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To the Graduate Council:

I am submitting herewith a dissertation written by Robert Lane Cowsert entitled "The Effect of Varying the Energy Content of the Ration on the Voluntary Feed Intake of Ruminants with Different Energy Requirements." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Animal Science.

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THE EFFECT OF VARYING THE ENERGY CONTENT OF THE RATION ON THE VOLUNTARY FEED INTAKE OF RUMINANTS WITH DIFFERENT ENERGY REQUIREMENTS

A Dissertation

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Doctor of Philosophy

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by

Robert Lane Cowsert

December 1970

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ABSTRACT

Four experiments were conducted to study the proposed theory that ruminants are capable of adjusting their voluntary feed intake in order to meet physiological energy needs if fill is not a limiting factor.

Three experiments were conducted using 84 ruminant animals. These animals were used to study the effect of varying the energy content of the ration on voluntary feed intake and the digestibility of various ration components. The digestibility values were determined by the chromic oxide and acid detergent lignin techniques. The energy content of the rations were varied by feeding rations composed of various forage-to-concentrate ratios. The following forage-to-concentrate ratios were fed: (1) 100:0, (2) 82.5:17.5, (3) 65:35, (4) 47.5:52.5, and (5) 30:70.

Thirty Holstein calves were fed rations 1, 2, and 3 in Experiment I. There were no significant differences in dry matter intakes between the three rations. Significant differences between rations did exist in the digestibility of dry matter and gross energy when determined by the chromic oxide indicator method. These differences were not noted when the digestibility values were determined by the acid detergent lignin indicator method. Significant differences were found in digestible energy intakes when determined by the acid detergent lignin method but not when determined by the chromic oxide method. No significant differences were observed between the average daily gains of the calves on the three rations.

Thirty Holstein heifers were fed rations 2, 3, and 4 in Experiment II. Decreases in dry matter intakes were noted as the amount of

concentrate increased in the ration. Significant differences were found in the digestibility of dry matter as determined by both indicator methods. No significant differences were found however in the digestibility of gross energy as determined by both methods. Significant differences did exist in the digestible energy intake of the animals on the three rations. No significant ration differences were noted in average daily gains or blood glucose values, whereas significant differences did exist in rumen pH values.

Fifteen Holstein cows and nine Jersey cows were fed rations 3, 4, and 5 in Experiment III. There were no significant ration differences in dry matter intakes or the digestibility of dry matter and gross energy when determined by the chromic oxide method. Significant differences between rations were observed in these digestibility values when determined by the acid detergent lignin method. There were no significant differences in digestible energy intakes when determined by both methods. Significant ration differences were also not observed in average daily gains, rumen pH, actual milk production, fat test, and fat-corrected-milk production between the three rations.

Three fistulated cows were used in Experiment IV to study the effect of increasing the energy content of the ration on voluntary feed intake. The energy content of the ration was increased by the intraruminal infusions of volatile fatty acid mixtures. The two volatile fatty acid mixtures used contained 57 percent acetic, 22 percent propionic, and 21 percent butyric acids and were neutralized to pH 6.15 with sodium hydroxide. One of the mixtures allowed 500 milliliters of the acids to be infused per day, whereas the other mixture

allowed 1000 milliliters to be infused per day. When the two acid mixtures were infused, they reduced dry matter intakes but also caused unphysiological conditions. Acid infusion appeared to have no effect on rumen pH and rumen volatile fatty acid concentrations.

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CHAPTER I

INTRODUCTION

The animal response obtained is usually directly proportional to the digestible energy intake of the animal with the digestible energy intake being a function of voluntary intake and energy digestibility. Of these two functions, voluntary intake is considered to be the more variable. It has also been proven that in the early stages of lactation a heavy lactating dairy cow is not able to consume enough energy to meet her energy needs. Because of the large variation in voluntary intake and the cow's inability to consume enough energy to meet her energy needs, it is important that we know more about mechanisms controlling intake.

Numerous theories have been proposed concerning the control of voluntary intake. One of these theories is that ruminants tend to regulate food intake to satisfy physiological energy needs when given diets in which fill does not limit consumption. If this theory is true, then the physiological energy requirement of the animal might determine whether the intake of a certain ration is or is not limited by fill.

The main purpose of this study was to determine if ruminants within different energy requirement groups are able to regulate food intake to meet physiological energy demand when fed rations varying in energy content.

CHAPTER II

REVIEW OF LITERATURE

Introduction

Many factors have been cited in the literature which may have an influence on the regulation of voluntary feed intake in ruminants. These factors can be grouped together into similar groups such as rumen load factors, chemostatic factors, and thermostatic factors. These factors can also be integrated together to form theories or hypotheses on how ruminants are able to regulate their voluntary feed intake. One of these theories is that ruminants are able to regulate their voluntary feed intake to maintain a constant digestible energy intake when fill or rumen load does not limit consumption. Research is being conducted not only to prove or disprove this theory but also to determine which metabolites are involved in the regulation of feed intake and what areas in the body are involved if this theory is correct.

Effect of Dietary Energy Concentration on Voluntary Intake

Adolph (1) observed that if food given to rats was mixed with cellulose or kaolin, they quickly adjusted by eating more total bulk of the mixed rations. However the quantity of utilizable nutrients ingested did not exceed that in the control periods when the rats were fed undiluted diets. This suggested that caloric content of the ration, and not simply the amount of food, was the factor that determined intake. Kennedy (43) also reported that young rats being

fed on meal mixed with an equal weight of kaolin were able to obtain an equal nutrient intake, as compared to an undiluted diet, and maintain their weight by doubling the bulk eaten. Kennedy (43) reported that in older rats the palatability of food has an effect on the weight considerably greater than is seen in the young animal, and becomes the principal determinant of the degree of obesity on unrestricted feeding.

Hathorn and Rakes (34) found that fistulated steers decreased the amount of hay consumed if hay was added directly to the rumen of these steers before feeding. These authors (34) did not state whether they believed the reduced intakes were caused by supplying a source of energy directly to the rumen or because fill was limiting intake. Fill may have been limiting intake because the addition of equal amount of wood shavings directly into the rumen of fistulated steers before feeding caused even a greater reduction in intake. Boling et al. (18), while investigating the effects of the addition of polyethylene to diets, found a trend toward compensatory food intake to meet energy requirements when increased fill and dietary density, palatability or quality were not factors decreasing feed intake.

Brent et al. (19) fed lambs completely pelleted rations containing 10, 20, 30, 40, 50, or 60 percent sorghum grain, with the remainder of the ration made up of average quality alfalfa hay. Average daily feed intake on a dry matter basis decreased from 1,200 grams per day on the 10 percent concentrate ration to 840 grams per day on the 60 percent concentrate ration. Woods and Rhodes (77)

compared an approximately 40 percent concentrate ration to an approximately 60 percent concentrate ration fed to lambs, and reported a significant reduction in consumption as the level of concentrate increased in the ration. This was true if the ration was in either the conventional, mixed, or pelleted form.

Donefer et al. (28) studied the effect of feeding completely pelleted rations varying in alfalfa:barley ratios on energy intake by sheep. Dry matter intake decreased as the amount of concentrate increased in the ration, but total digestible energy intake, as measured by Nutritive Value Index (NVI), remained essentially constant for all rations. These results suggested that the sheep were adjusting voluntary intake to meet energy needs.

Ernesto et al. (31) fed Holstein calves rations which contained 95.0, 81.3, 67.5, 53.8, and 40.0 percent concentrate. Voluntary intake increased with increasing concentrate, reaching a maximum of approximately 67 percent concentrate or 23 percent acid detergent fiber (ADF), and decreased thereafter. Fill, as percentage of live weight, decreased linearly as the concentrate content of the ration increased with fill being approximately 16 percent when voluntary intake started to decline. Digestible dry matter intake (DDMI) increased with increasing concentrate, reaching a maximum at approximately 67 percent concentrate, and remained essentially constant thereafter. These authors (31) concluded that at high fiber (above 23 percent ADF), physical factors are controlling intake and at low fiber (below 23 percent ADF) other mechanisms seem to be regulating voluntary intake.

Using Holstein and Red Danish heifers, Dinius et al. (26) fed rations in which 0.0, 1.5, 3.0, 4.5, and 6.0 percent glacial acetic

acid had been added (immediately before feeding) to both green corn forage and corn silage. Forage dry matter intakes tended to decrease with the addition of acetate to both the green corn forage and corn silage. However, when the forage and acetate energy intakes of the animals were computed, there were no significant differences in caloric intake due to treatment in either trial. Thus, as the proportion of energy supplied from acetate increased there was a concomitant reduction in energy intake from forage. This suggests that in these trials the physiological demands of the animals for energy rather than rumen fill were limiting intake.

Montgomery and Baumgardt (53) studied the effect of various rations varying in nutritive value on the energy intake of Holstein heifers. They stated that the intake of rations which are low in nutritive value (digestible dry matter times density) is probably limited by gastrointestinal tract fill, whereas the intake of rations high in nutritive value is probably regulated by chemostatic or thermostatic mechanisms.

The effect of varying alfalfa meal:corn ratios on energy intake was studied in Holstein heifers by Montgomery and Baumgardt (52). Four completely pelleted rations were used consisting of the following alfalfa meal:corn ratios: 100:0, 80:20, 60:40, and 40:60. The respective dry matter intakes on a percent body weight basis were 2.28, 2.01, 1.82, and 1.68. However, because of an almost linear increase in the digestibility of gross energy, with increasing concentrate in the ration the digestibile energy intake of these animals was essentially the same. The conclusion might be drawn that

the animals were consuming enough of each of the rations to maintain equivalent energy intakes. It should be pointed out that these authors were concerned about the decreasing crude protein content associated with the increasing amounts of concentrate in the rations. Therefore, Cowsert and Montgomery (22) fed Holstein heifers three completely pelleted isonitrogenous rations consisting of the following alfalfa hay:concentrate ratios: 100:0, 67:33, and 33:67. Again dry matter intakes decreased, whereas the digestibility of gross energy increased with increasing amounts of concentrate. Because of this the digestible energy intakes of the heifers on the three rations were essentially the same. These authors concluded that it was the intake of digestible energy and not protein or fill that was limiting the intake of these rations.

This work has also been substantiated by Dinius and Baumgardt (25). They fed sheep a basic concentrate mixture diluted from 5 to 50 percent at 5 percent increments with each of four diluents: (1) oak sawdust, (2) oak sawdust with constant 3 percent kaolin clay, (3) verxite, an expanded hydrobiotite, and (4) oak sawdust with nitrogen kept constant at 17.4 percent crude protein equivalent. The fourth dilution sequence was kept isonitrogenous by altering the amount of corn and soybean meal in the concentrate. A total of 40 pelleted rations were evaluated. Dry matter intake in grams per unit of metabolic size increased as the digestible energy per gram increased to 2.5 kilocalories (65 percent concentrate) for ration sequences 1, 2, and 4. With rations having digestible energy values above 2.5 kilocalories per gram, dry matter intake decreased and digestible energy intake remained static.

Apparently, fill limited the intake of these sheep when the digestible energy content of the rations was less than 2.5 kilocalories per gram, whereas above this level energy intake was regulated. The sheep rejected ration sequence 3 when the digestible energy was less than 3.0 kilocalories per gram (greater than 15 percent verxite), because the rations may have been unpalatable.

McCullough and Sisk (50) fed dairy heifers silage alone and silage to corn or beet pulp ratios of 80:20, 60:40, and 40:60. A total of seven different rations were evaluated. The silage was a wheat plus ryegrass mixture. When silage and corn were fed and compared to silage alone dry matter intake increased but was not improved over the 80:20 ratio by higher levels of concentrate. When silage and beet pulp were fed and compared to silage alone dry matter intake increased with increased percentage of beet pulp to the 60:40 ratio, however at the 40:60 ratio intake was similar to silage alone. Estimated net energy intake reached a maximum on the 60:40 ratio of both silage plus corn and silage plus beet pulp rations. In both cases, no improvement in intake of energy resulted from using 60 percent concentrate instead of 40. Therefore, it appeared that the heifers were able to regulate their intake to a constant energy intake on the 40 and 60 percent concentrate mixtures for both the corn and beet pulp rations.

Conrad et al. (21), using lactating dairy cows, stated that from the standpoint of the physiological events that regulate feed intake, it is valid to assume that the intake of digestible nutrients is determined by the demand for metabolites for the production of milk

energy and retained protein and is subsequent to them. Ronning and Laben (60) fed rations containing various levels of concentrates and reported levels of feed intake to be inversely related to the energy concentrations of the diets. Mather et al. (46) fed lactating cows different amounts of concentrate along with grass silage, and they reported a decline in forage dry matter intake of 0.235 unit for each additional unit of concentrate consumed. Spahr et al. (65) stated that after the ration reaches a certain concentration of digestible energy, physiological factors become more important in determining intake than does the proportion of dietary concentrates.

Ward and Kelley (76) fed lactating cows ratios of alfalfa hay and concentrate of 1:0, 5.1:1, 2.2:1, and 1:1 by weight. The respective feed intake in kilograms per 100 kilograms of body weight was 2.90, 3.18, 3.53, and 4.02. The estimated net energy intakes showed a steady rate of increase from rations containing zero to 50 percent concentrate. Apparently, physiological energy-regulating mechanisms did not control feed consumption within the limits of this experiment, since total food consumption increased consistently with increasing amounts of concentrate. Energy-regulating mechanisms might be expected to become limiting at higher levels of energy availability.

Nelson et al. (58), using lactating dairy cows, studied the effect of varying Coastal Bermudagrass:concentrate ratios on energy intake. Five completely pelleted rations were used consisting of the following Coastal Bermudagrass:concentrate ratios: 100:0, 85:15, 70:30, 55:45, and 40:60. The respective digestible energy intakes

as a percent of body weight were as follows: 1.10, 1.73, 1.97, 2.31, and 2.33. These workers (58) concluded that fill was limiting the intake of the first three rations, whereas digestible energy intake was limiting the intake of the last two rations.

In the literature previously cited, it has been shown that lambs, sheep, calves, heifers, and lactating dairy cows seem to be able to regulate their intake in order to maintain a constant digestible energy intake if fill or rumen load does not limit consumption. However, it has not been clearly stated at what threshold point the limitation due to rumen fill ceases and intake regulation from energy intake begins. Also, it has not been stated whether this threshold point is the same for all ruminants or varies according to the energy requirements of the animals. Dinius and Baumgardt (25) did state in their experiments that the threshold point between bulk or fill limitation to intake and energy intake regulation was 2.47 kilocalories of digestible energy per gram. Their experiments were conducted with sheep weighing about 37 kilograms at the start of the trials and about 50 kilograms at the end. These workers (25) were quick to point out that this value should not be construed as the threshold points between bulk limitation to intake and energy intake regulation for all ruminants. They stated that rapidly growing or lactating animals have a higher energy requirement, and it is anticipated that the threshold point between bulk limitation and energy regulation would be higher for these animals.

Mechanisms of Energy Intake Regulation

Chemostatic mechanism. Several workers (22, 28, 52, 53) have

proposed that when energy intake is being regulated, chemostatic and thermostatic mechanisms are involved. Adolph (1) suggested that animals eat for calories. The question then arises as to what metabolites furnish these calories. The various volatile fatty acids (VFA) produced by the microorganisms in the rumen have been studied as possible metabolites which are involved. One reason for this is because ruminants are able to utilize these VFA to supply a large proportion of their energy requirements.

Dinius et al. (26) fed rations in which acetic acid had been added to both green corn forage and corn silage. Forage dry matter intakes tended to decrease with the addition of acetate to both forages, but there were no significant differences in caloric intake due to the different treatments. Senel and Owen (62) reported that the voluntary intake of dry matter was not affected by 2 percent acetic, 1 percent butyric, or a combination of these acids added to a hay-concentrate ration.

Montgomery et al. (54) reported that in dairy cows the intraruminal infusion of acetic acid at levels normally produced by one half of a daily ration of hay caused a significant reduction in voluntary intake of long hay. When the acetic acid was supplied as the sodium salt or when partially neutralized at pH 5.0 with sodium hydroxide, there was only a small reduction in hay intake. Propionic acid infusion did not result in a significant decrease in hay consumption, and butyric acid infusion caused only moderate decreases in hay intake.

Rook et al. (61) observed that during continuous intraruminal

infusion of acetic acid at a level of 3,500 kilocalories per day, ad libitum intake was decreased significantly when compared to the infusion of water. Similar results were not observed with the infusion of propionic or butyric acids. Bhattacharya and Warner (15) reported that the intraruminal infusion of acetic acid (neutralized to pH 6.5) reduced hay consumption in fistulated dairy heifers by 39 percent. If a portion of the acetate was substituted by an equicaloric amount of propionate, the depression in hay consumption was prevented. Addition of citrate to the acetate only partially alleviated the depression. These authors (15) suggested that a balance of the VFA in the rumen may be involved in controlling their voluntary feed intake.

Simkins et al. (64) infused intraruminally isocaloric amounts of acetate, propionate, butyrate, and a VFA mixture (60, 20, and 20 percent of the calories from acetate, propionate, and butyrate, respectively). They concluded that all three of the compounds could act as satiety signal compounds in the regulation of food intake. These authors (64) suggested that if chemoreceptors are involved then the receptors must be sensitive to all three of the VFA investigated, since they all caused a reduction in food intake. It would appear that chemoreceptors for propionate and butyrate would have to be located in the rumen wall, in the portal system, or in the liver, since the concentrations of these two metabolites in the peripheral circulation are very low. Acetate chemoreceptors could be located in the periphery in addition to the three sites mentioned for propionate and butyrate. Baile (6) stated that there was no evidence for receptors in the hypothalamus for acetate or propionate, although there are

probably receptors for these metabolites in the ruminal area which can act to depress feeding.

In another experiment by Simkins et al. (63), they studied the variation in blood and rumen metabolites in relation to feed intake of dairy cattle. They reported that blood acetate concentrations were directly proportional to rumen acetate concentrations with satiation occurring when blood and rumen VFA concentrations were at a maximum. They also pointed out however, that the fact that maximum blood and rumen levels of certain metabolites occur at the same time as satiety does not show any cause-and-effect relationship. One reason for this statement was the fact that ruminal load was also at its maximum when satiation occurred. These authors (63) believe that in some way certain blood metabolites may be able to activate the satiety centers in the hypothalamus. Of the blood constituents investigated, they believe that acetate and the ketones would be the most probable signal compounds for a chemoreceptor since their concentrations in blood do increase after food intake.

Thye et al. (70) studied the relationship of various blood metabolites to voluntary feed intake in lactating ewes. They found that acetate, propionate, and glucose levels were poorly correlated to feed intake patterns. Butyrate, ketone, and free fatty acid levels were the most highly correlated to subsequent voluntary feed intake. These authors (70) concluded that the chemostatic regulation of appetite, if it exists, is not comprised of a single factor, but of several interrelated factors having a combined effect on voluntary feed intake.

Dowden and Jacobson (29) observed that the intravenous infusion of high levels of acetic acid or sodium acetate significantly decreased voluntary intake in dairy cattle during an eight hour infusion period. Propionic acid also caused a marked decrease in hay consumption. Administration of glucose, valeric acid, lactic acid, or hexanoic acid caused very little reduction in consumption. Holder (36) reported that sodium acetate infused intravenously into sheep did not produce a fall in intake despite blood VFA levels almost three times the normal range. Holder (36) explained the difference obtained by stating that Dowden and Jacobson (29) were using unphysiological levels of anions in the peripheral system.

Baile and Mayer (7), using goats, reported that sodium acetate injections into the rumen depressed feed intake while the same amounts injected intravenously had no such effect. They explained this difference by suggesting that receptors sensitive to acetate are more likely to be located in the lumen side of the ruminoreticulum than in an area where they would respond to blood levels.

Baile and McLaughlin (11) injected acetate, propionate, or a VFA mixture (55 percent acetate, 30 percent propionate, and 15 percent butyrate) into the dorsal rumen, ventral rumen, ventral reticulum, or abomasum of goats during spontaneous meals. Acetate injected into the dorsal rumen or abomasum was more effective in depressing feed intake of goats than acetate injected into the ventral rumen or reticulum. Propionate injections into each of the gastric areas were equally effective in decreasing feed intake. The injection of the VFA mixture caused responses comparable to those of acetate and propionate

injected separately. Presumably, the propionate of the mixture was sufficient to cause a significant decrease in feed intake at all sites of injection. The authors (11) concluded that the dorsal rumen probably contains receptors for acetate and propionate, but the propionate response may be due, in addition, to receptors in the gastric veins. Injections into the abomasum, in contrast to those in the ruminoreticulum, probably resulted in unphysiological concentration changes although there were similar decreases in feed intake.

Research with non-ruminants has indicated that blood glucose may act as a short term regulator of intake (48). Apparently there are glucoreceptors, located either in the hypothalamus or peripherally, which are sensitive to blood glucose, or more specifically to the rate of glucose utilization. Several workers (29, 36, 44) have studied the effect of intravenous infusion of glucose with ruminants, and they report that blood glucose does not appear to be involved in the regulation of voluntary feed intake. Houpt and Hance (37) used the stimulation of food intake by 2-deoxy-D-glucose (2-DG) as a test for the presence of a glucostatic control of food intake in ruminants. The glucose analogue 2-DG is a competitive inhibitor of glucose metabolism within cells and can cause the central nervous system to show signs of glucoprivation. These workers (37) determined the lowest level of plasma 2-DG necessary to activate the sympathetic nervous system and compared this level with similar measurements on dogs. Incomplete results indicated that the ruminant central nervous system "glucoreceptors" were about as sensitive as canine ones. Higher levels of 2-DG caused the goats to go through brief periods of voracious eating.

The effects of the intravenous administration of insulin on blood metabolites and acetate disappearance in sheep has been studied by Muller and Colenbrander (56). They indicated that insulin depresses plasma acetate levels and influences acetate metabolism by causing an apparent increase in utilization. However, insulin administration in sheep did not stimulate feed intake (55). Baile and Mayer (8) reported essentially the same results when they studied the effects of insulin-induced hypoglycemia and hypoacetoemia on eating behavior in goats. They reported that ruminants apparently do not have the response of other mammals of eating to correct hypoglycemia. The goats also did not increase feed intake to offset hypoacetoemia, although the serum acetate concentration decreased to only one-third of normal levels. Baile et al. (10) concluded that the central nervous system has a similar function in the control of feed intake in both ruminants and monogastric animals in spite of the fact that there are probably differences in the feedbacks and receptors making energy balance possible in the two types of animals.

Thermostatic mechanism. Just because animals eat for calories does not mean that only a chemostatic mechanism is involved. Brobeck, as reported by Mayer (47), has suggested that "animals eat to keep warm and stop eating to prevent hyperthermia." This means that eating is a response to a fall in heat production. Armstrong and Blaxter (3, 4) have shown that the heat increment of the steam VFA is higher under high levels of feeding than at fasting or maintenance levels of intake. Since some of the heat produced from the ingestion of food and the infusion of VFA is accounted for as heat increment, there

is a possibility that there may be a thermostatic mechanism, which along with other mechanisms, controls voluntary feed intake. Simkins et al. (64) believed this to be the case when they reported that the heat released during the assimilation of the infused VFA was responsible for the depression in food intake.

Andersson and Larsson (2) have demonstrated with goats that local cooling of an area of the hypothalamus caused eating in the fed animal, whereas warming inhibited eating in the same goat when hungry. However, Baile et al. (9) reported that hypothalamic temperature decreased following eating, force feeding, acetic acid infusion, and sodium acetate infusion. The fact that hypothalamic temperature does not increase during a large meal, a force feed or intraruminal acetate injections is evidence that short term satiety in ruminants is not normally a function of hypothalamic temperature. Bhattachayra and Warner (15) reported, however, that the temperature of the tympanum of the ear increased following infusion of acetate. This was accompanied by a 39 percent reduction in hay consumption.

Dinius et al. (27) measured the temperature of goats in metabolism stalls at several sites during oral, intraruminal, or false intraruminal feeding. Temperature was monitored by thermistor probes in the hypothalamus, rectum, and rumen and on the horn, ear, and chest. Hypothalamic temperature increased at the time of oral, intraruminal, or false intraruminal feeding and also when ruminal fluid was sampled. Hypothalamic temperature decreased when the goats lay down. These authors (27) concluded that hypothalamic temperature was related to activity rather than to food consumption

per se, with the goats being more active during eating. There was no consistent temperature changes at any of the body locations that could be correlated with food consumption.

Other evidence to support a thermostatic mechanism of food intake regulation is the fact that environmental temperature affects voluntary feed intake. Mather (45) reported that weather characteristics such as temperature and humidity, particularly at the extremes, certainly influence intake. This is in agreement with the work of Davis and Merilan (24).

Bhattacharya and Warner (16) reported that the temperature of the rumen has an effect on voluntary feed intake regulation. Hourly infusions of cold (5°C) or warm (49°C) water effected slight changes in rectal and tympanic temperature when compared to a control (30°C) infusion. Rumen temperature was altered but quickly returned to normal. No significant effect on hay intake was observed. When these workers (16) increased the infusion rate to every half-hour, a more marked change in rectal and tympanic temperature was observed and the rumen temperature remained altered for a longer period of time. Compared to a control (30°C) treatment, infusions of cold (5°C) water increased consumption of an all-pellet diet by 24 percent while a warm (49°C) infusion depressed intake by 9 percent. These authors (16) concluded that under physiological conditions, a decline in central or body temperature could be an important signal for controlling feed consumption in ruminants.

Rumen load mechanism. Donefer et al. (28) believe that rumen load or fill mechanisms may be involved in energy intake regulation.

They explained that the cause of the decreased feed consumption with increases in concentrate intake, is that there is a radical change in the nature of the microbial fermentation in the rumen as demonstrated by the changes in the molar proportions of the VFA produced. This shift toward soluble carbohydrate fermentation may produce a lowering of the rumen pH, thus inhibiting the activity of cellulolytic organisms. As a consequence, the rate and extent of digestion of the fibrous component of the diet is reduced and intake limited according to the theory of Crampton et al. (23). Crampton et al (23) believe that voluntary intake is regulated by recurring hunger associated with different rates of rumen load reduction with the rate of rumen load reduction being a function of the rate of digestion of the cellulose and hemicellulose in the rumen.

The explanation given by Donefer et al. (28) can to a certain extent be substantiated in the literature. The depression of cellulose digestion by starch has been noted by Head (35). That this effect might be caused by a lowering in rumen pH due to an accumulation of lactic acid has been demonstrated by Reid et al. (59). Bhattacharya and Warner (14) also believe that a drop in rumen pH may influence voluntary feed intake and could be of physiological importance with some diets. Campling (20) also studied the effect of concentrates on the rate of disappearance of digesta from the alimentary tract of cows. He reported that the addition of large amounts of concentrates to the diet of cows offered hay ad libitum decreased the voluntary intake of hay and decreased markedly the digestibility of the crude fiber of the diet. The addition of concentrate also increased the

mean time of retention of stained hay residues in the alimentary tract. He (20) also reported that at the end of a meal, the amount of digesta in the reticulo-rumen of the cow offered hay ad limitum with restricted amounts of concentrate was about the same as that found when hay was offered ad libitum as the only feed.

Contradictory evidence to the theory of Donefer et al. (28) is the fact that Ernesto et al. (31) and Montgomery and Baumgardt (52) found a decrease in fill as the amount of concentrate increased in the ration.

Other mechanisms. Mather (45) believes that there is something inherent in the animal which may make it satisfied with the minimum, or to make it want to eat until it has to stop. He calls this an intensity factor which he believes in a combination of hormonal and neural factors, both of which seem likely to be inherited to some extent.

McCullough (49) believes that in general terms, the problem of intake can be summarized as follows: At a stated level and stage of animal production, a forage may be defined as adequate when it is supplied in such a quantity, is of sufficient palatability and its per-unit concentration of usable nutrients is high enough to permit the animal to meet its nutritional requirements concurrent with the satiation by bulk.

Van Soest (74) believes that intake is regulated by some form of equilibrium between the desire to consume, the demand for energy, the distention in the tract and the ability to adjust digestion to a faster rate of passage.

Baile (6) stated that short term feed intake of ruminants is probably controlled by peripheral feedback signals acting on hypothalamic areas. Little is known about signals or receptor areas for long term control of feed intake or the input for energy balance regulation, but the ventromedial hypothalmus is intimately involved.

Summary

Several experiments have been reported to show that ruminants are able to regulate their intake in order to maintain a constant digestible energy intake if fill or rumen load factors are not involved. However, it has not been clearly stated at what threshold point the limitation due to rumen fill ceases and intake regulation from energy intake begins. Also, it has not been stated whether this threshold point is the same for all ruminants or varies according to the energy requirements of the animals.

Although several mechanisms have been proposed for the control of energy intake regulation, it is not clear as to which mechanism or mechamisms and what areas of the ruminant body are involved in digestible energy intake regulation.

CHAPTER III

GENERAL EXPERIMENTAL PROCEDURE

Objective of Experiments

The principal objective of the study was to investigate the theory that ruminants within different energy requirement groups are able to regulate the amount of food consumed to maintain a constant digestible energy intake when fed rations varying in energy content. The effect of different dietary energy levels on the digestibility of several nutrients was also studied. Three experiments were conducted in which the energy content of the rations was varied by feeding rations composed of various forage to concentrate ratios. Another experiment was conducted in which the energy content of the ration was varied by infusing, directly into the rumen, various levels of a mixture of acetic, propionic, and butyric acids.

Materials and Methods

Digestibility determinations. The digestibility of the rations used in Experiments I, II, and III was determined by two different methods. Both chromic oxide and lignin were used as indicators to estimate fecal output. Chromium sesquioxide (r_2O_3) was the type of chromic oxide used.

The chromic oxide was placed in capsules and the capsules were given twice daily at 7 a.m. and 5 p.m. during the last 14 days of each experiment. The animals in Experiment I received a total of

6 grams of chromic oxide per day, whereas the animals in Experiments II and III received a total of 10 grams of chromic oxide per day.

The chromic oxide capsules were given over a seven-day preliminary period, followed by a seven-day collection period. During the seven-day collection period, fecal grab samples were collected from each animal twice daily at 8 a.m. and 5 p.m. The grab samples from each animal were placed in a labeled, plastic bag and kept refrigerated over the seven-day collection period. At the end of the collection period, the fecal samples were mixed on an individual animal basis. A small portion of this sample was retained for dry matter determination. The remainder of the fresh fecal sample was dried in a forced draft oven at 50°C, ground through a 1 millimeter screen and stored for laboratory analyses.

In order to determine the daily excretion pattern of the chromic oxide, fecal grab samples were taken every three hours over a 24-hour period from approximately one-half of the animals in Experiments I, II, and III. These samples were taken the last day of each of these experiments. These values were used to make corrections for the diurnal excretion pattern of chromic oxide.

Acid detergent lignin (ADL), by the method of Van Soest (72), was determined on the fed and refusal ration samples in Experiments I, II, and III, and also on the fecal samples from each animal in these experiments. Using these data, along with feed intake data, the fecal output and digestibilities were calculated on an individual animal basis.

Sampling. Samples of the fed and refused rations were taken

weekly in each experiment. These samples were used for dry matter determinations. The fed and refused samples were then composited, ground through a 1 millimeter screen, and saved for laboratory analyses.

The procedure used in collecting fecal samples has already been explained earlier under digestibility determinations.

Rumen samples were taken every two weeks in Experiments II and III. Samples were taken approximately three hours post feeding with a stomach tube and vacuum pump. Rumen samples were taken weekly in Experiment IV. Samples were taken approximately one hour and three hours post feeding via rumen fistula and were strained through several layers of cheesecloth to remove the coarse feed material. The pH of the rumen fluid collected in Experiments II, III, and IV was determined immediately after collection of the sample. To each 25 milliliters of the rumen fluid, one-half milliliter of saturated mercuric chloride solution was added as a preservative and the samples stored in a refrigerator until analyzed for volatile fatty acids.

Blood samples were collected immediately before the rumen samples in Experiment II. Approximately 30 milliliters of blood were taken from the jugular vein. Potassium oxalate was used as the anticoagulant.

A morning and an evening milk sample was taken and composited for each cow once a week in Experiment III. Milk fat test was determined immediately on these samples.

Chemical analyses. The dry matter content of the rations (fed or refused) used in all experiments was determined by drying in a

forced draft oven at 50°C for 3 days. The dry matter content of the wet feces in Experiments I, II, and III was determined by drying in a forced draft oven at 100°C for 3 days. The dry matter content of the air dried, uniformly ground composite rations (fed and refused) and feces samples was determined by drying in a vacuum oven overnight at 100°C.

Rumen volatile fatty acids (VFA) were determined by gas-liquid chromotography (12). A 5 milliliter aliquot of rumen fluid was acidified with 1 milliliter of 25 percent metaphosphoric acid and centrifuged to remove the precipitate. The clear supernatant fluid was used for VFA analyses. Gas chromatographic analysis for VFA was conducted utilizing an F and M Model 810-19 Analytical Gas Chromatograph equipped with a hydrogen flame detector. The column was one-fourth inch coiled stainless steel and was packed with 15 percent Carbowax 20 M and terephthalic acid on 80/100 mesh Chromosorb W (AW-DMCS). Nitrogen was used as the carrier gas. Rumen pH was determined with a Leeds and Northrup glass electrode pH meter.

Protein-free filtrates of the blood were prepared by the method of Folin and Wu (32). From these filtrates blood sugar levels were determined by the method of Benedict (13). Milk fat was determined by the Babcock method (5).

Energy determinations on the ration samples and feces samples were made with a Parr plain (isothermal jacket) bomb calorimeter. Cell wall constituents (CWC), acid detergent fiber (ADF), and acid detergent lignin (ADL) were determined by the methods of Van Soest (75, 72). Crude protein was determined by the conventional Kjeldahl

method for nitrogen (5). The chromic oxide concentration in the feces was determined by the method proposed by Stevenson and de Langen (67).

Statistical analyses. Statistical analyses of the data were based on the methods outlined by Steel and Torrie (66). Analyses of covariance were made, where appropriate, as outlined by Steel and Torrie (66). Portions of the data were processed with the aid of an IBM computer and auxiliary equipment.

CHAPTER IV

EXPERIMENT I

Objective of Experiment

The objective of this investigation was to determine whether Holstein calves have the ability to regulate the amount of food consumed to maintain a constant digestible energy intake when fed various forage:concentrate ratios. The effect of different dietary energy levels on the digestibility of several nutrients was also studied.

Experimental Procedure

Thirty Holstein calves were used in a 4-week continuous feeding trial. The first 14 days were used as an adjustment period, and the last 14 days were used to determine intake. The chromic oxide capsules were given and fecal grab samples taken as described in the general experimental procedure. The calves were placed on the experiment in groups when they reached a bodyweight of approximately 250 to 300 pounds. The animals were grouped according to bodyweight and assigned to the various rations at random.

Rations used in this experiment consisted of various alfalfa-orchardgrass hay:concentrate ratios, pelleted into three-fourths by three-fourths inch range pellets. The alfalfa-orchardgrass hay:concentrate ratios used were the following: Ration 1, 100:0; Ration 2, 82.5:17.5; and Ration 3, 65:35. The concentrate mixtures in rations 2 and 3 were composed of ground shelled corn and soybean oil meal in the appropriate ratio in an attempt to make all three rations isonitrogenous. The

rations were individually fed twice daily at 7 a.m. and 5 p.m. in amounts to insure ad libitum consumption. Refusals were taken once daily at the p.m. feeding. Fed and refusal weights were recorded daily. The animals were housed in individual pens in the calf barn. Trace mineralized salt and water were available to the calves at all times.

All the animals were weighed for three consecutive days at the start and end of the experiment and every week during the experimental period. Notes were kept on the individual health and general condition of each calf.

Results and Discussion

The chemical composition of the individual rations is found in Table 1. The percentage of CWC, ADF, and ADL found in the rations decreased as the amount of concentrate increased in the ration. The decrease in these three constituents from ration 2 to ration 3 was not as great as expected. An almost linear decrease in cellulose, hemicellulose, and lignin was expected due to the addition of equal increments of concentrate to the ration.

One calf on ration 3 was omitted from the statistical analyses because of bloat. Statistical analyses were computed using unequal subclass numbers.

There were no significant differences in dry matter intake expressed either as percent of body weight of in grams per kilogram metabolic weight (Table 2). Results of this experiment do not agree with those of Montgomery and Baumgardt (52) and Cowsert and Montgomery (22). These workers reported a decrease in the

TABLE 1

CHEMICAL COMPOSITION OF RATIONS FED IN EXPERIMENT I

Ration	Dry Matter	Dry Matter Constituents				Gross Energy
		Crude Protein	CWC	ADF	ADL	
	%					(kcal/g)
1	92.70	17.05	44.54	36.56	7.97	4.51
2	92.59	17.32	36.51	26.92	7.05	4.51
3	92.39	17.44	34.47	26.62	6.45	4.56

CWC = Cell Wall Constituents; ADF = Acid Detergent Fiber; ADL = Acid Detergent Lignin.

TABLE 2

EFFECT OF FORAGE:CONCENTRATE RATIOS FED IN EXPERIMENT I ON DRY MATTER INTAKE AND APPARENT DIGESTIBILITY COEFFICIENTS DETERMINED BY CHROMIC OXIDE

Ration	Dry Matter Intake		Apparent Digestibility Coefficients					
	(% B.W.)	($gm/W_{kg}^{.75}$)	Dry Matter	Crude Protein	CWC	ADF	ADL	Gross Energy
			%					
1	3.34^{a}	119.06^{a}	62.12^{a}	68.38^{a}	44.64^{a}	48.12^{a}	11.08^{a}	61.73^{a}
2	3.04^{a}	107.98^{a}	67.63^{b}	69.46^{a}	42.87^{a}	41.57^{b}	24.73^{b}	66.95^{b}
3	3.23^{a}	115.24^{a}	66.26^{b}	67.60^{a}	37.99^{b}	40.58^{b}	17.52^{ab}	65.57^{b}

Values within columns with different superscripts are significantly different ($P<0.05$).

CWC = Cell Wall Constituent; ADF = Acid Detergent Fiber; ADL = Acid Detergent Lignin.

dry matter intake of heifers as the percent concentrate increased in the ration.

The apparent digestibility coefficients of the various nutrients as determined by chromic oxide are found in Table 2. There were significant differences ($P<0.05$) between rations in apparent digestibility of dry matter (DM), and gross energy (GE), with the all forage ration being significantly lower in DM and GE digestibility. Even though there were significant ration differences in the digestibility of DM and GE, the trends of increasing digestibility of DM and GE as the amount of concentrate increased in the ration were not found. This does not agree with the results of Montgomery and Baumgardt (52) and Cowsert and Montgomery (22).

There was no significant difference ($P>0.05$) for the apparent digestibility of crude protein (CP). This is in agreement with Montgomery and Baumgardt (52) but not with Cowsert and Montgomery (22). Significant ration differences ($P<0.05$) were found for the apparent digestibility of CWC, ADF, and ADL. The apparent digestibility of CWC and ADF decreased as the amount of concentrate increased in the ration. This is in agreement with Campling (20) who reported that the addition of large amounts of concentrate to the diet decreased the digestibility of crude fiber. Head (35) also reported that the addition of starch to the diet decreased the digestibility of cellulose. The apparent digestibility of ADL is difficult to explain since Van Soest (73) reported that the fraction of the feed which is represented by ADL should be nearly indigestible.

The apparent digestibility coefficients for the various nutrients

as determined by ADL are found in Table 3. In all cases the values determined by ADL are lower than those determined by chromic oxide because when ADL was used as the indicator the estimated fecal output was higher than when chromic oxide was used as an indicator to estimate fecal output. When the changes or trends in digestibility of the various nutrients due to the addition of concentrate to the ration are compared between the two methods, it can be seen that in no case do these values agree. Therefore, it can be concluded that the two methods of determining digestibility are not in agreement in this experiment.

Energy intake data are presented in Table 4. There were no significant differences in digestible dry matter intake (DDMI) when the digestibility of DM was determined either by the chromic oxide technique or ADL technique. There were also no significant differences in digestible energy intake (DEI) when chromic oxide was used to determine the digestibility of energy. When the ADL technique was used to determine the digestibility of energy, there were significant ration differences ($P<0.05$) in the DEI of the calves on the three rations.

If the chromic oxide technique of determining digestibilities is considered to be correct, then the energy intake data agree with the results of Montgomery and Baumgardt (52) and Cowsert and Montgomery (22). This is true even though the trends in dry matter intake (DMI), DM digestibility, and GE digestibility of this experiment do not agree with those of Montgomery and Baumgardt (52) and Cowsert and Montgomery (22). The reason these calves were able to maintain a constant DDMI and DEI (as determined by chromic oxide) is because DMI followed inversely

TABLE 3

EFFECT OF FORAGE:CONCENTRATE RATIOS FED IN EXPERIMENT I ON APPARENT DIGESTIBILITY COEFFICIENTS DETERMINED BY ACID DETERGENT LIGNIN

Ration	Apparent Digestibility Coefficients				
	Dry Matter	Crude Protein	CWC	ADF	Gross Energy
	%				
1	57.32[a]	64.39[a]	37.65[a]	41.55[a]	56.89[a]
2	56.72[a]	59.17[b]	23.69[b]	22.00[c]	55.82[a]
3	58.76[a]	60.45[b]	24.32[b]	27.56[b]	57.89[a]

Values within columns with different superscripts are significantly different ($P<0.05$).

CWC = Cell Wall Constituents; ADF = Acid Detergent Fiber.

TABLE 4

EFFECT OF FORAGE:CONCENTRATE RATIOS FED IN EXPERIMENT I ON ENERGY INTAKE, DIGESTIBLE DRY MATTER INTAKE, AND AVERAGE DAILY GAIN

		Ration		
		1	2	3
DDMI-Cr_2O_3	($gm/W_{kg}^{.75}$)	73.99[a]	73.02[a]	76.22[a]
DDMI-ADL	($gm/W_{kg}^{.75}$)	68.28[a]	61.13[a]	67.47[a]
DEI-Cr_2O_3	($kcal/W_{kg}^{.75}$)	333.96[a]	325.97[a]	343.97[a]
DEI-ADL	($kcal/W_{kg}^{.75}$)	305.26[a]	271.34[b]	303.19[a]
ADG	(lbs/day)	2.49[a]	2.32[a]	2.21[a]

Values within rows with different superscripts are significantly different ($P<0.05$).

DDMI = Digestible Dry Matter Intake; DEI = Digestible Energy Intake; Cr_2O_3 means values were determined by chromic oxide; ADL means values were determined by acid detergent lignin; ADG = Average Daily Gain.

both the digestibility of DM and GE when they were determined by the chromic oxide technique. This was not true when the ADL technique was used to determine digestibilities.

There was no significant difference in the average daily gain (ADG) of the calves on the three rations (Table 4). The calves on the all forage ration had the highest ADG, whereas the calves on the highest concentrate ration had the lowest ADG. This is difficult to explain especially since the trends in ADG did not follow the trends in DEI when determined by either of the indicator techniques.

Individual data for the measured variables studied are presented in Appendix Tables 20 through 23.

If it is assumed that the digestibility values obtained by using the chromic oxide technique are correct, it might be concluded that the calves in this experiment were adjusting their feed intake in order to maintain a constant digestible energy intake. With the other contradictory data that has been presented, it would be difficult to make this assumption.

CHAPTER V

EXPERIMENT II

Objective of Experiment

The objective of this investigation was to determine whether Holstein heifers have the ability to regulate the amount of food consumed to maintain a constant digestible energy intake when fed various forage:concentrate ratios. The effects of different dietary energy levels on the digestibility of several nutrients, rumen pH, and blood sugar levels were also studied.

Experimental Procedure

Thirty Holstein heifers were used in a 4-week continuous feeding trial. The first 14 days were used as an adjustment period, and the last 14 days were used to determine intake. The chromic oxide capsules were given and fecal grab samples taken as described in the general experimental procedure. The heifers were grouped according to body-weight and assigned to the various rations at random. The heifers weighed an average of 575 pounds when they were placed on the experiment.

Rations used in this experiment consisted of various alfalfa-orchardgrass hay:concentrate ratios, pelleted into three-fourths by three-fourths inch range pellets. The hay used in Experiment II contained a larger portion of orchardgrass as compared to alfalfa than the hay used in Experiment I. The alfalfa-orchardgrass hay:concentrate ratios used were the following: Ration 2, 82.5:17.5; Ration 3, 65:35; and Ration 4, 47.5:52.5. The concentrate mixtures in rations

2, 3, and 4 were composed of ground shelled corn and soybean oil meal in the appropriate ratio in an attempt to make all three rations isonitrogenous. The heifers were kept in pens in groups of four. Individual feed intake data were obtained by fastening the animals to their respective feed manger for a period of 3 hours two times per day. It was believed that this would insure or simulate ad libitum consumption. The rations were fed twice daily at 7 a.m. and 5 p.m. with refusals being taken once daily at the p.m. feeding. Fed and refusal weights were recorded daily. Trace mineralized salt and water were available to the heifers all the time that they were not fastened to their feed mangers.

All the animals were weighed for three consecutive days at the start and end of the experiment and every week during the experimental period. Notes were kept on the individual health and general condition of each heifer.

Rumen and blood samples were taken and analyzed according to the procedure given earlier under general experimental procedure.

Results and Discussion

The chemical composition of the individual rations used in Experiment II is found in Table 5. The crude protein content of the three rations varied slightly as the amount of concentrate increased in the rations. There was an almost linear decrease in the percentage of CWC, ADF, and ADL as the percent of concentrate increased in the rations.

One heifer on ration 2 obtained an abscess in her throat and had to be removed from the experiment. Therefore, the statistical

TABLE 5

CHEMICAL COMPOSITION OF RATIONS FED IN EXPERIMENT II

Ration	Dry Matter	Dry Matter Constituents				Gross Energy
		Crude Protein	CWC	ADF	ADL	
	%					(kcal/g)
2	93.95	16.38	40.39	29.96	6.50	4.45
3	93.90	18.76	32.27	24.41	5.27	4.45
4	93.43	17.86	25.95	19.00	4.50	4.24

CWC = Cell Wall Constitutents; ADF = Acid Detergent Fiber; ADL = Acid Detergent Lignin.

analyses of this experiment were computed by using unequal subclass numbers.

Dry matter intake, expressed either as percent of body weight or in grams per kilogram metabolic weight, decreased as the percent concentrate in the ration increased (Table 6). Results of this experiment disagree with Experiment I but agree with those of Donefer et al. (28) and Montgomery and Baumgardt (52).

The apparent digestibility coefficients of the various nutrients as determined by the chromic oxide technique are found in Table 6. There were significant differences ($P<0.05$) between rations in apparent digestibility of DM and GE. The trends in the digestibility of DM and and GE from one ration to another are not consistent with those reported in Experiment I or those of Montgomery and Baumgardt (52) and Cowsert and Montgomery (22). These workers (22, 52) report increasing digestibilities of DM and GE with increasing levels of concentrate in the ration.

As reported in Experiment I, there were no significant ration differences ($P>0.05$) for the apparent digestibility of CP. This is also in agreement with the results of Montgomery and Baumgardt (52). Significant differences ($P<0.05$) between rations were found for the apparent digestibility of CWC and ADF. No significant ration differences were found for the digestibility of ADL. As reported in Experiment I, the apparent digestibility of CWC and ADF decreased as the amount of concentrate increased in the ration. Even though there were no significant ration differences in the digestibility of ADL, the values of 15.52 and 10.18 would be hard to

TABLE 6

EFFECT OF FORAGE:CONCENTRATE RATIOS FED IN EXPERIMENT II ON DRY MATTER INTAKE AND APPARENT DIGESTIBILITY COEFFICIENTS DETERMINED BY CHROMIC ACID

Ration	Dry Matter Intake		Apparent Digestibility Coefficients					
	(% B.W.)	($gm/W_{kg}^{.75}$)	Dry Matter	Crude Protein	CWC	ADF	ADL	Gross Energy
			%					
2	2.76^{a}	114.17^{a}	68.43^{a}	71.94^{a}	51.01^{a}	47.55^{a}	15.52^{a}	67.35^{a}
3	2.58^{a}	106.37^{a}	64.64^{b}	73.30^{a}	32.87^{b}	31.21^{b}	2.62^{a}	64.90^{a}
4	2.35^{b}	96.13^{b}	66.42^{b}	73.27^{a}	26.44^{c}	26.77^{c}	10.18^{a}	67.78^{a}

Values within columns with different superscripts are significantly different ($P<0.05$).

CWC = Cell Wall Constituents; ADF = Acid Detergent Fiber; ADL = Acid Detergent Lignin.

explain since Van Soest (73) reported that ADL should be nearly indigestible.

The apparent digestibility coefficients for the various nutrients as determined by using the ADL technique are found in Table 7. As in Experiment I, when ADL was used as the indicator the estimated fecal output was higher than when chromic oxide was used. Therefore, in all cases the values determined by ADL were lower than those determined by chromic oxide. Even though the values determined by ADL are lower, the trends or changes between rations in the digestibility of CWC, ADF, and CP do agree between the two methods. This is not true for the digestibility of DM and GE.

Energy intake data are presented in Table 8. When the digestibility of DM and GE were determined by both the chromic oxide and ADL techniques, there were significant decreases ($P<0,05$) in both DDMI and DEI. This does not agree with the results of Montgomery and Baumgardt (52) and Cowsert and Montgomery (22).

The ADG of the heifers on the three rations did not differ significantly (Table 8). The heifers on the highest concentrate ration did have the highest ADG, but these were also the heifers with the lowest DDMI and DEI. As in Experiment I, it is difficult to explain how the ADG values correspond to the energy intake data.

There was a significant difference ($P<0.05$) in rumen pH of the heifers on ration 3 as compared to those on ration 4. The significant difference is in agreement with Cowsert and Montgomery (22) but the trend observed is not. Cowsert and Montgomery (22) found that rumen pH values decreased with the addition of concentrate to the ration.

TABLE 7

EFFECT OF FORAGE:CONCENTRATE RATIOS FED IN EXPERIMENT II ON APPARENT DIGESTIBILITY COEFFICIENTS DETERMINED BY ACID DETERGENT LIGNIN

Ration	Apparent Digestibility Coefficients				
	Dry Matter	Crude Protein	CWC	ADF	Gross Energy
	%				
2	62.46[a]	66.65[a]	42.92[a]	37.32[a]	61.25[a]
3	63.44[a]	72.29[b]	30.71[b]	30.60[a]	63.65[a]
4	62.01[a]	69.81[b]	17.01[c]	17.16[b]	63.64[a]

Values within columns with different superscripts are significantly different ($P<0.05$).

CWC = Cell Wall Constituents; ADF = Acid Detergent Fiber.

TABLE 8

EFFECT OF FORAGE:CONCENTRATE RATIOS FED IN EXPERIMENT II ON ENERGY INTAKE, DIGESTIBLE DRY MATTER INTAKE, AVERAGE DAILY GAIN, RUMEN pH, AND BLOOD GLUCOSE

		Ration		
		2	3	4
DDMI-Cr_2O_3	($gm/W_{kg}^{.75}$)	78.25[a]	68.90[b]	63.92[b]
DDMI-ADL	($gm/W_{kg}^{.75}$)	71.19[a]	67.41[a]	59.58[b]
DEI-Cr_2O_3	($kcal/W_{kg}^{.75}$)	342.73[a]	307.72[b]	276.33[c]
DEI-ADL	($kcal/W_{kg}^{.75}$)	310.56[a]	300.85[a]	259.04[b]
ADG	(lbs/day)	2.24[a]	2.09[a]	2.96[a]
Rumen pH		7.55[a]	7.19[b]	7.49[a]
Blood Glucose	(mg/100 ml)	62.46[a]	58.16[a]	57.42[a]

Values within rows with different superscripts are significantly different ($P<0.05$).

DDMI = Digestible Dry Matter Intake; DEI = Digestible Energy Intake; Cr_2O_3 means values were determined by chromic oxide; ADL means values were determined by acid detergent fiber; ADG = Average Daily Gain.

Even though there was a slight decrease in blood glucose values with increasing levels of concentrate, there were no significant differences in blood glucose levels. This is in agreement with several workers (29, 36, 44) who reported that blood glucose does not appear to be involved in the regulation of voluntary feed intake in ruminants.

Individual data for the measured variables studied are presented in Appendix Tables 24 through 28.

If it is assumed that the digestibility values obtained by using either the chromic oxide or ADL techniques are correct, it can be concluded that the heifers in this experiment were not able to adjust their feed intake in order to maintain constant energy intakes.

CHAPTER VI

EXPERIMENT III

Objective of Experiment

The objective of this investigation was to determine whether lactating dairy cows have the ability to regulate the amount of food consumed to maintain a constant digestible energy intake when fed various forage:concentrate ratios. The effects of different dietary energy levels on the digestibility of several nutrients, rumen pH, actual milk production, milk fat test, and fat corrected milk (FCM) production were also studied.

Experimental Procedure

Fifteen Holstein cows and nine Jersey cows were used in a 6-week continuous feeding trial. The first 21 days were used as an adjustment period and the last 21 days were used to determine intake. The chromic oxide capsules were given and fecal grab samples taken as described in the general experimental procedure. The cows were assigned to trios within breeds based on 4 percent FCM production before the experimental period. The cows within each trio were assigned to the various rations at random.

Rations used in this experiment consisted of various alfalfa-orchardgrass hay:concentrate ratios, pelleted into three-fourths by three-fourths inch range pellets. The hay used in this experiment was the same as that used in Experiment I. The alfalfa-orchardgrass hay:concentrate ratios used were the following: Ration 3, 65:35;

Ration 4, 47.5:52.5; and Ration 5, 30:70. The concentrate mixtures in rations 3, 4, and 5 were composed of ground shelled corn and soybean oil meal in the appropriate ratio in an attempt to make all three rations isonitrogenous. The rations were individually fed twice daily at 7 a.m. and 5 p.m. in amounts to insure ad libitum consumption. Refusals were taken once daily at the p.m. feeding. Fed and refusal weights were recorded daily. The animals were housed in tie-stalls with individual feed mangers. All of the cow's rations were fed in these feed mangers with no grain being fed in the milking parlor. Trace mineralized salt and water were available to the cows at all times.

All the animals were weighed for three consecutive days at the start and end of the experiment and every two weeks during the experimental period. Notes were kept on the individual health and general condition of each cow.

Rumen and milk samples were taken and analyzed according to the procedure given earlier under general experimental procedure.

Results and Discussion

The chemical composition of the individual rations used in Experiment III is found in Table 9. The percentage of CWC, ADF, and ADL decreased as the amount of concentrate increased in the ration.

Dry matter intake, expressed either as percent of body weight or in grams per kilogram metabolic weight, remained essentially the same as the amount of concentrate increased in the ration (Table 10). This does not agree with previous research (22, 52).

TABLE 9

CHEMICAL COMPOSITION OF RATIONS FED IN EXPERIMENT III

Ration	Dry Matter	Dry Matter Constituents				Gross Energy
		Crude Protein	CWC	ADF	ADL	
	%					(kcal/g)
3	91.91	19.57	38.63	25.06	5.26	4.65
4	90.98	19.68	29.89	19.03	3.60	4.68
5	90.78	20.01	25.57	15.22	2.70	4.63

CWC = Cell Wall Constituents; ADF = Acid Detergent Fiber; ADL = Acid Detergent Lignin.

TABLE 10

EFFECT OF FORAGE:CONCENTRATE RATIOS FED IN EXPERIMENT III ON DRY MATTER INTAKE AND APPARENT DIGESTIBILITY COEFFICIENTS DETERMINED BY CHROMIC OXIDE

Ration	Dry Matter Intake		Apparent Digestibility Coefficients					
	(% B.W.)	($gm/W_{kg}^{.75}$)	Dry Matter	Crude Protein	CWC	ADF	ADL	Gross Energy
			%					
3	1.90[a]	89.77[a]	28.90[a]	49.19[a]	-12.83[a]	-22.02[a]	-77.20[a]	30.17[a]
4	1.89[a]	89.73[a]	43.03[a]	51.04[a]	-10.58[a]	-12.28[a]	-84.80[a]	44.03[a]
5	1.94[a]	92.04[a]	37.24[a]	47.10[a]	-42.29[a]	-43.95[a]	-141.83[a]	38.36[a]

Values within columns with different superscripts are significantly different ($P<0.05$).

CWC = Cell Wall Constituents; ADF = Acid Detergent Fiber; ADL = Acid Detergent Lignin.

The apparent digestibility coefficients of the various nutrients as determined by the chromic oxide technique are found in Table 10. It can be seen at a quick glance that none of the values appeared to be correct. The apparent digestibility values for DM, GE, and CP are too low for high concentrate rations and the values for CWC, ADF, and ADL are all negative. The exact reason for these values is not known, but possible explanations are discussed later.

The apparent digestibility coefficients for the various nutrients as determined by using the ADL technique are found in Table 11. These values are closer to the digestibility values reported in previous research (52, 22) for high concentrate rations. There were significant increases ($P<0.05$) in the digestibility of DM and GE with increasing concentrate levels. This is in agreement with the results of Montgomery and Baumgardt (52) and Cowsert and Montgomery (22). There were also significant differences ($P<0.05$) in the digestibility of CP with the values increasing with increasing concentrate levels. There were no significant differences in the digestibility of CWC, but there were significant differences ($P<0.05$) for the digestibility of ADF. However, both the digestibility of CWC and ADF increased with increasing concentrate levels. This does not agree with the results of Experiments I and II.

Energy intake data are found in Table 12. There were no significant ration differences in DDMI and DEI when digestibility values were determined by chromic oxide. Because of the low digestibility values as determined by chromic oxide, these values are not very reliable. This is also seen by the low DDMI and DEI. When the ADL

TABLE 11

EFFECT OF FORAGE:CONCENTRATE RATIOS FED IN EXPERIMENT III ON APPARENT DIGESTIBILITY COEFFICIENTS DETERMINED BY ACID DETERGENT LIGNIN

Ration	Apparent Digestibility Coefficients				
	Dry Matter	Crude Protein	CWC	ADF	Gross Energy
	%				
3	59.88[a]	71.30[a]	34.53[a]	31.08[a]	60.30[a]
4	68.89[b]	73.92[ab]	39.43[a]	38.21[b]	69.40[b]
5	73.50[c]	77.77[b]	40.08[a]	39.14[b]	71.08[b]

Values within columns with the same superscripts are significantly different ($P<0.05$).

CWC = Cell Wall Constituents; ADF = Acid Detergent Fiber.

TABLE 12

EFFECT OF FORAGE:CONCENTRATE RATIOS FED IN EXPERIMENT III ON ENERGY INTAKE, DIGESTIBLE DRY MATTER INTAKE, AVERAGE DAILY GAIN, AND RUMEN pH

		Ration		
		3	4	5
DDMI-Cr_2O_3	($gm/W_{kg}^{.75}$)	27.62^a	39.24^a	35.23^a
DDMI-ADL	($gm/W_{kg}^{.75}$)	53.78^a	61.36^{ab}	67.31^b
DEI-Cr_2O_3	($kcal/W_{kg}^{.75}$)	133.38^a	188.00^a	174.32^a
DEI-ADL	($kcal/W_{kg}^{.75}$)	251.31^a	289.33^a	300.52^a
ADG	(lbs/day)	1.88^a	1.63^a	2.17^a
Rumen pH		5.61^a	5.99^a	5.52^a

Values within rows with different superscripts are significantly different ($P<0.05$).

DDMI = Digestible Dry Matter Intake; DEI = Digestible Energy Intake; Cr_2O_3 means values were determined by chromic oxide; ADL means values were determined by acid detergent lignin; ADG = Average Daily Gain.

technique was used to determine digestibilities, DDMI and DEI increased with increasing concentrate levels. This was a significant difference ($P<0.05$) with DDMI but not with DEI.

As in Experiments I and II, the ADG of the cows on the three rations did not differ significantly (Table 12). Also as with the first two experiments, the trends in ADG do not correspond with the trends in energy intake. With lactating dairy cows the level of milk production could affect ADG. However, in this experiment the ADG of the animals does not correspond to the levels of milk production.

There were no significant differences in the rumen pH values of the cows in Experiment III (Table 12). This does not agree with the results of Cowsert and Montgomery (22), who reported decreased rumen pH values with the addition of concentrate to the ration.

Adjusted covariate means for actual milk production, milk fat percent, and FCM production are presented in Table 13. No significant differences ($P>0.05$) in actual milk production, milk fat percent, and FCM production were observed between the three rations. There were appreciable drops in the milk fat tests from the standardization period to the experimental period. The average milk fat percent was 4.13, 4.37, and 4.38 for the cows on rations 3, 4, and 5 during the standardization period and 3.00, 3.18, and 3.01 during the experimental period. The reduction in milk fat test due to the feeding of high levels of concentrate is well established in the literature as reported in a review article by Van Soest (71).

Individual data for the measured variables studied are presented in Appendix Tables 29 through 34.

TABLE 13

ACTUAL MILK PRODUCTION, MILK FAT PERCENT, AND FAT-CORRECTED-MILK PRODUCTION FOR COWS IN EXPERIMENT III

Ration	Adjusted Means		
	Actual Milk (lbs/day)	Milk Fat (%)	FCM (lbs/day)
3	34.74[a]	3.14[a]	30.28[a]
4	31.64[a]	3.11[a]	25.52[a]
5	33.60[a]	2.93[a]	26.72[a]

Values within columns with different superscripts are significantly different ($P<0.05$).

FCM= Fat-Corrected-Milk.

Because the digestibility values determined by chromic oxide are considered incorrect and because there were no significant differences in DEI as determined by ADL, it might be concluded that the cows in this experiment were able to adjust their voluntary feed intake in order to maintain constant digestible energy intakes. However, this conclusion does not seem too reliable because of increases in DDMI (significant increase) and DEI (nonsignificant increase) with increasing levels of concentrate in the ration.

CHAPTER VII

EXPERIMENT IV

Objective of Experiment

The principle objective of this study was to determine whether fistulated cows have the ability to regulate the amount of food consumed to maintain a constant digestible energy intake when part of their energy requirement is supplied by the intraruminal infusion of various levels of a mixture of acetic, propionic, and butyric acids. The effects of the intraruminal infusion of these acids on rumen pH and rumen VFA concentration were also studied.

Experimental Procedure

Three non-lactating, fistulated, Jersey cows were used in this experiment. The experiment was conducted as follows:

Weeks 1-2	Adjustment period
Week 3	Control intake period
Week 4	Water infusion period
Week 5	500 milliliters VFA infusion
Week 6	1000 milliliters VFA infusion

One ration was fed to all the cows over the entire period of the experiment. The ration consisted of 1 percent salt, 12 percent soybean oil meal, 43 percent beet pulp, and 44 percent ground shelled corn. The ration was fed individually twice daily at 7 a.m. and 5 p.m. in amounts to insure ad libitum consumption. Refusals were taken once daily at the p.m. feeding. Fed and refusal weights were

recorded daily. The animals were housed in tie-stalls with individual mangers. Water was made available to the animals at all times.

In all of the infusion periods a total of 4 liters of liquid was infused each day. This amount of liquid was infused over a 4-hour period from 7 a.m. until 11 a.m. The liquids were infused by the use of variable speed pumps which along with the containers containing the liquids were mounted directly above the fistula of the cows. A small hose carried the liquid from the containers to the pump and then to the cannula of the fistulated cows. The hose was fastened or unfastened (depending on whether infusion was or was not taking place) to the tube portion of the bleeding needle placed permanently in the lids of the cannulas. Another small hose was fastened to the tube portion of the bleeding needle on the inside of the cannula. This hose was fastened to the outside of a plastic bottle filled with water and placed in the rumen contents. This remained inside the cows during all the infusion periods.

The daily acid mixtures which were infused during the two acid infusion periods are in Table 14. The sodium hydroxide was added to adjust the pH of the VFA mixtures to 6.15 which was the average pH of the rumen fluid during the adjustment and control intake periods. The ratio of acetic, propionic, and butyric acids used in the mixtures was also determined by the average ratio of these acids found in the rumen samples collected from all the cows during the adjustment and control intake periods.

All the animals were weighed for three consecutive days during the adjustment, control, and two infusion periods. Notes

TABLE 14

DAILY VFA MIXTURES INFUSED IN EXPERIMENT IV

Components	Week 5	Week 6
	ml	
Acetic	285	570
Propionic	110	220
Butyric	105	210
NaOH (45%)	620	1,200
Water	2,880	1,800
Total	4,000	4,000

were kept on the individual health and general condition of each cow.

Rumen samples were taken and analyzed according to the procedure given earlier under general experimental procedure.

Results and Discussion

The ration used in Experiment IV contained 91.75 percent dry matter, 21.38 percent protein (dry matter basis), and 18.77 percent ADF (dry matter basis).

No statistical analyses were made in this experiment since only three cows were used. As seen in Table 15, Animal 138 went off feed and had to be placed on a regular hay ration. She increased in hay intake and was placed back on the experiment during the 1000 milliliter infusion period. During the 1000 milliliter infusion period both Animals 239 and 138 went off feed and showed symptoms of muscular twitching. Because of this these animals were removed from the experiment. Animal 239 recovered when placed on a hay ration, but Animal 138 died two days after being removed from the experiment. Animal 197 showed a slight amount of muscular twitching on one occasion. The exact reason the animals showed these symptoms is not known. An autopsy of Animal 138 showed no signs of irritation inside the rumen due to acid infusion. It is believed that the high levels of sodium (sodium salts) infused may have caused the observed effects.

Dry matter intakes, expressed either as pounds per day or percentage of body weight, are found in Table 15. Dry matter intakes appeared to increase in the water infusion period as compared to the control period. When the 500 milliliter acid mixture was infused,

TABLE 15

EFFECT OF ACID INFUSION ON DRY MATTER INTAKE AND BODY WEIGHTS OF FISTULATED COWS IN EXPERIMENT IV

Period	Cow	Dry Matter Intake (lbs/day)	Body Weight (lbs)	Dry Matter Intake (% B.W.)
Control	239	15.12	1008	1.50
Water		17.58	1008	1.74
500		10.16	1024	.99
1000		2.09	928	.23
Control	197	22.78	1122	2.03
Water		22.54	1122	2.01
500		16.22	1142	1.42
1000		6.18	1056	.59
Control	138	14.96	1100	1.36
Water		*		
500				
1000		.44	dead	
Control	Average	17.62	1076	1.63
Water		20.06	1065	1.88
500		13.19	1083	1.21
1000		2.90	992	.41

500 = 500 ml acid infusion period.

1000 = 1000 ml acid infusion period.

* = Animal became sick and had to be removed from the experiment.

DMI decreased approximately 7 pounds. When the acid infused was increased up to 1000 milliliters per day, DMI decreased approximately 10 pounds. From these results it would appear that the animals were decreasing their DMI or energy intake, to account for the energy being added directly to the rumen by the infusion of the acid mixtures. However, the estimated energy intakes of the animals during the different periods did not confirm this statement.

Five hundred and 1000 milliliters of the acid mixture were infused each day because according to Stewart et al. (68) this should be approximately one-fourth and one-half of the amount of acids produced daily. According to Blaxter (17) the 500 milliliter infusion supplied 2,185 kilocalories of energy, whereas the 1000 milliliter infusion supplied 4,370 kilocalories. Using these values and the National Research Council's (57) values for the DE content of the ration, the respective DEI of the cows during the control, water infusion, 500 milliliter acid infusion, and 1000 milliliter acid infusion periods were 28.86, 32.86, 23.79, and 9.12 megacalories. The energy requirement of these animals averaged only 14.60 megacalories of DE. From these values it might be concluded that the cows were not adjusting their voluntary feed intake to a constant energy need. This is evidenced by the lowering of DEI due to acid infusion and also by the fact that in all periods except the 1000 milliliter infusion period the animals were consuming more energy than they required.

Because the animals during the control and water infusion periods were consuming approximately twice their energy requirements, it might be concluded that mechanisms other than energy intake

regulation were controlling voluntary feed intake. The reduced DMI and estimated DEI during the 500 and 1000 milliliter infusion periods could have been caused by complications arising from the infusion of the acid mixtures.

The effect of acid infusion on rumen pH values can be seen in Table 16. The acid mixtures were prepared so that the pH of the infused mixture would be equal to the pH of the rumen fluid during the adjustment and control period. Rumen pH values were essentially the same during the water infusion period and increased only slightly during the acid infusion periods. At least the acid mixture did not cause a large decrease in rumen pH due to acid infusion. Because there is no difference in rumen pH values from 9 a.m. to 11 a.m., it is believed that no drastic changes in rumen pH values were taking place in the rumen due to the infusion of the acid mixtures.

The effect of acid infusion on rumen VFA concentrations can be seen in Table 17. The acid mixtures infused during the two acid infusion periods contained 57, 22, and 21 percent acetic, propionic, and butyric acid, respectively. There appeared to be no definite trends in the VFA concentrations due either to the different infusion periods or time of sampling. The only evidence of any trends was slight increases in the percentages of acetic acid during the two acid infusion periods and slight decreases in the percentages of propionic and butyric acids (especially butyric). These trends may be misleading since data were only available for two cows in the 500 milliliter infusion period and only one cow in the 1000 milliliter

TABLE 16

EFFECT OF ACID INFUSION ON RUMEN pH OF FISTULATED COWS IN EXPERIMENT IV

Period	Time	Cow 239	Cow 197	Cow 138	Average
Adjustment	9 a.m.	6.45	6.00	5.90	6.12
	11 a.m.	6.20	5.60	5.85	5.88
Control	9 a.m.	6.40	6.35	6.30	6.35
	11 a.m.	6.15	6.25	6.20	6.20
Water	9 a.m.	6.65	6.05	6.15	6.28
	11 a.m.	5.90	5.60	6.55	6.02
500	9 a.m.	6.60	6.60	*	6.60
	11 a.m.	6.60	6.60		6.60
1000	9 a.m.	*	6.70		6.70
	11 a.m.		6.70		6.70

500 = 500 ml acid infusion period.

1000 = 1000 ml acid influsion period.

* = Animals became sick and due to medical treatment no samples were taken.

TABLE 17

EFFECT OF ACID INFUSION ON RUMEN VOLATILE FATTY ACIDS COLLECTED AT 9 A.M. AND 11 A.M. FROM FISTULATED COWS IN EXPERIMENT IV

Volatile Fatty Acid	Time	Period				
		Adjustment	Control	Water	500*	1000**
Acetic[1]	9 a.m.	400.0	288.2	356.9	409.5	330.3
	11 a.m.	379.3	330.6	443.4	325.7	323.4
Propionic[1]	9 a.m.	146.8	113.4	117.2	120.2	96.3
	11 a.m.	171.7	116.1	157.5	94.6	95.6
Butyric[1]	9 a.m.	153.4	105.4	116.6	106.6	89.4
	11 a.m.	146.4	103.6	125.1	88.2	89.4
Isovaleric[1]	9 a.m.	23.5	22.2	24.7	14.6	16.1
	11 a.m.	25.5	17.7	24.0	15.5	0.0
Valeric[1]	9 a.m.	11.0	8.3	0.0	8.2	3.0
	11 a.m.	11.9	1.2	0.0	7.6	0.0
Total VFA[1]	9 a.m.	734.7	537.5	615.4	655.0	535.1
	11 a.m.	734.8	569.2	750.0	531.5	508.3
Acetic[2]	9 a.m.	54.4	53.7	57.9	62.5	61.7
	11 a.m.	51.5	58.1	59.1	61.1	63.6
Propionic[2]	9 a.m.	20.0	20.8	18.9	18.5	18.0
	11 a.m.	23.3	20.4	21.0	18.0	18.8
Butyric[2]	9 a.m.	20.9	19.7	19.1	16.3	16.7
	11 a.m.	20.0	18.2	16.6	16.6	17.6
Isovaleric[2]	9 a.m.	3.2	4.1	4.1	2.2	3.0
	11 a.m.	3.5	3.1	3.2	2.9	0.0
Valeric[2]	9 a.m.	1.4	1.5	0.0	1.2	0.6
	11 a.m.	1.6	0.2	0.0	1.4	0.0
A/P Ratio	9 a.m.	2.8	2.7	3.1	3.4	3.4
	11 a.m.	2.2	2.9	2.8	3.4	3.4

[1](mg/100 ml) [2]Percent of total.

*Values are the average of only two cows.

**Values are for only one cow.

infusion period. Even though these trends did exist, it can be concluded that no drastic changes in the percentage of the VFA occurred due to the infusion of the acid mixtures.

CHAPTER VIII

SUMMARY AND CONCLUSIONS

A summary of the DMI, GE digestibilities, DEI, and ADG obtained in Experiments I, II, and III is found in Table 18. The trends observed when concentrate was added to the rations in each experiment are in disagreement when compared to the trends of all the variables (DMI, GE digestibility, and DEI) obtained in the experiments of Donefer et al. (28), Montgomery and Baumgardt (52), and Cowsert and Montgomery (22).

The values obtained by taking the average of the variables within ration and across the three experiments agree more closely with the values of Donefer et al. (28), Montgomery and Baumgardt (52), and Cowsert and Montgomery (22). The decreases observed in the average DMI may be due to decreases in the metabolic rate of the older animals. There are also other limitations involved in using the average values. If the average values across experiments are used there is no way to determine if different mechanisms of feed intake regulation do exist between rumunants with different energy requirements. Also if the average values are used, the GE digestibility values determined by chromic oxide or ADL are being averaged together. Therefore a new method is being used to determine GE digestibility.

The DMI along with GE digestibilities and DEI obtained by averaging the GE digestibilities determined by chromic oxide and ADL on an individual experiment basis are found in Table 19. Again the trends of all the variables (DMI, GE digestibility, and DEI) are in disagreement with the trends obtained by Donefer et al. (28),

TABLE 18

DATA SUMMARY FOR EXPERIMENTS I, II, AND III

Variable		Ration 1	2	3	4	5
DMI		119.06	107.98	115.24		
($gm/W_{kg}^{.75}$)			114.17	106.37	96.13	
				89.77	89.73	92.04
Average		119.06	111.08	103.79	92.93	92.04
GE	Cr_2O_3	61.73	66.95	65.57		
Digestibility	ADL	56.89	55.82	57.89		
%	Cr_2O_3		67.35	64.90	67.78	
	ADL		61.25	63.65	63.64	
	Cr_2O_3			30.17*	44.03*	38.35*
	ADL			60.30	69.40	71.08
Average		59.31	62.84	62.46	66.94	71.08
DEI	Cr_2O_3	333.96	325.97	343.97		
($kcal/W_{kg}^{.75}$)	ADL	305.26	271.34	303.19		
	Cr_2O_3		342.73	307.72	276.33	
	ADL		310.56	300.85	259.04	
	Cr_2O_3			133.38*	188.00*	174.32*
	ADL			251.31	289.33	300.52
Average		319.61	312.64	301.41	274.90	300.52
ADG		2.48	2.31	2.20		
(lbs/day)			2.24	2.08	2.96	
				1.87	1.69	2.31
Average		2.48	2.28	2.05	1.55	2.31

*Values were not used to compute the average values due to the explanations discussed on page 69.

TABLE 19

DATA SUMMARY FOR EXPERIMENT I, EXPERIMENT II, AND EXPERIMENT III AND DAILY DE REQUIREMENTS

Experiment	Ration	DMI ($gm/W_{kg}^{.75}$)	GE Digestibility (%)	DEI ($kcal/W_{kg}^{.75}$)	DE Requirements ($kcal/W_{kg}^{.75}$)
I	1	119.06	59.31	319.61	366.07
	2	107.98	61.39	298.66	360.46
	3	115.24	61.73	323.58	342.76
II	2	114.17	64.30	326.65	312.97
	3	106.37	64.28	304.29	305.50
	4	96.13	65.71	267.69	384.30
III	3	89.77	60.30*	251.31*	455.31
	4	89.73	69.40*	289.33*	402.48
	5	92.04	71.08*	300.52*	446.57

*Values determined by ADL only.

Note: The DE requirements in Experiments I and II were determined by making allowance for maintenance and ADG using the formula of Swanson (69). The DE requirements in Experiment III were determined by making allowances for maintenance and ADG using the formula of Swanson (69) and milk production using the values of National Research Council (57).

Montgomery and Baumgardt (52), Cowsert and Montgomery (22). Therefore the problem arises in trying to explain these differences. It is also difficult to explain why all the animals except those on rations 2 and 3 in Experiment II had lower DEI than they had DE requirements. The DE requirements were calculated by using the formula of Swanson (69) and the values of National Research Council (57).

One explanation might be that the indicator techniques used to determine the apparent digestibilities of the various nutrients may not have accurately determined the actual digestibilities of the various rations. It should be pointed out however that several workers (39, 42, 51) obtained comparable results when they compared the chromic oxide method to the total collection method of determining digestibilities. Kane et al. (40) compared the total collection, lignin, and chromic oxide methods of determining digestibility and found no significant differences due to the different methods.

All of the results obtained from using the chromic oxide technique have not been favorable. Hardison (33) reported that in only one out of three experiments that he conducted were satisfactory estimates of the daily fecal dry matter output obtained.

It is difficult to compare the results obtained in one experiment in which the chromic oxide method of determining digestibilities is used to that of another experiment using the chromic oxide technique. The reason for this is that several factors such as the amount of chromic oxide given, the method and time of giving the chromic oxide, the time and method of collecting feces samples, the length of time feces samples were collected, the method used for the analysis of chromic

oxide in the feces, and other factors can effect the end results obtained. This may be an important point since little if any research has been reported in which chromic oxide capsules were given along with the feeding of a pelleted ration. Research has been reported (30, 51) in which chromic oxide was mixed with the ration and then the chromic oxide plus the ration were pelleted together. However, this is entirely a different set of conditions than those which existed in these experiments. Information is needed on how chromic oxide, given in capsules, mixes with the ingesta of a pelleted ration in the digestive tract, and how it passes with the ingesta of a pelleted ration through the digestive tract.

One of the problems involved in using chromic oxide is that is has a diurnal excretion pattern. Kane et al. (41) and Elam et al. (30) reported a diurnal variation in the excretion of chromic oxide in cattle. One way to reduce the variation due to the diurnal excretion of chromic oxide is to sample the feces twice daily for several consecutive days (38). If the diurnal excretion pattern is also known, adjustments can be made to account for either an over or under estimation of fecal output.

Chromic oxide determinations were made on the fecal grab samples which were collected every three hours during the last 24 hours of Experiments I, II, and III from approximately one-half of the animals in each experiment. When the average of the 8 a.m. plus 5 p.m. samples is compared with the overall average of all samples; 96.88, 100.97, and 101.33 percent of the overall average was collected using these two times from the animals on rations 1, 2, and 3 of Experiment I. Using

these same two collection times, 97.77, 102.38, and 100.94 percent of the overall average was collected from the animals on rations 2, 3, and 4 of Experiment II, while 100.13, 98.48, and 104.68 percent was collected from the animals on rations 3, 4, and 5 of Experiment III. Using these figures corrections were made on the chromic oxide determinations of the 7-day composite grab samples for each animal on a particular ration. This was done to remove some of the variation which exists in the excretion of chromic oxide. In order to make these corrections it is assumed that the same percentage of chromic oxide was collected from the two collection times each day of the 7-day collection period as was collected from the two collection times during the last 24-hour collection period.

Even though several workers have obtained reliable results using indicators to determine digestibility and even though corrections can be made to remove some of the variation associated with the excretion of chromic oxide, there is still no way to know for sure that the digestibility values obtained in these experiments is correct. This is especially true since the digestibility values determined by the two indicator methods do not agree with each other. The only digestibility values that we can assume are incorrect are the values determined by the chromic oxide technique in Experiment III. This statement can be made because not only are the digestibility values determined by chromic oxide much lower than those determined by ADL, but also because the values determined by chromic oxide are too low for rations containing high levels of concentrates. The reason why the digestibility values determined by the chromic oxide technique in Experiment III are low

is not known, unless the cows were receiving grain in the milking parlor which was not recorded.

The differences observed between this work and that of Donefer et al. (28), Montgomery and Baumgardt (52), and Cowsert and Montgomery (22) can not be explained extirely by the different methods of determining digestibilities. Even if the digestibility values are forgotten, the trends observed in DMI, except for Experiment II, do not agree with those of Donefer et al. (28), Montgomery and Baumgardt (52), and Cowsert and Montgomery (22). Therefore it would appear that other explanations are needed to explain the observed differences.

Another explanation might be that the observed differences may be due tc the different ways in which the experiments were conducted. The experiments of Donefer et al. (28), Montgomery and Baumgardt (52), and Cowsert and Montgomery (22) used small numbers of animals in Latin-square designs. In these experiments large numbers of animals were used in continuous feeding trial designs.

Few experiments have been conducted in which digestibility values were determined on a large number of animals. The reason being that much labor and expense is involved in doing this type of experiment especially if conventional methods are used to determine digestibility. Part of the labor and expense can be reduced in continuous feeding experiments utilizing large numbers of animals by the use of indicator methods to determine digestibility. If it is assumed that the digestibility values determined by indicator techniques are less accurate than those determined by conventional methods, the choice may be to accept less reliable digestibility

values in order to be able to utilize more animals and thus more observations per treatment. The question is whether the evidence obtained from both types of experimentation will be the same. Probably the best conclusion that can be made from Experiments I, II, and III is that in this case the two different types of experimentation did not obtain the same results.

This research really seeks the answers to other questions. Which type of experimentation gives the results which actually explain feed intakes regulation? Are the results obtained by using large numbers of animals in continuous feeding trials employing indicator techniques more reliable than the results obtained by using fewer animals in Latin-square experiments employing conventional methods of digestibility determination? These experiments actually point out the need for more research to answer these questions.

Probably the best summary for Experiment IV would be to conclude that a certain type of confounding existed. Were the reduced intakes observed in Experiment IV due to the fact that the animals were obtaining enough energy from the infused acid mixtures or were the reduced intakes due to unphysiological conditions resulting from the infusing of the acid mixtures? Since it is believed that the high levels of sodium (sodium salts) that were infused is what caused the unphysiological conditions, this experiment should be conducted again with the pH of the acid mixtures being adjusted by another method. Maybe by using another method to adjust the pH of the acid mixtures the unphysiological conditions would be eliminated. If the unphysiological conditions were eliminated, this would also eliminate

the confounding and maybe some positive conclusions could be made about feed intake regulation.

In general the results reported in this dissertation do not agree with the theory that ruminants are able to regulate the amount of food consumed in order to maintain constant digestible energy intakes. This does not mean that this theory is incorrect. It does mean that certain questions dealing with different experimental designs and different methods of determining digestibility should be answered. Only after these questions are answered by future research can this theory be assumed to be either correct or incorrect.

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APPENDIX

TABLE 20

INDIVIDUAL DRY MATTER INTAKE, BODY WEIGHTS, AND AVERAGE DAILY GAIN FOR CALVES IN EXPERIMENT I

Ration	Animal	Dry Matter Intake (lbs/day)	Body Weights (lbs)	Average Daily Gain (lbs/day)
1	521	12.06	404	3.00
	523	10.79	339	3.29
	525	12.98	338	4.29
	528	11.96	341	1.57
	532	12.39	430	2.14
	538	14.00	358	2.14
	543	12.17	329	1.86
	544	9.55	318	2.14
	547	10.59	334	2.86
	553	12.61	396	1.57
	Mean	11.91	359	2.49
2	520	12.38	380	3.86
	522	9.16	371	2.43
	524	9.11	313	0.57
	529	10.14	324	3.86
	531	11.79	383	0.00
	537	12.18	389	2.86
	540	8.93	294	4.86
	541	13.96	362	1.57
	545	8.49	305	2.43
	549	9.79	352	0.71
	Mean	10.59	347	2.32
3	518	12.26	341	3.43
	519	11.96	384	3.71
	526	7.51	304	-0.57
	527	11.74	361	4.00
	536	13.49	398	1.71
	542	12.36	361	1.86
	546	10.85	357	2.57
	548	14.09	382	0.71
	550	9.99	326	2.43
	Mean	11.58	357	2.21

TABLE 21

INDIVIDUAL APPARENT DIGESTIBILITY COEFFICIENTS FOR DRY MATTER AND GROSS ENERGY DETERMINED BY CHROMIC OXIDE AND ACID DETERGENT LIGNIN FOR CALVES IN EXPERIMENT I

Ration	Animal	Apparent Digestibility Coefficients			
		Dry Matter		Gross Energy	
		Cr_2O_3	ADL	Cr_2O_3	ADL
		%			
1	521	64.30	58.74	64.80	59.18
	523	60.51	56.74	60.35	56.56
	525	65.44	55.47	64.04	53.45
	528	61.24	57.58	61.95	58.35
	532	65.57	56.68	61.95	58.35
	538	62.50	59.67	60.94	58.04
	543	61.75	57.40	61.10	56.71
	544	61.47	55.10	61.45	55.31
	547	61.81	59.53	61.86	59.60
	553	56.56	56.21	54.92	54.44
	Mean	62.12	57.32	61.73	56.89
2	520	69.67	51.86	69.48	51.48
	522	71.55	57.08	71.34	56.68
	524	66.50	54.03	65.32	52.53
	529	62.29	55.72	61.95	55.16
	531	67.63	59.84	66.96	59.00
	537	70.40	57.76	70.03	57.18
	540	65.50	62.62	63.82	60.86
	541	67.77	54.51	67.10	53.59
	545	67.21	54.60	67.42	54,84
	549	67.82	59.13	66.03	56.83
	Mean	67.63	56.72	66.95	55.82
3	518	66.37	53.93	65.96	53.29
	519	65.84	57.02	65.68	56.79
	526	70.47	60.23	69.23	58.46
	527	65.79	61.30	64.30	59.58
	536	69.50	56.69	69.05	56.12
	542	67.33	57.93	67.35	58.10
	546	65.00	66.62	64.33	65.79
	548	62.43	56.21	61.10	54.55
	550	63.65	58.94	63.14	58.31
	Mean	66.26	58.76	65.57	57.89

TABLE 22

INDIVIDUAL APPARENT DIGESTIBILITY COEFFICIENTS FOR CRUDE PROTEIN AND CELL WALL CONSTITUENTS BY CHROMIC OXIDE AND ACID DETERGENT LIGNIN FOR CALVES IN EXPERIMENT I

Ration	Animal	Apparent Digestibility Coefficients			
		Crude Protein		Cell Wall Constituents	
		Cr_2O_3	ADL	Cr_2O_3	ADL
		%			
1	521	67.54	62.48	48.45	40.43
	523	67.69	64.54	43.83	38.49
	525	71.27	63.00	48.67	33.84
	528	73.49	70.97	42.19	36.72
	532	69.70	61.86	52.94	40.79
	538	68.79	66.43	42.28	37.92
	543	67.85	64.23	41.62	34.98
	544	69.03	63.94	43.33	34.01
	547	66.64	64.63	45.58	42.33
	553	61.79	61.86	37.46	36.95
	Mean	68.38	64.39	44.64	37.65
2	520	71.62	55.25	46.66	15.36
	522	73.17	59.49	50.70	25.61
	524	65.97	53.28	40.39	18.21
	529	68.60	63.11	32.10	20.29
	531	70.31	63.13	42.62	28.80
	537	73.66	62.44	49.42	27.82
	540	67.28	64.58	36.93	31.66
	541	70.06	57.70	44.66	21.89
	545	70.73	59.47	39.06	15.58
	549	63.22	53.22	46.16	31.63
	Mean	69.46	59.17	42.87	23.69
3	518	69.06	57.01	37.33	14.17
	519	67.34	58.85	37.89	21.82
	526	71.92	62.15	46.81	28.40
	527	68.61	64.45	33.94	25.28
	536	70.41	57.96	46.87	24.54
	542	68.03	58.84	40.71	23.65
	546	64.35	66.05	35.15	38.15
	548	62.96	56.84	29.18	17.47
	550	65.73	61.26	33.99	25.41
	Mean	67.50	60.45	37.99	24.32

TABLE 23

INDIVIDUAL APPARENT DIGESTIBILITY COEFFICIENTS FOR ACID DETERGENT FIBER AND ACID DETERGENT LIGNIN BY CHROMIC OXIDE AND ACID DETERGENT LIGNIN FOR CALVES IN EXPERIMENT I

Ration	Animal	Apparent Digestibility Coefficients		
		Acid Detergent Fiber		Acid Detergent Lignin
		Cr_2O_3	ADL	Cr_2O_3
		%		
1	521	51.57	44.02	13.19
	523	48.54	43.62	8.64
	525	51.65	37.64	22.04
	528	43.61	38.29	8.62
	532	54.51	42.76	20.47
	538	48.11	44.19	7.00
	543	45.76	39.56	10.21
	544	49.05	40.68	14.17
	547	47.37	44.23	5.65
	553	41.00	40.53	0.80
	Mean	48.12	41.55	11.08
2	520	47.85	17.23	37.05
	522	48.65	22.57	33.65
	524	39.53	17.04	27.01
	529	36.57	25.53	14.85
	531	38.65	23.88	19.24
	537	47.62	25.26	29.86
	540	32.80	27.17	7.62
	541	42.81	19.23	29.10
	545	38.83	15.25	27.72
	549	42.38	26.88	21.18
	Mean	41.57	22.00	24.73
3	518	42.13	20.75	26.86
	519	42.40	27.53	20.54
	526	47.51	29.33	25.78
	527	34.22	25.60	11.61
	536	48.04	26.20	29.44
	542	43.61	27.35	22.42
	546	35.36	38.35	-4.73
	548	34.37	23.50	14.33
	550	37.58	29.44	11.43
	Mean	40.58	27.56	17.52

TABLE 24

INDIVIDUAL DRY MATTER INTAKE, BODY WEIGHT, AND AVERAGE DAILY GAIN FOR HEIFERS IN EXPERIMENT II

Ration	Animal	Dry Matter Intake (lbs/day)	Body Weight (lbs)	Average Daily Gain (lbs/day)
2	467	17.71	759	2.71
	471	21.00	710	3.43
	479	19.04	715	1.43
	476	20.27	601	1.29
	478	17.53	655	1.71
	485	17.01	606	1.57
	490	16.72	605	0.86
	497	14.86	621	3.57
	502	16.37	573	3.57
	Mean	17.83	649	2.24
3	464	18.27	726	2.14
	469	17.70	749	4.71
	473	16.84	664	1.43
	474	18.65	665	1.29
	468	14.44	582	1.57
	486	15.55	615	2.71
	487	18.24	620	2.00
	498	17.44	635	1.86
	481	12.38	530	1.43
	501	14.89	587	1.71
	Mean	16.44	637	2.09
4	465	15.15	686	5.57
	466	16.69	730	2.14
	472	13.61	586	4.71
	475	13.61	586	4.71
	482	13.12	590	0.71
	483	15.65	650	1.00
	484	14.06	602	2.57
	491	12.76	539	3.00
	492	13.46	598	2.43
	499	13.49	529	2.43
	Mean	14.46	616	2.96

TABLE 25

INDIVIDUAL APPARENT DIGESTIBILITY COEFFICIENTS FOR DRY MATTER AND GROSS ENERGY DETERMINED BY CHROMIC OXIDE AND ACID DETERGENT LIGNIN FOR HEIFERS IN EXPERIMENT II

Ration	Animal	Apparent Digestibility Coefficients			
		Dry Matter		Gross Energy	
		Cr_2O_3	ADL	Cr_2O_3	ADL
		%			
2	467	65.52	63.63	64.21	62.41
	471	67.45	59.30	67.17	58.85
	479	72.13	59.49	71.88	59.08
	476	73.01	62.56	71.77	60.73
	478	68.45	64.26	67.95	63.72
	485	64.81	64.93	62.11	62.30
	490	70.08	62.02	68.63	60.27
	497	69.02	65.83	68.33	65.08
	502	65.39	60.14	64.10	58.78
	Mean	68.43	62.46	67.35	61.25
3	464	64.21	65.46	66.61	67.88
	469	66.70	61.01	66.96	61.31
	473	61.49	65.40	62.90	66.67
	474	69.13	62.24	69.27	62.46
	468	64.32	68.09	64.52	68.20
	486	58.51	63.86	57.81	63.29
	487	65.09	60.45	64.86	60.14
	498	68.70	59.89	67.25	58.10
	481	60.39	60.68	61.76	62.02
	501	67.86	67.31	67.08	66.46
	Mean	64.64	63.44	64.90	63.65
4	465	66.53	68.53	66.51	68.58
	466	67.03	68.03	67.25	68.41
	472	68.48	63.61	69.05	64.29
	475	69.84	63.66	69.48	63.34
	482	61.91	60.32	67.76	66.50
	483	67.80	64.30	68.18	64.72
	484	67.30	63.94	66.82	63.43
	491	64.49	61.89	65.55	62.98
	492	65.43	58.78	69.39	63.27
	499	65.39	47.03	67.80	50.85
	Mean	66.42	62.01	67.78	63.64

TABLE 26

INDIVIDUAL APPARENT DIGESTIBILITY COEFFICIENTS FOR CRUDE PROTEIN AND CELL WALL CONSTITUENTS BY CHROMIC OXIDE AND ACID DETERGENT LIGNIN FOR HEIFERS IN EXPERIMENT II

Ration	Animal	Apparent Digestibility Coefficients			
		Crude Protein		Cell Wall Constituents	
		Cr_2O_3	ADL	Cr_2O_3	ADL
		%			
2	467	70.69	69.06	45.78	42.79
	471	69.89	62.38	48.70	46.47
	479	77.67	67.52	55.99	36.02
	476	75.49	66.00	58.64	42.61
	478	69.56	65.51	52.95	46.71
	485	69.39	69.50	44.07	44.25
	490	71.04	63.25	53.50	40.98
	497	71.08	68.13	54.02	49.29
	502	72.68	68.52	45.44	37.16
	Mean	71.94	66.65	51.01	42.92
3	464	72.58	73.52	34.20	36.48
	469	74.58	70.25	39.20	28.82
	473	73.92	76.59	22.67	30.54
	474	76.38	71.11	41.99	29.04
	468	73.47	76.29	31.77	38.95
	486	70.16	73.99	19.77	30.09
	487	73.25	69.65	34.61	25.90
	498	75.43	68.48	40.16	23.35
	481	69.65	69.90	23.83	24.41
	501	73.61	73.13	40.53	39.51
	Mean	73.30	72.29	32.87	30.71
4	465	70.42	72.20	32.76	36.81
	466	73.45	74.27	27.29	29.50
	472	73.96	69.91	32.25	21.79
	475	74.94	69.82	35.54	22.34
	482	75.24	74.23	12.65	9.00
	483	74.26	71.46	28.05	20.24
	484	73.96	71.30	27.00	19.52
	491	70.98	68.80	20.66	14.86
	492	71.88	66.55	23.84	11.73
	499	73.58	59.60	24.38	-15.73
	Mean	73.27	69.81	26.44	17.01

TABLE 27

INDIVIDUAL APPARENT DIGESTIBILITY COEFFICIENTS FOR ACID DETERGENT FIBER AND ACID DETERGENT LIGNIN BY CHROMIC OXIDE AND ACID DETERGENT LIGNIN FOR HEIFERS IN EXPERIMENT II

Ration	Animal	Apparent Digestibility Coefficients		
		Acid Detergent Fiber		Acid Detergent Lignin
		Cr_2O_3	ADL	Cr_2O_3
		%		
2	467	42.00	38.82	5.18
	471	45.61	31.97	20.04
	479	54.24	30.07	31.28
	476	55.76	38.62	27.92
	478	48.32	41.46	11.74
	485	40.95	41.15	-0.27
	490	50.62	37.42	21.25
	497	47.38	41.99	9.24
	502	43.03	34.36	13.28
	Mean	47.55	37.32	15.52
3	464	16.36	34.21	-3.48
	469	38.59	28.08	14.62
	473	24.15	31.84	-11.36
	474	41.64	28.62	18.30
	468	33.19	40.25	-11.73
	486	16.80	27.52	-14.77
	487	36.27	27.79	11.73
	498	40.12	23.26	22.01
	481	25.27	25.83	-0.86
	501	39.68	38.64	1.71
	Mean	31.21	30.60	2.62
4	465	33.09	37.10	-6.32
	466	28.48	30.65	-3.19
	472	33.62	23.34	13.36
	475	38.95	26.43	17.04
	482	5.57	1.63	4.23
	483	31.65	24.24	9.85
	484	27.34	19.86	9.25
	491	21.74	15.99	6.80
	492	22.25	7.24	16.04
	499	25.03	-14.88	34.78
	Mean	26.77	17.16	10.18

TABLE 28

INDIVIDUAL RUMEN pH AND BLOOD GLUCOSE VALUES
FOR HEIFERS IN EXPERIMENT II

Ration	Animal	Rumen pH	Blood Glucose (mg/100 ml)
2	467	7.63	47.82
	471	7.54	49.03
	479	7.59	60.40
	476	7.46	87.29
	478	7.55	58.66
	485	7.53	65.86
	490	7.49	55.46
	497	7.58	79.96
	502	7.55	57.67
	Mean	7.55	62.46
3	464	7.39	63.38
	469	7.20	64.55
	473	7.23	52.04
	474	7.22	55.92
	468	7.23	76.70
	486	7.15	61.68
	487	7.10	69.93
	498	7.17	43.06
	481	7.14	49.20
	501	7.02	45.09
	Mean	7.19	58.16
4	465	7.55	86.71
	466	7.59	39.78
	472	7.54	49.90
	475	7.50	56.67
	482	7.47	56.67
	483	7.57	62.98
	484	7.51	43.40
	491	7.36	60.70
	492	7.44	56.71
	499	7.39	60.68
	Mean	7.49	57.42

TABLE 29

INDIVIDUAL DRY MATTER INTAKE, BODY WEIGHT AND AVERAGE DAILY GAIN FOR COWS IN EXPERIMENT III

Ration	Animal	Dry Matter Intake (lbs/day)	Body Weight (lbs)	Average Daily Gain (lbs/day)
3	404	26.03	1117	3.79
	64	14.96	1259	1.43
	419	22.83	1151	2.93
	364	24.47	1260	3.21
	432	21.64	1160	1.21
	T270	22.21	935	1.00
	T257	15.90	1036	0.00
	T256	19.80	1014	1.43
	Mean	20.98	1117	1.88
4	380	28.52	1496	1.64
	435	21.54	1129	-0.43
	441	26.55	1012	2.93
	390	23.33	1375	2.50
	353	19.17	1258	1.00
	T264	11.82	922	2.21
	T233	21.93	1026	1.79
	T282	18.24	899	1.43
	Mean	21.39	1140	1.63
5	422	27.55	1146	4.14
	399	23.18	1342	1.36
	126	23.17	1417	0.57
	436	23.85	1194	2.64
	366	28.00	1484	5.79
	T281	20.81	852	1.00
	T259	14.84	928	3.00
	T271	15.07	835	-1.14
	Mean	22.06	1150	2.17

TABLE 30

INDIVIDUAL APPARENT DIGESTIBILITY COEFFICIENTS FOR DRY MATTER AND GROSS ENERGY DETERMINED BY CHROMIC OXIDE AND ACID DETERGENT LIGNIN FOR COWS IN EXPERIMENT III

Ration	Animal	Apparent Digestibility Coefficients			
		Dry Matter		Gross Energy	
		Cr_2O_3	ADL	Cr_2O_3	ADL
		%			
3	404	52.57	60.58	53.67	61.56
	64	19.52	59.18	20.69	59.70
	419	31.57	61.84	32.05	62.03
	364	39.15	58.34	42.93	58.43
	432	25.88	60.37	25.94	60.48
	T270	30.78	58.62	31.08	58.71
	T257	3.93	59.54	6.56	60.63
	T256	27.78	60.59	28.40	60.84
	Mean	28.90	59.88	30.17	60.30
4	380	42.94	66.70	43.93	67.24
	435	40.56	68.61	42.03	69.34
	441	51.98	62.94	52.05	63.07
	390	55.48	75.17	57.18	75.72
	353	46.76	71.20	47.59	71.70
	T264	35.81	71.19	35.77	71.27
	T233	62.37	66.89	63.30	67.73
	T282	8.34	68.47	10.39	69.16
	Mean	43.03	68.89	44.03	69.40
5	422	48.28	68.42	48.62	68.62
	399	57.03	71.55	57.45	71.85
	126	50.34	76.52	51.90	77.34
	436	41.93	78.51	42.91	78.80
	366	46.62	76.54	48.83	55.01
	T281	36.47	66.50	34.16	65.25
	T259	35.97	76.40	38.46	77.38
	T271	-18.74	73.57	-15.50	74.42
	Mean	37.24	73.50	38.36	71.08

TABLE 31

INDIVIDUAL APPARENT DIGESTIBILITY COEFFICIENTS FOR CRUDE PROTEIN AND CELL WALL CONSTITUENTS BY CHROMIC OXIDE AND ACID DETERGENT LIGNIN FOR COWS IN EXPERIMENT III

Ration	Animal	Apparent Digestibility Coefficients			
		Crude Protein		Cell Wall Constituents	
		Cr_2O_3	ADL	Cr_2O_3	ADL
		%			
3	404	67.88	73.32	20.14	33.61
	64	35.99	67.49	-31.13	33.49
	419	50.17	72.22	12.00	37.55
	364	51.43	66.75	3.63	34.02
	432	51.60	74.10	-27.33	31.91
	T270	49.58	69.87	-10.36	34.03
	T257	32.87	71.72	-50.84	36.47
	T256	54.00	74.90	-18.76	35.19
	Mean	49.19	71.30	-12.83	34.53
4	380	52.20	72.11	-14.02	33.45
	435	44.67	70.76	9.31	42.28
	441	61.78	73.23	6.79	28.82
	390	67.98	82.03	0.70	43.70
	353	57.06	76.76	-5.93	42.71
	T264	35.83	71.17	-11.36	50.04
	T233	69.38	73.04	27.12	35.87
	T282	19.42	72.29	-78.62	38.55
	Mean	51.04	73.92	-10.58	39.43
5	422	56.35	73.35	-11.40	31.97
	399	59.02	72.90	6.69	38.23
	126	63.68	82.82	-16.54	44.88
	436	57.56	84.28	-46.60	45.75
	366	62.49	83.50	-31.36	42.26
	T281	42.57	69.69	-33.65	29.53
	T259	46.74	80.39	-49.07	45.04
	T271	-11.60	75.21	-156.41	42.95
	Mean	47.10	77.77	-42.29	40.08

TABLE 32

INDIVIDUAL APPARENT DIGESTIBILITY COEFFICIENTS FOR ACID DETERGENT FIBER AND ACID DETERGENT LIGNIN BY CHROMIC OXIDE AND ACID DETERGENT LIGNIN AND RUMEN pH FOR COWS IN EXPERIMENT III

Ration	Animal	Apparent Digestibility Coefficients			Rumen pH
		Acid Detergent Fiber		Acid Detergent Lignin	
		Cr_2O_3	ADL	Cr_2O_3	
		%			
3	404	16.10	30.25	-20.35	5.20
	64	-34.69	31.71	-97.31	5.80
	419	-18.80	33.76	-79.16	6.91
	364	-2.24	30.12	-46.03	5.30
	432	-34.32	28.19	-87.02	5.70
	T270	-14.12	31.79	-67.18	5.65
	T257	-60.34	32.48	-137.15	5.05
	T256	-27.75	30.31	-83.43	5.30
	Mean	-22.02	31.08	-77.20	5.61
4	380	-11.89	34.68	-71.27	5.20
	435	-12.53	40.58	-89.39	6.70
	441	5.50	27.06	-29.50	5.20
	390	-3.39	41.40	-76.31	6.85
	353	-11.80	39.54	-85.08	5.30
	T264	-16.16	47.88	-122.91	5.90
	T233	25.03	34.04	-13.64	6.74
	T282	-72.97	40.50	-190.34	6.00
	Mean	-12.28	38.21	-84.80	5.99
5	422	-8.38	33.83	-63.87	5.40
	399	16.73	37.18	-50.76	5.10
	126	-23.03	41.83	-111.02	5.65
	436	-54.70	42.77	-170.38	5.60
	366	-35.96	40.25	-127.29	6.73
	T281	-26.82	33.14	-89.95	4.90
	T259	-54.29	43.10	-171.04	4.90
	T271	-165.12	41.02	-350.33	5.90
	Mean	-43.95	39.14	-141.83	5.52

TABLE 33

INDIVIDUAL MILK PRODUCTION, MILK FAT PERCENT, AND FAT-CORRECTED-MILK PRODUCTION FOR COWS IN EXPERIMENT III
STANDARDIZATION PERIOD

Ration	Animal	Actual Milk (lbs/day)	Milk Fat (%)	FCM (lbs/day)
3	404	47.70	3.85	46.56
	64	50.57	2.63	40.34
	419	43.62	3.45	39.95
	364	40.34	3.30	36.41
	432	36.90	3.15	32.47
	T270	35.53	6.13	46.99
	T257	39.61	5.15	46.49
	T256	27.81	5.38	33.69
	Mean	40.26	4.13	40.36
4	380	50.86	2.88	42.45
	435	43.26	3.50	40.34
	441	42.92	3.23	38.11
	390	32.21	4.58	35.09
	353	33.54	3.25	29.77
	T264	37.83	7.00	55.05
	T233	36.16	5.38	43.79
	T282	32.64	5.10	38.02
	Mean	38.68	4.37	40.33
5	422	45.10	3.45	41.72
	399	48.74	2.98	41.56
	126	40.66	3.45	37.26
	436	40.73	2.75	33.41
	366	29.58	3.50	27.37
	T281	45.94	5.68	57.46
	T259	29.51	6.45	40.32
	T271	27.76	6.75	39.26
	Mean	38.50	4.38	39.80

TABLE 34

INDIVIDUAL MILK PRODUCTION, MILK FAT PERCENT, AND FAT-CORRECTED-MILK PRODUCTION FOR COWS IN EXPERIMENT III
EXPERIMENTAL PERIOD

Ration	Animal	Actual Milk (lbs/day)	Milk Fat (%)	FCM (lbs/day)
3	404	48.50	2.50	37.57
	64	33.83	1.54	21.54
	419	39.63	2.02	28.00
	364	36.50	2.09	26.12
	432	33.68	2.17	24.65
	T270	34.48	5.83	43.98
	T257	34.27	3.49	31.81
	T256	27.34	4.34	28.75
	Mean	36.03	3.00	30.30
4	380	49.36	1.88	29.77
	435	37.57	3.02	32.05
	441	36.40	1.97	21.69
	390	23.83	2.91	20.34
	353	24.48	2.13	17.64
	T264	21.59	5.33	26.10
	T233	29.90	4.05	30.16
	T282	25.64	4.18	26.58
	Mean	31.10	3.18	25.54
5	422	43.76	2.27	32.24
	399	43.76	1.98	30.67
	126	33.16	2.03	23.63
	436	37.01	1.93	25.55
	366	22.37	1.96	15.70
	T281	44.35	3.28	39.59
	T259	18.98	4.92	21.64
	T271	19.49	5.68	24.38
	Mean	32.86	3.01	26.68

VITA

Robert Lane Cowsert was born October 15, 1944, at Martin, Tennessee. He was reared on a dairy farm in the rural area of Martin where he attended Martin public schools. After graduation from Martin High School in May, 1962, he attended The University of Tennessee at Martin and graduated in June, 1966, with a Bachelor of Science degree in General Agriculture. While at the University of Tennessee at Martin, he was selected for membership in Pi Sigma Phi and Who's Who in American Colleges and Universities.

He came to The University of Tennessee in September, 1966, on an NDEA Fellowship. He received the Master of Science degree in Dairying in June, 1968. He continued graduate studies at The University of Tennessee, working toward the Doctor of Philosophy degree with a major in Animal Science. Since August, 1969, he has been working toward this degree as a research assistant.

He is a member of the American Dairy Science Association, Alpha Zeta, Gamma Sigma Delta, and Phi Kappa Phi.

His wife, Robbie Rawls Cowsert, and he were married in June, 1965, and they now have a daughter, Lisa Elaine, who was born January 3, 1967.