of 23 yearling steers were used in an acid-insoluble ash indicator digestion trial. The steers were each randomly assigned to a 2 x 12 meter individual feeding and loafing pen starting on 10/16/79 and remained there until slaughter.

Feeding Procedure

Throughout the digestion trial, the steers were fed measured, modified ad libitum amounts of corn (Zea maize) silage twice a day,

at 7 a.m. and 4 p.m. and ground corn-cottonseed meal mixture which was fed top-dressed over the silage. The ground corn-cottonseed meal mixture was fed in a constant ratio, i.e., about 10% of the previous day's consumption of corn silage. The amount of the silage offered was adjusted, so that the daily refusal was less than 10% of the amount offered. Daily representative feed samples were taken twice a day before feeding and representative refusal samples at 4 p.m. the same day. Both the feed and refusal samples were deposited in plastic bags labeled with steer number and sampling date. The bags were sealed and stored at -20 C until drying. Nutrient composition of the ration is given in Table 11.

The methods followed in sampling feces, in laboratory procedure, in laboratory analyses and in the determination of digestion coefficients were identical to those procedures followed in the cow trials 1, 2 and 3 and are given in Chapter IV. Intake and digestibility values are given in Table A-13.

Animal Variables

During the course of the study, measurements were made of the yearling steers. The age of the animals in days was the period between date calved and the last day of the collection period. The weight, in kg, was the mean of weights at the start and end of the digestion trial and metabolic weight represented $w_{kg}^{.75}$. Height of the animal, in cm, represented the vertical length measurement of the animal at the withers. Condition of the animal was estimated from the ratio of weight in kg to height in cm of the animals. The yearling steers' daily rate of gain was determined from weight

Table 11. Components of Ration Fed to Yearling Steers (Percent Dry Basis)

Items	Corn silage	Ground shelled corn + cottonseed meal
Dry matter	30.25	88.75
Neutral detergent fiber	52.65	16.41
Neutral detergent solubles	47.35	83.59
Acid detergent fiber	30.59	5.82
Hemicellulose	22.06	10.59
Cellulose	27.79	4.47
Crude protein	13.47	17.24
Lignin	3.40	1.35
Acid-insoluble ash	0.89	0.11

differences at weaning and the last day of the collection period. The interval covered the period between 10/16/79 and 3/14/80 and was a total of 151 days. The yearling steers' body parameters are presented in Table A-14.

Statistical Analysis

The data were analyzed by the method of multiple linear regression (SAS, 1979). Initially, the multiple regression model included weight or metabolic size, ratio of weight to height, age and breed as independent variables and daily nutrient intake or digestibility as dependent variables. However, the independent variables having no measurable influence ($P > .10$) were deleted from the model. From the final model the partial coefficients of regression and determination values were computed. Least square means for the class variables were calculated from the best fitting models. When analyses of variance revealed a significant difference among the breed means, mean separation was conducted with orthogonal contrast. The best fitting models were:

Intake = Intercept, Metabolic size and breed

Digestibility = Intercept, nutrient intake, metabolic size
and breed.

Results and Discussion

Relation of Metabolic Size and Nutrient Intake

The yearling steers' age ranged between 395 and 450 days and the mean age was 424 days. Their metabolic size was determined and

ranged between 62 and 84 kg and the mean metabolic size was 74 kg. The analyses of variance (ANOVA) between steer parameters and nutrient intake is given in Table 12. The differences in metabolic weight and breed accounted for 60% of the variation ($P < .01$) in the dry matter intake and of the total variation about 82% ($R^2 = 49\%$) of the variation was due to metabolic weight difference of the steers. The coefficients of partial regression and least square means for nutrient intake are presented in Table 13. The steer with a 1 kg advantage in metabolic weight consumed about 110 g more ($P < .001$) dry matter than the lighter steer.

Daily Nutrient Intake and Digestibility

The daily intake of the dry matter ranged between 4.7 kg and 7.0 kg (mean = 6.1 kg/head/day). The ANOVA of the relation between intake of a specific nutrient and its digestibility is presented in Table 14. Increased daily nutrient intake depressed nutrient digestibility (Table 15). The steer that increased its daily intake by 1 kg more had the dry matter, neutral detergent fiber and neutral detergent soluble digestibility depressed by 2.1%, 7.2% and 4.8% ($P < .05$), respectively. The same phenomenon was observed in the mature cow fed grass hay (Chapter IV).

Steer Breed and Digestibility

The data relating steer breed to nutrient digestibility are given in Table 14. The difference in steer breed accounted for 31.4% of the variation ($P < .10$) in the digestibility of dry matter, 28.0% ($P < .10$) of the variation in the digestibility of neutral

Table 12. Analyses of Variance of Nutrient Intake of Yearling Steers in the Indicator-Ratio Digestion Trial.

Source	DF	Intake, kg/head/day ^a						
		Mean squares						
		DM	NDF	NDS	ADF	HCL	CL	CP
Metabolic size, kg	1	5.87***	1.02***	2.49**	.35***	.15***	.26***	.13***
Breed	3	.06	.02	.05	.01	.00	.01	.00
Residual	18	.27	.04	.21	.01	.01	.01	.01
R ²		.60	.64	.50	.66	.54	.64	.57

P<.01; *P<.001.

^aDM (dry matter); NDF (neutral detergent fiber); NDS (neutral detergent solubles); ADF (acid detergent fiber); HCL (hemicellulose); CL (cellulose); CP (crude protein).

Table 13. Coefficients of Partial Regression and Least Square Means for Nutrient Intake of the Yearling Steers in the Indicator-Ratio Digestion Trial.

Source	Intake, kg/head/day ^a					
	DM	NDF	NDS	ADF	HCL	CP
Intercept	-2.22	-1.89	-1.89	-.71	-.25	-.31
Metabolic size, kg	.11***	.07***	.07**	.03***	.02***	.02***
Breed						
Angus	6.01	2.39	3.62	1.30	1.08	1.17
Hereford x Angus	5.92	2.32	3.56	1.27	1.06	1.14
Hereford	6.24	2.45	3.62	1.35	1.11	1.22
Angus x Hereford	6.09	2.47	3.45	1.36	1.11	1.22

P<.01; *P<.001.

^aDM (dry matter); NDF (neutral detergent fiber); NDS (neutral detergent solubles); ADF (acid detergent fiber); HCL (hemicellulose); CL (cellulose); CP (crude protein).

Table 14. Analyses of Variance of Nutrient Digestibility of Yearling Steers in the Indicator-Ratio Digestion Trial.

Source	DF	DM	NDF	NDS	Digestibility, % ^a				
					Mean squares				
					ADF	HCL	CL	CP	
Intake, kg/head/day	1	21.04	36.52	84.85*	.26	125.59	39.43	7.07	
Metabolic size, kg	1	24.61	60.07	38.68	12.92	122.87	36.23	4.75	
Breed	3	69.04*	132.01 ⁺	43.27 ⁺	101.42	193.47*	73.53 ⁺	59.35	
Residual		23.72	51.67	15.85	63.38	59.61	40.27	33.91	
R ²		.39	.38	.42	.28	.44	.34	.33	

⁺P<.10; *P<.05.

^aDM (dry matter); NDF (neutral detergent fiber); NDS (neutral detergent solubles); ADF (acid detergent fiber); HCL (hemicellulose); CL (cellulose); CP (crude protein).

Table 15. Coefficients of Partial Regression and Least Square Means for Nutrient Digestibility of the Yearling Steers in the Indicator-Ratio Digestion Trial.

Source	Digestibility, % ^a					
	DM	NDF	NDS	ADF	HCL	CP
Intercept	47.21	25.01	56.17	26.23	32.55	41.80
Intake, kg/head/day	-2.09	-7.19	-4.78*	-1.10	-28.21	-15.40
Metabolic size, kg	.35	.58	.38	.27	.73	.45
Breed						
Angus	61.67 ^b	51.61 ^b	69.21 ^b	48.23 ^b	55.38 ^b	59.63 ^b
Hereford x Angus	59.56 ^b	47.27 ^b	68.20 ^b	44.97 ^b	50.62 ^b	56.86 ^b
Hereford	60.35 ^b	50.04 ^b	67.19 ^b	44.97 ^b	55.86 ^b	56.98 ^b
Angus x Hereford	53.89 ^c	40.78 ^c	62.85 ^c	38.38 ^c	43.36 ^c	51.03 ^c
						57.32 ^b
						57.13 ^b
						56.42 ^b
						50.55 ^b

[†]P<.10; *P<.05.

^aDM (dry matter); NDF (neutral detergent fiber); NDS (neutral detergent solubles); ADF (acid detergent fiber); HCL (hemicellulose); CL (cellulose); CP (crude protein).

^{b,c}Means under the same column with different superscript letters are significantly different at P<.05.

detergent fiber, 27.7% ($P < .10$) of the variation in the digestibility of neutral detergent solubles and 32.3% ($P < .05$) of the variation in the digestibility of hemicellulose. The difference in nutrient digestibility among the straightbred and the reciprocal crosses is given in Table 15. Nutrient digestibility in Angus, Hereford or Hereford x Angus crosses was similar. However, the Angus x Hereford crosses digested significantly less of most of the nutrients. The Angus x Hereford crosses, as compared to the Angus steers, digested 7.8% less dry matter, 10.8% less neutral-detergent fiber, 6.4% less neutral detergent solubles, 10.3% less acid detergent fiber, 12.0% less hemicellulose and 8.6% less cellulose and all of the differences were significant ($P < .05$). This difference is not understood. However, Warwick and Cobb (1974) reviewed the very scanty data relating breed and nutrient digestion and concluded the variability in digestive powers is too small to justify selection based on digestive efficiency.

CHAPTER VI

SUMMARY

A total of 59 beef cattle were used in investigations relating inherent and production differences to intake and digestibility of nutrients. Twelve lactating cows in a total-collection digestion trial, 24 cows in 3 successive acid-insoluble ash indicator-ratio digestion trials (trials 1, 2 and 3) and 23 yearling steers in another indicator-ratio digestion trial were fed mainly grass hay, grass silage and corn silage, respectively. The data were analyzed by the method of linear multiple regression.

The cows in the total-collection digestion trial offered the orchard grass-timothy hay (OGTH) consumed 1.6 kg more ($P < .10$) dry matter than those cows fed the tall fescue-timothy hay (TFTH). More of neutral detergent fiber (14.6%, $P < .001$), acid detergent fiber (14.7%, $P < .01$), hemicellulose (9.4%, $P < .01$), cellulose (21.7%, $P < .001$) and crude protein (12.5%, $P < .01$) were digested by the cows fed TFTH than those cows fed the OGTH. Cow weight was positively related to the digestibility of dry matter, neutral detergent fiber, neutral detergent solubles, acid detergent fiber and crude protein and the respective regression coefficients were .07% ($P < .05$), .06% ($P < .10$), .10% ($P < .05$), .04% and .10% ($P < .10$). Calf age accounted for about 29% ($P < .05$) of the variation in digestibility of the dry matter and for about 5% ($P < .05$) of the variation in digestibility of the neutral detergent fiber by their dams.

In the 3 successive indicator-ratio digestion trials the daily dry matter intake was higher in the pregnant than in the nonpregnant cows by about 2.0 kg ($P < .05$) in a 66-day (range, 25 to 89 days) pregnancy (trial 2) and by about 1.5 kg ($P < .01$) in a 108-day (range, 67 to 131 days) pregnancy (trial 3). Stage of gestation did not affect nutrient intake at 34 days (range, 25 to 48 days) post-conception (trial 1). However, as pregnancy advanced to 66 days (trial 2) and 108 days (trial 3) a 1-day increase in the length of gestation was associated with a 40-g decrease in the daily dry matter intake in trial 2 and a 30-g decrease in trial 3. The nonpregnant cows digested 3.9% more ($P < .05$) of the neutral detergent fiber and 4.3% more ($P < .01$) of the hemicellulose in trial 2 but .73% less ($P < .05$) of the hemicellulose in trial 3. In trial 2 a 1-day increase in the age of the in situ developing fetus caused a rise in digestibility of neutral detergent fiber and hemicellulose of .12% ($P < .10$) and .19% ($P < .01$), respectively. However, in trial 3, a 1-day increase in the age of the in situ developing fetus caused a reduction of .19% ($P < .05$) in the digestibility of hemicellulose. In trial 1, the cow whose milk production was higher by 1 kg digested significantly more of the dry matter (3.0%, $P < .05$), neutral detergent fiber (3.3%, $P < .05$), acid detergent fiber (3.6%, $P < .05$), hemicellulose (3.5%, $P < .001$) and cellulose (3.0%, $P < .05$).

The study with the yearling steers revealed that the steer with a 1 kg advantage in metabolic size consumed about 110 g more dry matter ($P < .001$) than the lighter steer. A comparison in nutrient digestibility among Angus (A), Hereford (H), A x H and H x A revealed

that nutrient digestibility was similar in A, H and H x A. However, the A x H steer as compared to the A steers digested significantly less ($P < .05$) of the dry matter (7.8%), neutral detergent fiber (10.8%), neutral detergent solubles (6.4%), acid detergent fiber (10.3%), hemicellulose (12.0%) and cellulose (8.0%).



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APPENDIX

CRANESHAW CREST

Table A-1. Intake and Digestibility of Nutrients by Cows in Total-Collection Digestion Trial.

Cow No.	Consumption, kg/day, dry basis						Digestion coefficients, %							
	DM	NDF	NDS	ADF	HCL	CL	CP	DM	NDF	NDS	ADF	HCL	CL	CP
Orchard grass-timothy hay														
518	8.6	5.4	3.2	2.9	2.5	2.4	.66	58.1	53.7	65.6	33.0	77.6	41.4	44.6
2477	6.3	3.8	2.5	2.5	1.8	1.6	.50	58.8	52.7	68.0	45.1	76.5	39.0	48.2
201	9.2	5.7	3.5	3.0	2.7	2.5	.72	57.8	53.8	64.4	32.1	77.9	41.6	43.5
420	9.9	6.4	3.6	3.4	2.9	2.9	.76	58.4	54.0	66.4	38.8	71.9	49.4	49.6
9758	8.6	5.5	3.1	2.9	2.6	2.5	.67	53.4	48.1	62.8	29.2	69.8	45.2	39.2
9525	8.8	5.6	3.2	3.0	2.7	2.5	.69	59.1	54.7	66.8	37.9	73.6	49.8	47.3
Means	8.6	5.4	3.2	3.0	2.5	2.4	.67	57.6	52.8	65.7	36.0	74.6	44.4	45.4
S.E.	.50	.35	.15	.12	.16	.17	.04	.86	.98	.76	2.34	1.35	1.83	1.55
C.V., %	14.2	16.0	11.3	10.1	15.7	17.4	13.4	3.66	4.56	2.82	15.94	4.44	10.12	8.35
Tall fescue-timothy hay														
448	6.2	4.5	1.6	2.3	2.0	2.1	.81	68.4	73.0	56.5	57.6	88.9	70.5	64.6
9636	7.6	5.6	2.1	2.9	2.7	2.6	.97	59.3	66.5	40.0	48.4	85.6	65.4	51.0
117	7.3	5.3	2.0	2.7	2.6	2.4	.94	65.2	71.3	49.4	55.9	87.2	68.6	58.1
1561	8.0	5.8	2.2	3.0	2.8	2.7	1.0	60.4	67.4	42.0	53.1	82.6	65.4	52.7
81	4.7	3.3	1.4	1.7	1.6	1.5	.62	57.8	62.4	46.5	45.6	80.3	61.0	51.9
1448	8.4	6.1	2.3	3.2	2.9	2.9	1.1	61.8	67.9	45.4	54.5	82.6	67.7	53.3
Means	7.0	5.1	2.0	2.6	2.4	2.4	.91	62.1	68.1	46.6	52.5	84.5	66.4	55.3
S.E.	.55	.41	.14	.21	.21	.20	.07	1.63	1.53	2.40	1.89	1.32	1.35	2.12
C.V., %	19.2	20.0	17.3	20.1	20.8	20.4	18.6	6.41	5.50	12.61	8.81	3.84	4.96	9.39

Table A-2. Cow Parameters of the Total-Collection Digestion Trial.

Cow No.	Breed	Age, days	Weight, kg	Height, cm	Weight/height, kg/cm	Metabolic size, kg	Milk production, kg/day
<u>Orchard grass-timothy hay</u>							
518	A	4051	408.2	122.4	3.3	90.8	5.4
2477	A	4140	365.1	115.6	3.2	83.5	7.6
201	A	3000	406.0	114.6	3.5	90.4	5.2
420	A	3366	426.4	117.1	3.6	93.8	7.3
9758	A	4175	430.9	111.5	3.9	94.6	7.1
9525	A	5076	363.0	108.7	3.4	83.2	6.6
Means		3968	399.9	115.0	3.5	89.4	6.5
S.E.		295	12.0	1.9	.10	2.0	.4
C.V.,%		18	7.4	4.1	7.3	5.2	15.5
<u>Tall fescue-timothy hay</u>							
448	A	4080	464.9	112.5	4.4	100.1	6.9
9636	A	4657	406.0	111.8	3.6	90.4	6.0
117	A	4433	408.2	111.0	3.7	90.8	5.3
1561	A	2991	369.7	110.7	3.3	84.3	7.0
81	A	3015	378.6	116.6	3.3	85.9	6.2
1448	A	4093	369.7	115.6	3.2	84.3	6.5
Means		3878	399.5	113.0	3.6	89.3	6.3
S.E.		291	14.8	1.0	.18	2.5	.25
C.V.,%		18	9.1	2.2	12.5	6.8	9.9

Table A-3. Calf Parameters of the Total-Collection Digestion Trial

Dam No.	Age, days	Weight, kg	Average daily gain, kg
<u>Orchard grass-timothy hay</u>			
518	32	42.1	.42
2477	37	46.8	.68
201	28	40.9	.49
420	26	47.5	.87
9758	25	47.0	.65
9525	45	51.7	.65
Means	32	46.0	.63
S.E.	3	1.6	.06
C.V.,%	24	8.6	25.2
<u>Tall fescue-timothy hay</u>			
448	37	60.2	.55
9636	31	52.6	.39
117	31	43.2	.36
1561	40	59.0	.65
81	22	44.0	.49
1448	46	66.1	.42
Means	35	54.2	.48
S.E.	3	3.8	.04
C.V.,%	24	17.1	23.0

Table A-4. Intake and Digestibility of Nutrients by Cows (Trial 1).

Cow No.	Nutrient consumption, kg/day							Digestion coefficients, %						
	DM	NDF	NDS	ADF	HCL	CL	CP	DM	NDF	NDS	ADF	HCL	CL	CP
959	10.1	6.3	3.3	4.3	1.9	3.6	1.2	72.4	74.0	68.5	69.1	85.0	76.7	68.8
2871	9.0	6.1	2.3	4.2	1.9	3.5	1.1	68.2	68.9	66.8	64.7	80.0	73.6	69.1
P259	7.6	4.6	2.5	3.6	1.5	2.3	.92	72.7	71.7	69.6	69.0	85.8	76.6	71.0
1189	11.8	7.9	3.9	5.5	2.4	4.6	1.4	61.3	61.5	61.0	56.7	72.4	66.3	63.0
579	11.5	7.7	3.7	5.4	2.4	4.5	1.4	62.1	62.7	60.9	58.1	73.0	68.6	61.9
1487	9.2	6.2	3.0	4.3	1.9	3.6	1.1	64.7	64.1	66.0	60.5	71.5	69.8	65.4
991	7.9	5.3	2.6	3.7	1.6	3.1	.93	71.7	73.1	68.9	68.8	82.8	76.1	66.4
1427	7.7	5.2	2.5	3.6	1.6	3.0	.92	57.4	60.3	51.4	53.9	74.8	65.0	52.6
1271	9.7	6.6	3.2	4.6	2.0	4.2	1.2	59.5	60.4	57.7	55.3	71.9	66.5	57.6
420	8.9	6.0	3.0	4.2	1.8	3.5	1.0	68.9	69.9	67.0	65.5	79.8	73.6	66.2
1132	10.6	7.2	3.4	5.0	2.2	4.2	1.3	69.1	70.8	65.7	66.9	79.4	74.5	65.2
228	8.2	5.5	2.6	3.8	1.7	3.2	.96	60.4	61.0	59.0	57.3	69.4	68.0	58.0
318	8.8	6.0	3.0	4.1	1.8	3.4	1.0	59.5	61.4	55.5	54.6	76.7	66.8	55.3
1337	8.2	5.5	2.7	3.9	1.7	3.2	1.0	60.0	60.7	58.3	53.0	78.3	63.4	60.5
30	8.3	5.6	3.0	3.9	1.7	3.2	1.0	55.7	58.8	49.2	53.0	78.6	62.3	50.4
762	6.8	4.6	2.2	3.2	1.4	2.7	.80	67.0	68.6	63.5	62.3	82.8	70.8	63.7
1101	8.6	5.8	2.8	4.0	1.8	3.3	1.0	58.6	60.2	55.2	52.5	77.9	63.5	53.1
127	7.8	5.3	2.5	3.6	1.6	3.0	.92	59.6	62.3	53.9	55.4	78.0	66.7	54.6
954	8.4	5.6	2.7	3.9	1.7	3.3	1.0	63.7	63.1	64.8	58.0	74.6	67.8	61.1
1312	4.9	3.3	1.6	2.3	1.0	1.9	.59	76.9	76.9	77.0	72.7	86.2	79.3	73.8
1448	9.1	6.3	3.0	4.3	1.9	3.6	1.1	70.7	71.5	70.4	65.9	82.2	73.7	66.6
1199	9.1	6.2	3.0	4.3	1.9	3.6	1.1	57.2	55.6	60.6	49.6	69.4	60.8	56.3
1581	8.1	5.5	2.6	3.8	1.7	3.2	.96	56.2	55.0	58.8	48.6	69.2	60.8	54.1
1031	6.0	4.1	2.0	2.8	1.3	2.4	.71	66.7	65.0	70.2	60.8	74.6	69.4	65.0
Means	8.6	5.8	3.0	4.0	1.8	3.4	1.0	64.2	64.9	62.5	59.6	77.3	69.2	61.6
S.E.	.31	.21	.10	.14	.06	.12	.04	1.2	1.4	1.4	1.1	1.1	1.1	1.3
C.V.,%	17.9	18.1	18.1	17.7	17.3	18.0	17.7	9.5	9.2	11.0	11.4	6.8	7.7	10.4

Table A-5. Intake and Digestibility of Nutrients by Cows (Trial 2).

Cow No.	Nutrient consumption, kg/day						Digestion coefficients, %							
	DM	NDF	NDS	ADF	HCL	CL	CP	DM	NDF	NDS	ADF	HCL	CL	CP
959	8.9	6.2	2.8	4.0	2.2	3.2	3.2	1.3	67.6	67.5	67.9	62.3	77.3	65.2
2871	10.1	6.7	3.1	4.5	2.5	3.7	1.4	59.5	59.4	60.1	51.9	73.1	69.3	61.2
P259	6.5	2.5	2.0	2.9	1.6	2.4	.9	76.6	77.1	75.3	73.0	84.6	78.4	75.3
1189	11.0	7.6	3.4	4.9	2.7	4.0	1.5	60.2	63.0	54.0	54.1	79.3	64.4	58.4
579	11.9	8.1	3.7	5.3	2.9	4.3	1.7	60.9	63.2	55.6	54.6	79.0	65.2	59.1
1487	8.4	5.8	2.6	3.7	2.1	3.0	1.2	66.0	67.2	63.6	57.1	85.3	67.2	62.4
991	6.9	4.7	2.1	3.0	1.7	2.5	.95	75.7	76.9	73.0	71.5	86.8	77.9	69.4
1427	6.7	4.6	2.1	3.0	1.6	2.5	.93	69.6	71.1	66.1	64.0	83.9	76.8	65.1
1271	8.6	6.4	2.7	3.8	2.1	3.1	1.2	67.6	70.0	62.4	60.3	87.7	67.5	62.5
420	7.5	5.2	2.3	3.3	1.8	2.7	1.1	69.2	67.7	62.1	62.9	89.5	71.7	61.0
1132	11.3	7.7	3.5	5.0	2.8	4.1	1.6	70.3	71.9	66.6	62.9	88.2	71.2	63.9
228	7.0	4.8	2.2	3.1	1.7	2.5	.97	58.1	60.1	53.5	46.7	84.4	59.1	50.3
318	7.9	5.4	2.4	3.5	1.9	2.8	1.1	61.5	70.0	58.2	53.0	80.8	63.7	54.0
1337	6.0	4.1	1.8	2.6	1.5	2.1	.84	72.1	73.8	68.3	67.3	85.4	74.8	67.8
30	9.0	6.2	2.8	4.0	2.2	3.2	1.3	57.2	58.8	53.6	49.8	75.2	61.1	50.4
762	6.8	4.7	2.1	3.0	1.7	2.4	.94	74.8	77.6	68.5	70.6	90.2	76.6	72.5
1101	8.6	5.9	2.7	3.8	2.1	3.1	1.2	70.2	71.8	66.8	65.9	82.4	72.9	66.7
127	7.1	4.9	2.2	3.1	1.8	2.6	1.0	67.3	69.7	61.9	61.5	84.6	70.3	65.3
954	8.7	6.0	2.7	3.9	2.2	3.2	1.2	71.5	75.6	62.1	65.7	93.5	73.6	65.0
1312	3.9	2.7	1.2	1.7	1.0	1.4	.57	75.9	79.9	67.0	72.1	94.1	78.2	70.4
1448	9.2	6.4	2.9	4.1	2.3	3.3	1.3	67.1	71.2	57.9	60.3	90.9	68.6	61.12
1199	7.9	5.5	2.5	3.5	2.0	2.9	1.1	57.7	61.3	49.7	48.2	85.0	58.8	52.3
1581	7.3	5.1	2.3	3.3	1.8	2.6	1.0	69.4	72.3	62.9	61.1	92.5	70.3	66.6
1031	6.1	4.2	1.9	2.7	1.5	2.2	.84	74.7	76.7	70.1	66.7	94.8	73.2	70.4
Means	8.0	5.5	2.5	3.6	2.0	2.9	1.1	67.5	69.7	62.8	61.0	85.4	70.2	63.2
S.E.	.38	.29	.12	.17	.09	.14	.05	1.26	1.26	1.34	1.56	1.20	1.19	1.36
C.V., %	22.9	25.6	23.1	22.9	22.4	22.8	22.6	9.16	8.88	10.44	12.57	6.91	8.29	10.56

Table A-6. Intake and Digestibility of Nutrients by Cows (Trial 3).

Cow No.	Nutrient consumption, kg/day				Digestion coefficients, %			
	DM	NDF	NDS	ADF	HCL	CL	CP	CP
959	9.5	5.4	4.2	3.9	1.5	3.0	1.6	72.6
2871	9.7	5.4	4.3	3.9	1.5	3.1	1.6	66.5
P259	8.4	4.7	3.7	3.5	1.3	2.7	1.4	66.5
1189	9.6	5.4	4.2	3.9	1.5	3.0	1.6	77.8
579	10.3	5.8	4.5	4.2	1.6	3.2	1.7	71.2
1487	9.5	5.3	4.2	3.9	1.5	3.0	1.6	74.6
991	8.4	4.7	3.7	3.4	1.3	2.6	1.4	68.4
1427	7.6	4.3	3.3	3.2	1.2	2.4	1.3	72.2
1271	9.5	5.3	4.2	3.9	1.5	3.0	1.6	67.1
420	7.8	4.4	3.4	3.2	1.2	2.5	1.3	70.9
1132	8.2	4.6	3.6	3.3	1.3	2.1	1.4	66.6
228	8.3	4.6	3.6	3.4	1.3	2.6	1.4	66.8
318	7.1	4.0	3.1	2.9	1.1	2.3	1.2	73.2
1337	-	-	-	-	-	-	-	78.0
30	9.6	5.4	4.2	3.9	1.5	3.0	1.6	67.4
762	6.5	3.7	2.8	2.7	.99	2.1	1.1	63.5
1101	8.3	4.6	3.6	3.4	1.3	2.6	1.4	75.3
127	8.3	4.6	3.6	3.4	1.3	2.6	1.4	69.8
954	8.3	4.7	3.6	3.4	1.3	2.6	1.4	78.2
1312	7.1	3.4	3.1	2.9	1.1	2.3	1.2	72.5
1448	8.8	4.5	3.9	3.6	1.4	2.8	1.5	68.6
1199	9.5	5.3	4.1	3.9	1.4	3.0	1.6	76.4
1581	7.9	4.4	3.4	3.2	1.2	2.5	1.3	79.1
1031	5.9	3.3	2.6	2.4	.90	1.9	.99	72.6
Mean	8.4	4.7	3.7	3.5	1.3	2.7	1.4	73.6
S.E.	.23	.13	.10	.09	.04	.07	.04	61.7
C.V.,%	13.3	13.2	13.5	13.2	13.2	13.2	13.6	66.7

Table A-7. Cow Parameters (Trial 1).

Cow No.	Breed	Age, days	Weight, kg	Height, cm	Weight/height, kg/cm	Metabolic size, kg	Stage of gestation, days	Milk production, kg/1/2 day
959	H	3779	432.7	113.8	3.8	94.9	-	3.6
2871	A	2848	349.7	119.8	2.9	80.9	-	3.2
P259	A	3819	464.0	113.8	4.1	100.0	30	5.9
1189	H	3775	585.8	121.7	4.8	119.1	33	3.2
579	H	3775	503.0	118.3	4.3	106.2	-	4.1
1487	A	4482	461.1	117.4	3.9	99.5	47	3.6
991	A	2843	413.0	110.2	3.6	91.6	39	4.5
1427	H	4534	483.8	122.3	4.0	103.2	27	3.2
1271	H	4509	501.2	116.6	4.3	105.9	32	3.2
420	A	3440	447.9	115.9	3.9	97.4	26	3.6
1132	A	2688	420.3	118.0	3.6	92.8	42	2.7
228	H	4191	398.3	112.4	3.5	89.2	25	3.2
318	H	4182	546.8	117.8	4.6	113.1	48	3.6
1337	A	4483	468.6	117.3	4.0	100.7	-	3.6
30	A	3456	456.5	117.1	3.9	98.8	-	3.2
762	H	2742	466.8	117.4	4.0	100.4	29	3.6
1101	H	3057	477.0	115.3	3.1	102.1	25	4.1
127	A	882	365.8	112.1	3.3	83.7	35	4.1
954	A	2009	423.7	114.0	3.7	93.4	37	2.7
1312	H	2694	459.3	120.1	3.8	99.2	-	3.2
1448	A	4167	387.6	114.7	3.4	87.4	-	4.5
1199	H	3788	463.3	114.1	4.1	99.7	29	1.8
1581	A	3066	307.6	111.8	3.7	90.7	35	1.8
1031	H	3055	379.6	116.2	3.3	85.9	-	2.3
Means		3428	448.4	116.17	3.9	97.3	34	3.4
S.E.		181	11.3	.63	.09	1.8	2	.18
C.V., %		26	12.3	2.67	11.1	9.2	22	25.8

Table A-8. Steer Calf Preweaning Body Parameters (Trial 1).

Calf No.	Breed	Age, days	Weight, kg	Average daily gain, kg
U1789	AH	160	99.3	.53
U1829	AA	155	121.1	.56
6229	HA	126	116.1	.81
U889	HH	138	108.9	.49
U1799	AH	158	79.8	.56
U2029	AA	122	90.3	.56
U1929	HA	153	117.0	.49
U919	HH	137	101.2	.34
U1869	AH	153	113.9	.59
U1989	AA	130	100.3	.56
U1839	HA	149	88.0	.42
U1059	HH	117	88.9	.51
U949	AH	136	108.0	.48
U1999	AA	131	84.4	.45
6089	HA	161	128.8	.59
219	HH	171	130.2	.57
U839	AH	142	124.7	.62
U1779	AA	159	136.1	.56
6029	HA	171	136.1	.67
329	HH	168	102.5	.41
U1939	AA	151	114.3	.52
U1079	AH	116	88.5	.45
6119	HA	161	147.4	.81
1419	HH	143	86.6	.48
Means		146	108.8	.54
S.E.		3	3.9	.02
C.V., %		11	17.3	20.25

Table A-9. Cow Parameters (Trial 2).

Cow No.	Breed	Age, days	Weight, kg	Height, cm	Weight/height, kg/cm	Metabolic size, kg	Stage of gestation, days	Milk production, kg/1/2 day
959	H	3820	432.5	113.8	3.8	93.2	26	1.8
2871	A	2889	356.1	119.8	3.0	82.0	38	5.4
P259	A	3860	435.2	113.8	3.8	95.3	71	5.9
1189	H	3816	576.1	121.7	4.7	117.2	74	5.9
579	H	3816	489.7	118.3	4.1	104.1	25	4.1
1487	A	4523	462.2	117.4	3.9	99.7	88	3.2
991	A	2884	410.5	110.2	3.7	91.2	80	4.1
1427	H	4575	487.4	122.3	4.0	103.7	68	3.6
1271	H	4550	496.9	116.6	4.3	105.3	73	3.2
420	A	3481	451.6	115.9	3.9	98.0	67	1.4
1132	A	2729	428.0	118.0	3.6	94.1	83	1.8
228	H	4232	394.4	112.4	3.5	88.5	66	3.6
318	H	4223	533.4	117.8	4.5	111.0	89	1.8
1337	A	4523	465.8	117.3	4.0	100.3	-	.91
30	A	3497	469.2	117.1	4.0	100.8	36	2.3
762	H	2783	454.7	117.4	3.9	98.5	70	2.3
1101	H	3098	468.8	115.3	4.1	100.8	66	3.2
127	A	923	356.5	112.1	3.2	82.1	76	2.7
954	A	2050	427.3	114.0	3.8	94.0	78	3.2
1312	H	2735	438.9	120.1	3.7	95.9	-	3.2
1448	A	4208	376.9	114.7	3.3	85.6	-	1.4
1199	H	3829	459.3	114.1	4.0	99.2	70	2.7
1581	A	3107	409.1	111.8	3.7	91.0	76	4.5
1031	H	3096	363.8	116.2	3.1	83.9	-	4.1
Means		3469	443.5	116.2	3.8	96.4	66	3.2
S.E.		181	11.0	.63	.08	1.8	4	.29
C.V., %		26	12.1	2.7	10.8	9.1	29	44.0

Table A-10. Steer Calf Preweaning Body Parameters (Trial 2).

Calf No.	Breed	Age, days	Weight, kg	Average daily gain, kg
U1789	AH	201	129.3	.68
U1829	AA	196	142.4	.48
6229	HA	167	152.4	.82
U889	HH	179	134.7	.59
U1799	AH	199	100.2	.46
U2029	AA	163	110.7	.46
U1929	HA	194	145.6	.65
U919	HH	178	112.9	.28
U1869	AH	194	138.4	.56
U1989	AA	171	135.4	.79
U1839	HA	190	111.1	.53
U1059	HH	158	108.9	.45
U949	AH	177	135.2	.62
U1999	AA	172	102.5	.41
6089	HA	202	150.6	.49
219	HH	212	142.0	.27
U839	AH	183	145.2	.46
U1779	AA	200	162.3	.62
6029	HA	212	159.7	.54
329	HH	209	114.8	.28
U1939	AA	192	134.7	.46
U1079	AH	157	107.5	.43
6119	HA	202	172.8	.58
1419	HH	184	100.7	.32
Means		187	131.2	.51
S.E.		3	4.3	.03
C.V., %		9	16.1	28.7

Table A-11. Cow Parameters (Trial 3).

Cow No.	Breed	Age, days	Weight, kg	Height, cm	Weight/height, kg/cm	Metabolic size, kg	Stage of gestation, days	Milk production, kg/1/2 day
959	H	3862	441.4	113.8	3.9	96.3	68	2.3
2871	A	2931	360.4	119.8	3.0	82.7	80	2.3
P259	A	3902	439.1	113.8	3.9	95.9	113	2.7
1189	H	3858	561.3	121.7	4.6	115.3	116	2.3
579	H	3858	475.6	118.3	4.0	101.8	67	1.4
1487	A	4565	456.3	117.4	3.9	98.7	130	1.8
991	A	2926	423.7	110.2	3.8	93.4	122	1.8
1427	H	4617	473.3	122.3	3.9	101.5	110	2.3
1271	H	4592	491.9	116.6	4.2	104.5	115	.91
420	A	3523	462.4	115.9	4.0	99.7	109	1.8
1132	A	2771	437.3	118.0	3.7	95.6	125	.91
228	H	4274	390.5	112.4	3.5	87.9	108	1.8
318	H	4265	532.7	117.8	4.5	110.9	131	2.3
1337	A	-	-	-	-	-	-	-
30	A	3539	443.4	117.1	3.8	96.6	78	1.8
762	H	2825	443.6	117.4	3.8	96.7	112	2.3
1101	H	3140	460.4	115.3	3.4	99.4	108	2.3
127	H	965	353.1	112.1	3.2	81.5	118	1.4
954	A	2092	424.3	114.0	3.7	93.5	120	.91
1312	H	2777	437.3	120.1	3.6	95.6	-	.91
1448	A	4250	367.0	114.7	3.2	83.8	-	2.3
1199	H	3871	453.8	114.1	4.0	98.3	112	1.4
1581	A	3149	402.6	111.8	3.6	89.9	118	.91
1031	H	3138	373.1	116.2	3.2	84.9	-	1.8
Means		3464	439.3	116.1	3.8	95.8	108	1.8
S.E.		183	10.7	.66	.08	1.8	4	.12
C.V., %		25	11.7	2.7	10.5	8.8	18	32.4

Table A-12. Steer Calf Preweaning Body Parameters (Trial 3).

Calf No.	Breed	Age, days	Weight, kg	Average daily gain, kg
U1789	AH	243	156.5	.63
U1829	AA	238	176.5	.79
6229	HA	209	197.8	1.1
U889	HH	221	161.0	.61
U1799	AH	241	131.5	.73
U2029	AA	205	142.9	.75
U1929	HA	236	177.4	.74
U919	HH	220	138.4	.59
U1869	AH	236	163.3	.58
U1989	AA	213	175.1	.92
U1839	HA	232	137.9	.62
U1059	HH	200	138.4	.69
U949	AH	219	165.6	.71
U1999	AA	214	193.7	.44
6089	HA	244	166.9	.38
219	HH	254	173.7	.74
U839	AH	225	181.4	.84
U1779	AA	242	187.8	.57
6029	HA	254	186.0	.61
329	HH	251	134.3	.45
U1939	AA	234	158.8	.56
U1079	AH	199	131.1	.55
6119	HA	244	210.5	.88
1419	HH	226	119.8	.44
Means		229	162.8	.66
S.E.		3	5.0	.03
C.V., %		7	14.9	24.7

Table A-13. Intake and Digestibility of Nutrients by Yearling Steers.

Calf No.	Nutrient consumption, kg/day					Digestion coefficients, %								
	DM	NDF	NDS	ADF	HCL	CL	CP	DM	NDF	NDS	ADF	HCL	CL	CP
U1789	5.6	2.2	3.5	1.2	.99	1.1	.83	52.1	38.8	61.1	30.3	49.6	44.1	45.3
U1829	6.1	2.4	3.8	1.3	1.1	1.2	.91	64.8	55.6	71.2	51.3	61.2	62.1	55.8
6229	7.5	2.9	4.6	1.6	1.3	1.4	1.1	57.0	48.4	62.5	43.3	54.7	53.8	56.3
U889	6.5	2.5	4.0	1.4	1.1	1.2	.98	65.6	57.5	70.8	51.1	65.3	60.1	62.0
U1799	5.5	2.2	2.3	1.2	.99	1.1	.80	55.4	38.7	66.9	35.5	42.6	48.5	49.0
U2029	5.9	2.4	3.6	1.3	1.0	1.2	.89	54.0	36.8	66.4	35.7	38.3	49.0	49.2
U1929	6.7	2.7	4.1	1.5	1.2	1.3	1.0	59.0	43.5	69.6	45.4	41.3	55.5	58.8
U919	5.8	2.3	2.5	1.3	.98	1.2	.87	68.1	59.8	73.7	57.1	62.7	65.8	63.3
U1869	6.6	2.6	4.0	1.4	1.2	1.3	.98	57.2	44.9	65.3	46.8	42.6	56.2	58.1
U1989	6.4	2.5	3.8	1.4	1.1	1.3	.95	66.9	57.7	73.5	55.8	60.0	66.3	63.7
U1839	4.6	1.8	2.9	.99	.80	.90	.69	63.7	50.1	74.0	44.4	57.2	58.6	55.2
U1059	5.3	2.1	3.2	1.1	.94	1.0	.79	55.2	37.4	67.2	32.2	43.8	47.6	46.3
U949	5.8	2.7	3.1	1.5	1.2	1.4	.83	51.8	39.0	63.1	39.3	38.5	52.9	44.2
U1999	7.0	2.8	4.2	1.5	1.3	1.4	1.0	56.5	43.0	66.5	38.2	48.8	48.9	52.2
6089	7.0	2.8	4.2	1.5	1.3	1.4	1.0	62.8	53.0	69.8	49.2	57.8	58.4	58.4
219	6.3	2.5	3.8	1.4	1.1	1.2	.94	57.1	45.0	65.4	41.4	49.4	51.9	57.4
U839	6.0	2.4	3.6	1.3	1.1	1.2	.89	54.6	41.0	63.8	37.9	44.4	50.1	54.9
U1779	6.7	2.7	4.0	1.5	1.2	1.3	.99	60.6	56.6	63.3	53.5	60.4	63.1	59.9
6029	6.2	2.5	3.8	1.3	1.1	1.2	.92	60.3	50.9	66.9	52.9	48.5	62.5	62.6
U1939	4.7	1.9	2.8	1.0	.90	.92	.70	68.3	62.1	72.8	58.6	66.0	69.9	64.6
U1079	6.0	2.4	3.6	1.3	1.1	1.2	.89	50.9	37.6	59.8	38.2	37.4	50.2	49.1
6119	6.4	2.5	3.9	1.4	1.2	1.2	.94	59.0	47.0	66.9	41.2	54.1	59.0	57.6
1419	4.8	1.9	2.9	1.0	.98	.94	.71	51.4	43.7	57.0	37.4	50.8	55.2	48.2
Mean	6.1	2.4	3.6	1.3	1.1	1.2	.90	58.8	47.3	66.8	44.2	51.1	56.1	55.3
S.E.	.15	.1	.1	.04	.03	.03	.02	1.1	1.7	.96	1.7	1.9	1.4	1.3
C.V., %	12.2	12.4	16.4	13.0	11.5	12.3	12.5	9.3	16.9	6.9	18.6	17.7	12.2	11.3

Table A-14. Yearling Steers' Body Parameters.

Calf No.	Breed	Age, days	Weight, kg	Height, cm	Weight/height, kg/cm	Metabolic size, kg	Average daily gain, kg
U1789	AH	439	295.7	102.9	2.9	71.3	.66
U1829	AA	434	340.0	103.4	3.2	79.2	.77
6229	HA	405	353.4	103.4	3.4	81.5	.74
U889	HH	417	308.2	106.7	2.9	73.6	.74
U1799	AH	437	281.2	101.9	2.8	68.7	.72
U2029	AA	401	291.2	97.3	3.0	70.5	.75
U1929	HA	432	337.0	104.9	3.2	78.7	.77
U919	HH	416	284.0	102.4	2.8	69.2	.73
U1869	AH	432	315.7	105.4	3.0	74.9	.79
U1989	AA	409	339.1	100.3	3.4	79.0	.79
U1839	HA	428	290.1	102.1	2.8	70.3	.74
U1059	HH	396	265.4	101.9	2.6	65.8	.70
U949	AH	415	331.4	101.4	3.3	77.7	.83
U1999	AA	410	319.8	107.2	3.0	75.6	.19
6089	HA	440	328.6	106.7	3.1	77.2	.84
219	HH	450	315.3	106.4	3.0	74.8	.75
U839	AH	421	310.9	104.1	3.0	74.1	.60
U1779	AA	438	326.6	100.1	3.3	76.8	.72
6029	HA	450	316.2	106.7	3.0	75.0	.60
U1939	AA	430	266.9	104.2	2.6	66.0	.49
U1079	AH	395	271.9	99.1	2.8	67.0	.71
6119	HA	440	368.5	110.5	3.3	84.1	.83
1419	HH	422	247.7	102.6	2.4	62.4	.64
Means		424	308.9	103.5	3.0	73.6	.70
S.E.		3	6.4	.63	.06	1.2	.03
C.V., %		4	9.9	2.9	9.1	7.5	19.8

Table A-15. Analyses of Variance of Neutral Detergent Fiber Intake and Digestibility of Cows in the Indicator-Ratio Digestion Trial.

Source	Intake, kg/head/day						Digestibility, %					
	Trial 1 DF	MS	Trial 2 DF	MS	Trial 3 DF	MS	Trial 1 DF	MS	Trial 2 DF	MS	Trial 3 DF	MS
Intake, kg/head/day							1	20.46	1	95.77	1	131.60*
Metabolic size, kg	1	.38	1	1.38	1	.01	1	26.02	1	.27	1	69.10 [†]
Milk production, kg/day							1	193.72*				
Age, years					1	.41						
Pregnancy status ^a	1	.61	1	8.90*	1	2.77	1	40.57	1	133.43*	1	7.70
Gestation (pregnancy) ^b	1	.55	1	4.49	1	1.52*	1	20.45	1	92.33 [†]	1	33.55
Residual	20	.51	20	1.68	18	.27	18	27.53	19	23.26	18	19.61
R ²		.09		.26		.43		.41		.50		.42

[†]P<.10; *P<.05; **P<.01.

^aPregnant versus open.

^bStage of gestation in days.

Table A-16. Coefficients of Partial Regression and Least Square Means for Neutral Detergent Fiber Intake and Digestibility of Cows in the Indicator-Ratio Digestion Trial.

Source	Intake, kg/head/day			Digestibility, %		
	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
Intercept	0.99	4.54	6.17	65.67	71.41	79.71
Intake, kg/head/day				-0.99	-1.69	-5.00*
Metabolic size, kg	0.03	0.03	-0.01	-0.13	-0.01	0.23 [†]
Milk production, kg/day				3.30*		
Age, years			0.07			
Pregnancy status ^a						
Open	5.73	4.46*	4.02	66.71	72.96*	73.82
Pregnant	5.78	5.69	4.85	63.99	69.10	69.28
Gestation (pregnancy) ^b	0.03	-0.03	-0.02*	0.16	0.12 [†]	-0.08

[†]p<.10; *p<.05; **p<.01.

^a Asterisks above a mean indicate level of significance for the class effects.

^b Stage of gestation in days.

Table A-17. Analyses of Variance of Neutral Detergent Solubles Intake and Digestibility of Cows in the Indicator-Ratio Digestion Trial.

Source	Intake, kg/head/day						Digestibility, %					
	Trial 1 DF	MS	Trial 2 DF	MS	Trial 3 DF	MS	Trial 1 DF	MS	Trial 2 DF	MS	Trial 3 DF	MS
Intake, kg/head/day							1	21.81	1	102.82	1	53.34 [†]
Metabolic size, kg	1	.72	1	.20	1	.01	1	39.82	1	23.13	1	34.29
Milk production, kg/day							1	37.79				
Age, years					1	.25						
Pregnancy status ^a	1	.11	1	1.98*	1	1.69**	1	57.85	1	3.22	1	5.27
Gestation (pregnancy) ^b	1	.13	1	.90 [†]	1	.92*	1	30.44	1	6.20	1	.44
Residual	20	.25	20	.26	18	.18	18	47.53	19	39.88	18	13.46
R ²		.16		.33		.42		.21		.23		.39

[†]P<.10; *P<.05; **P<.01.

^apregnant versus open.

^bStage of gestation in days.

Table A-18. Coefficients of Partial Regression and Least Square Means for Neutral Detergent Solubles Intake and Digestibility of Cows in the Indicator-Ratio Digestion Trial.

Source	Intake, kg/head/day			Digestibility, %		
	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
Intercept	0.38	2.27	4.80	71.60	83.63	72.37
Intake, kg/head/day		0.01		-2.10	-4.47	-3.96 ⁺
Metabolic size, kg	0.02		-0.01	-0.16	-0.12	0.16
Milk production, kg/day				1.45		
Age, years			0.05			
Pregnancy status ^a						
Open	2.79	1.99 [*]	3.12 ^{**}	64.60	62.53	77.39
Pregnant	2.79	2.60	3.78	61.49	62.86	74.39
Gestation (pregnancy) ^b	0.01	-0.01 ⁺	-0.01 [*]	0.20	0.03	0.01

⁺p<.10; *p<.05; **p<.01.

^aAsterisks above a mean indicate level of significance for the class effects.

^bStage of gestation in days.

Table A-19. Analyses of Variance of Acid Detergent Fiber Intake and Digestibility of Cows in the Indicator-Ratio Digestion Trial.

Source	Intake, kg/head/day						Digestibility, %					
	Trial 1 DF	MS	Trial 2 DF	MS	Trial 3 DF	MS	Trial 1 DF	MS	Trial 2 DF	MS	Trial 3 DF	MS
Intake, kg/head/day							1	14.32	1	139.15	1	121.18 ⁺
Metabolic size, kg	1	1.40	1	.39	1	.01	1	39.66	1	2.25	1	68.41
Milk production, kg/day							1	237.87*				
Age, years					1	.22						
Pregnancy status ^a	1	.17	1	3.88*	1	1.45**	1	49.19	1	37.47	1	.82
Gestation (pregnancy) ^b	1	.25	1	1.71 ⁺	1	.80*	1	28.06	1	20.60	1	8.57
Residual	20	.48	20	.52	18	.14	18	37.61	19	50.53	18	29.54
R ²		.17		.32		.43		.36		.29		.39

⁺P<.10; *P<.05; **P<.01.

^apregnant versus open.

^bStage of gestation in days.

Table A-20. Coefficients of Partial Regression and Least Square Means for Acid Detergent Fiber Intake and Digestibility of Cows in the Indicator-Ratio Digestion Trial.

Source	Intake, kg/head/day			Digestibility, %		
	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
Intercept	0.67	3.24	4.46	60.62	73.32	69.61
Intake, kg/head/day				-1.22	-3.66	-6.56 ⁺
Metabolic size, kg	0.03	0.02	-0.01	-0.16	-0.04	0.23
Milk production, kg				3.64*		
Age, years			0.05			
Pregnancy status ^a						
Open	3.96	2.84*	2.94**	61.39	63.17	70.92
Pregnant	4.03	3.72	3.53	58.77	60.53	64.52
Gestation (pregnancy) ^b	0.02	-0.02 ⁺	-0.01*	0.19	0.06	-0.04

⁺p<.10; *p<.05; **p<.01.

^aAsterisks above a mean indicate level of significance for the class effects.

^bStage of gestation in days.

Table A-21. Analyses of Variance of Cellulose Intake and Digestibility of Cows in the Indicator-Ratio Digestion Trial.

Source	Intake, kg/head/day						Digestibility, %					
	Trial 1 DF	Trial 1 MS	Trial 2 DF	Trial 2 MS	Trial 3 DF	Trial 3 MS	Trial 1 DF	Trial 1 MS	Trial 2 DF	Trial 2 MS	Trial 3 DF	Trial 3 MS
Intake, kg/head/day							1	7.12	1	81.21	1	59.92 ⁺
Metabolic size, kg	1	1.05 ⁺	1	.26	1	.01	1	27.45	1	6.40	1	49.73 ⁺
Milk production, kg/day							1	158.15*				
Age, years					1	.13						
Pregnancy status ^a	1	.09	1	2.52*	1	.86**	1	31.82	1	5.48	1	.03
Gestation (pregnancy) ^b	1	.15	1	1.11 ⁺	1	.47*	1	21.45	1	2.73	1	13.20
Residual	20	.35	20	.34	18	.09	18	22.83	19	31.22	18	15.40
R ²		.17		.32		.43		.37		.24		.43

⁺P<.10; *P<.05; **P<.01.

^aPregnant versus open.

^bStage of gestation in days.

Table A-22. Coefficients of Partial Regression and Least Square Means for Cellulose Intake and Digestibility of Cows in the Indicator-Ratio Digestion Trial.

Source	Intake, kg/head/day			Digestibility, %		
	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
Intercept	0.52	2.63	3.45	69.50	84.74	77.61
Intake, kg/head/day				-1.01	-3.45	-5.96 ⁺
Metabolic size, kg	0.02 ⁺	0.01	-0.01	-0.14	-0.06	0.20 ⁺
Milk production, kg			0.04	2.97*		
Age, years						
Pregnancy status ^a						
Open	3.31	2.31 [*]	2.26 ^{**}	70.30	71.06	81.21
Pregnant	3.38	3.02	2.72	68.64	69.98	75.00
Gestation (pregnancy) ^b	0.01	-0.01 ⁺	-0.01*	0.16	0.02	-0.05

⁺P<.10; *P<.05; **P<.01; ***P<.001.

^aAsterisks above a mean indicate level of significance for the class effects.

^bStage of gestation in days.

Table A-23. Analyses of Variance of Crude Protein Intake and Digestibility of Cows in the Indicator-Ratio Digestion Trial.

Source	Intake, kg/head/day						Digestibility, %					
	Trial 1 DF	MS	Trial 2 DF	MS	Trial 3 DF	MS	Trial 1 DF	MS	Trial 2 DF	MS	Trial 3 DF	MS
Intake, kg/head/day												
Metabolic size, kg	1	.09	1	.04	1	.01	1	2.71	1	68.28	1	113.66
Milk production, kg/day												
Age, years					1	.04						
Pregnancy status ^a	1	.02	1	.38*	1	.25**	1	51.93	1	15.31	1	1.81
Gestation (pregnancy) ^b	1	.02	1	.18 ⁺	1	.14*	1	21.25	1	8.15	1	4.45
Residual	20	.03	20	.05	18	.03	18	38.94	19	41.46	18	25.98
R ²		.16		.32		.43		.25		.23		.40

⁺P<.10; *P<.05; **P<.01.

^aPregnant versus open.

^bStage of gestation in days.

Table A-24. Coefficients of Partial Regression and Least Square Means for Crude Protein Intake and Digestibility of Cows in the Indicator-Ratio Digestion Trial.

Source	Intake, kg/head/day			Digestibility, %		
	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
Intercept	0.16	1.01	1.82	58.60	82.06	83.75
Intake, kg/head/day				-2.07	-8.25	-15.04
Metabolic size, kg	0.01	0.01		-0.10	-0.13	0.09
Milk production, kg			0.02	2.45		
Age, years						
Pregnancy status ^a						
Open	1.02	0.90 [*]	1.19 ^{**}	64.11	64.62	73.91
Pregnant	1.02	1.17	1.45	60.42	62.90	68.09
Gestation (pregnancy) ^b	0.01	-0.01 ⁺	-0.01 [*]	0.16	0.04	-0.03

⁺p<.10; *p<.05; **p<.01.

^aAsterisks above a mean indicate level of significance for the class effects.

^bStage of gestation in days.

VITA

Seyoum Gelaye was born in Ethiopia on September 18, 1946. He completed both primary and high school education in Ethiopia. He graduated from the College of Agriculture in Ethiopia with a B.S. degree in August 1969.

Later, he attended the University of Florida in Gainesville for two years and received an M.S. degree in animal physiology in August 1973. In August 1981 he received the Doctor of Philosophy degree from The University of Tennessee, Knoxville with a major in animal nutrition.

Seyoum Gelaye is a member of the American Society of Animal Science and is also a member of the honorary societies Alpha Zeta, University of Florida Chapter, and Gamma Sigma Delta, The University of Tennessee, Knoxville Chapter.

He is married to Aylech Boggale. They have three children: Tewodros, Mamar and Enkutatash.