THE EFFECT OF DIETARY FIBER AND BODY CONDITION ON THE MILK PRODUCTION, DRY MATTER INTAKE AND BLOOD METABOLITES OF PERIPARTUM DAIRY COWS

By

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ABSTRACT

THE EFFECT OF DIETARY FIBER AND BODY CONDITION ON THE MILK PRODUCTION, DRY MATTER INTAKE AND BLOOD METABOLITES OF PERIPARTUM DAIRY COWS

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The effects of three different levels of ration ADF and body condition on dry matter intake and milk production in peripartum cows were evaluated. Thirty cows from two experimental herds were blocked by location, parity, expected calving date and balanced for body condition (multiparous=18; primiparous=12). Cows were body condition scored and were labeled thin (score <= 2.5) or fat (score > 2.5) on a scale of 1-5. Blood metabolites were also measured. Cows were placed on experiment three weeks before expected calving date and fed the herd dry cow ration. On day of parturition cows were abruptly changed to experimental diets which were fed for the next 11 weeks. Actual ration fiber levels were 17.4, 20.2 and 22.8% ADF and 33.4, 36.2 and 38.2% NDF respectively.

Prepartum fat cows tended to eat more, weighed more, gained more weight, had higher plasma insulin concentrations and had lower ratios of ß-hydroxybutryic acid (BHBA):acetoacetic acid (ACAC) than did thin cows. Primiparous cows weighed less and ate less than the

multiparous cows both before and after parturition. Postpartum cows fed 17% ADF ration produced more milk than those fed 23% ADF. Milk components were unaffected by either ration or body condition. Dry matter intake as a percentage of body weight tended to be higher for cows fed 17% ADF than 23%. NDF consumed was not different among treatments. ADF intake, however, tended to be lower for 17% ADF than 23% ADF ration on a percent of body weight basis. Correlation of ration NDF with dry matter intake was -.09 and ADF was -.15. Body condition had no effect on any intake parameter. Plasma insulin concentrations were not different between thin and fat cows, although primiparous cows tended to have higher insulin concentration along with significantly higher plasma glucose and lower NEFA. Plasma levels of NEFA and ratio of ketones were unaffected by ration or body condition. Cows fed rations with 17% and 20% ADF had significantly lower levels of BHBA than did those fed 24% ADF. Severity and duration of negative energy balance were not affected by ration or body condition.

Under the conditions imposed by this experiment, neither ration fiber level nor body condition had a significant impact on dry matter intake. It is concluded that in early lactation, the hormonal drive for milk production dominates the effects of ration and body condition on dry matter intake.

DEDICATION

Robert D. McCarthy

(1933-1987)

Judith C. Patton

Because they never gave up on me.

The dairy farmers of Michigan, New York and Pennsylvania

Because they have taught me much.

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REVIEW OF LITERATURE

The peripartum dairy cow is unable to satisfy her energy requirements from the diet (Coppock, 1985). This condition occurs for three reasons: (1) milk flow is increasing rapidly up to a point of 5-8 weeks post partum; (2) maximum dry matter intake is not reached until 3-4 weeks after peak milk production; (3) there is a maximum energy density that the cow can consume without digestive upset (Wangesness and Muller, 1981). This implies that during the early stages of lactation the dairy cow is in negative energy balance with resultant loss of adipose and protein tissue (Emery, 1988). Because there is some health risk and may be some production loss associated with this situation, it is desirable to increase dry matter intake to the maximum level as soon as possible after parturition to mitigate the period of negative energy balance.

The peripartum dairy cow can only obtain the additional nutrients required for high milk production in one of four ways: (1) increase the amount of feed consumed; (2) mobilize storage depots of fat and protein; (3) increase the rate of digestion and (4) increase the rate of passage from the rumen.

The feed that a cow consumes depends on a complex balance of the physical characteristics of the animal, the environment in which she is placed, the characteristics of the diet and the hormonal status of the cow (Forbes, 1986).

General Considerations

The dry matter that a dairy cow consumes is related to her energy needs (Conrad, 1966). As in other species, it is assumed that the cow eats to satisfy her energy requirements and maintain an energy reserve (Baile, 1975). Thus, a cow that requires more energy will consume more kilograms of feed in an attempt to increase caloric intake. When the caloric density of the ration is reduced on a dry matter basis, the cow must consume more dry matter to obtain the same amount of calories (Dinius and Baumgardt, 1970). When energy demands are only for maintenance and low milk production, the relationship between feed consumption and energy expenditure holds adequately. The dairy cow may not follow this relationship as closely as other species as evidenced by the "fat cow syndrome" condition (Forbes, 1986). In this case, the cow has consumed energy far in excess of her metabolic need.

It has been demonstrated that even at maintenance, as the caloric density of the diet increases, dry matter intake also increases (Forbes, 1986). These increases seem to occur until the animal reaches a new "set point" or degree of fattening. When this new set point is reached, energy intake returns to previous normal levels (Cohn and Joseph, 1962).

In the high producing cow, the increase in feed intake continues until the caloric density approaches 1.75 MCal/ kg of ration dry matter. At this point dry matter intake is also reduced (Wangesness and Muller, 1981). Although this result is expected for cattle at maintenance or at low levels of production because their energy needs have been met, this same phenomena occurs in high producing cows who are still energy deficient.

The total energy that the cow consumes is a function of both the energy density of the diet and the amount of dry matter that she eats. However, the amount of energy that the cow actually utilizes is a function not only of the feed consumed but also a function of the proportion of the diet that is digestible, of the rate of digestion and of the digestibility depression caused by increased dry matter intake (Mertens, 1987). If intake is increased a digestibility decrease is observed (Conrad et al., 1964) while if intake is restricted digestibility increases (Staples et al., 1984). Conversely, Robinson et al. (1987a,b) found a "protective mechanism" that allowed high producing cows (i.e., those cows with higher dry matter intake) to increase their rate of ruminal cell wall digestion as intake and rate of passage increased. Obviously, these differences in observations due to increased intake cannot be explained; the observations of Robinson et al need to be replicated.

There is considerable disagreement among nutritionists about which dietary factors are most important in controlling feed intake. It is generally assumed that in the high producing cow, rumen fill will limit intake before chemostatic mechanisms (Fisher et al., 1987).

Dietary Effects on Feed Intake

In terms of practical dairy cattle diets, energy will be diluted by the fiber content of the diet (Mertens, 1982). It is well appreciated that the dairy cow has a fiber requirement (Van Soest and Mertens, 1984). It is also believed that a minimum fiber requirement for a given physiological state is also the optimum fiber requirement in terms of promoting a rumen environment that maximizes digestion of dietary components, that encourages maximum microbial protein synthesis and that supplies the optimum amounts of volatile fatty acids and amino acids to the animal. This optimum level may change with the productive state of the cows (Wangesness and Muller, 1981).

The feed that a ruminant consumes has been divided into various components as a means of describing them nutritionally. The system of Van Soest (1982) has gained widest acceptance. Using this system, feed components are classified by their relationship to their role in the plant cell. The carbohydrate portion of the feeds may be classified as either structural (cell wall) or nonstructural (starches and sugars). Nonstructual

carbohydrates are relatively soluble and are digested relatively quickly in the rumen. Structural carbohydrates are more slowly digested and take up space in the rumen for longer periods of time. Cell walls are further classified into their main components: pectin, hemicellulose, cellulose and lignin. Neutral detergent fiber (NDF) is a measure of total cell wall except for pectin which is removed in neutral detergent solution. Acid detergent fiber (ADF) is a measure of cellulose and lignin. Neutral detergent fiber is a better measure of the total fiber content of the diet than is ADF.

In general, legumes will contain more lignin and less hemicellulose than will grasses at the same maturity (Smith et al., 1972). As plants mature, lignin content increases more rapidly in legumes and hemicellulose content increases to greater amounts in grasses (Smith et al., 1971). As a percent of dry matter, all cell wall constituents increase as forage plants mature. With increasing maturity, the percentage of the plant that is indigestible increases. This increase is probably related to increased lignification (Waldo et al., 1972). Higher levels of lignin appear both to increase the time required for bacterial attachment and to protect potentially digestible cellulose and hemicellulose from bacterial enzymes (Varel and Jung, 1986). Increased lignification does not appear to change the rate of digestion of digestible cellulose (Smith et al., 1972).

If the definitions of the feed fiber fractions are well established, their significance to the physiology of digestion is less well established. Conrad et al. (1964), the Baumgardt group (Montgomery and Baumgardt, 1965; Dinius and Baumgardt, 1972) and Mertens (1982) have all presented data indicating that the fiber content of the forage is related to the dry matter intake. This relationship is quadratic, implying that there is an optimum fiber intake at an intermediate level. Conrad (1966) and Orskov et al (1988) proposed that the potentially digestible dry matter content of the diet was highly correlated with dry matter intake explaining about 50% of the variation on different diets. Orskov et al (1988) were able to predict the dry matter intake of straws from 48-hour in vitro digestibilities. Smith et al (1972) had earlier established that digestibility of alfalfa could be predicted from 48-hr in vitro incubations, but that digestibility of grass hay was better predicted by 72 hr in vitro incubations. Mertens (1982) found dry matter intake highly correlated with the neutral detergent fiber (NDF) content across various forages while ADF was less well correlated. Mertens (1981) has also suggested that ADF is more closely related to the energy content of the diet than is NDF. Feed energy is usually predicted by ADF content (NRC, 1988). Calculations of Conrad et al. (1984), however, indicate that lignified NDF content is a better measure of feed energy.

Briceno et al. (1987) compiling data from various experiments argued that NDF content of the diet was not an accurate predictor of intake across various forages. However, this experiment may be criticized because NDF was estimated rather than measured on each diet. Body size and milk production explained the major differences in intake on their experiments. Allen and Mertens (1988b) found a relationship between NDF and intake in cows producing 18 kg but not in those producing 32 kg. Van Soest (1982) has suggested that the ADF content of the diet may reflect the build up of indigestible portions of the diet and that this may limit intake. The rate at which indigestible portions of feed leave the rumen is a major determinant of feed intake (Mertens and Ely, 1979.). Using sheep, Hogue (1987) demonstrated that the indigestible NDF was an accurate predictor of dry matter intake whereas NDF itself was not. Patton et al (1988) suggested that NDF would be a measure of the bulkiness of the current meal and ADF would better reflect the bulkiness of previously ingested, partially digested meals. Therefore, both of these measures should be better predictors of intake than either one alone. With cows fed high levels of by product feeds and producing at low levels, ADF was a more accurate predictor of feed intake than NDF (MacGregor et al., 1976). The use of either NDF or ADF as an indicator of potential feed intake is therefore not conclusively established.

Deswysen and Ellis (1988) using crossbred cattle fed ad libitum corn silage with measured amounts of protein supplement, measured the extent of NDF digestion in various areas of the rumen and the total digestive tract, and attempted to correlate it to voluntary dry matter intake. In these experiments, there were strong negative correlations between extent of NDF digestion in the ventral rumen and in the duodenum and voluntary feed intake. Total tract NDF digestion, however, was not related to feed intake. They suggested that the end products of fiber digestion rather than the fill properties of NDF may be limiting intake. However, these animals were essentially at maintenance and dry matter intake should have been limited by the energy intake of the animals rather than by rumen fill.

Feed intake in the previous experiments was most highly, and most negatively, correlated with the grams of NDF that flowed through the omasal orifice. Because they detected no differences in total tract NDF digestion with different levels of dry matter intake, in spite of the fact that higher levels of intake resulted in greater ruminal outflow of potentially digestible NDF, these authors suggested that if potentially digestible NDF left the rumen, it would be digested post ruminally. This has also been suggested by other authors (Robinson et. al. 1987,a,b).

In addition to the fiber content of the diet, other ration factors known to influence feed intake are the rate and extent of digestion (Allen and Mertens, 1988a) and the rate at which particles are broken down to a size that has potential to escape the rumen (Trolsen and Campbell, 1968). These factors are interrelated and perhaps are confounded. Feed particles must reach a size smaller than 4 mm before they are able to pass from the rumen (Cardoza and Mertens, 1969).

Reducing particle size of forage is known to increase DMI (Baumgardt, 1970). Grinding alfalfa hay increased rate of digestion (Dehority and Johnson, 1961), but grinding did not have the same effect on orchardgrass hay (Robles et al., 1980). Woodford and Murphy (1988a,b), feeding higher producing cows, found dry matter intake depressed when feed particle size was reduced. Reducing the size of alfalfa silage by rechopping, however, had no effect on dry matter intake (Armentano et al, 1988). Rodrigue and Allen (1960) showed that grinding of forage increased the extent of digestion *in vitro* but decreased digestion *in vivo* because of greater rates of passage from the rumen.

It is assumed when modeling rumen function that the faster feed particles are reduced to a size that can escape the rumen, the faster would be the rate at which the rumen would empty (Mertens, 1987). Therefore, there would be space in the rumen for ingestion of more feed. Size reduction of feed particles is a function of initial

particle size (Ellis et al.,1987), chewing time and sheer force (Latham et al., 1978) as well as rumination time (Welch, 1982). Rumination has been shown to have the greatest effect on the reduction of particle size and therefore would probably have a large effect on feed intake (Welch, 1982).

Ruminating time, total chewing time, number of boluses ruminated per day and total rumen contractions have all been shown to influence the rate of ruminal digestion. These factors therefore, may have an influence on the potential feed intake in cattle (Woodford et al, 1986). Total rumination time and total chewing time are positively related to the amount of NDF consumed (Welch and Smith, 1970). Rumination time and total chews per gram of ingested NDF, however, is reduced as NDF consumption increases. Chewing, besides providing more saliva and a better rumen environment, may increase the rate of digestion by reducing the lag time for bacterial attachment (Galyean and Owens, 1988).

Feed particles that pass through the same size screen will have different shapes (Emanuele and Staples, 1988). Legume feed particles tend to shatter in shapes that are of shorter lengths than grasses, although diameters will be approximately equal. The leaves of legumes will display a more rectangular pattern of shatter than will the stems. Within a species the smaller the feed particles the greater

will be the rate of *in vitro* digestion. Ehle (1984) was able to show that differences in digestion may be confounded by preferential sorting of leaf tissue into smaller size fractions. However, Ehle et al (1982) using protein feed particles and Cherney et al (1988) using grass stem internodes, were unable to show consistent effects of particle size on rate of digestion. Ellis et al (1987) also found that rate of digestion was not related to particle size, but lag time was related.

Dutch workers (Kwakkel et al, 1986) using the *in sacco* technique found that rates of NDF digestion were not different between grass silage and alfalfa silage but was 50% less for corn silage. Extent of digestion was least for alfalfa silage probably because of a large lignin component although the feed intake of steers was 20% greater for the alfalfa silage. Intakes of the grass silage and corn silage were not significantly different from each other. These observations led these workers to the conclusion that the cell wall geometry may have a greater affect on rate of digestion and intake than did the amount of cell wall present in the feeds. Crude protein levels in the diets and forage maturity differences may have confounded these studies, however.

If dry matter intake was held constant, Korver (1984) found that there was no difference between extent of NDF digestion for NDF that is digestible among forages. The similarity in rate of NDF digestion between different

forages was also shown by Jones et al (1988) using orchardgrass and bermudagrass hays, although the dry matter intake in this case was significantly greater for the forage with the lower NDF value. These studies demonstrate that the intrinsic nature of the fiber fraction may have a great influence on its digestibility and hence its potential intake.

Differences in level of intake (alfalfa greater than grasses), rate of digestion (alfalfa greater than grasses) and extent of digestion (alfalfa less than grasses) have often been reported. But these studies generally failed to standardize either the maturity, fiber content of the forage or the particle size. From the previous discussions, it is apparent that failure to standardize these effects could severely magnify the intrinsic differences in intake potential between grasses and legumes.

French workers have proposed a fill unit system for use in predicting the voluntary feed intake of ruminants (Jarrige et al. 1986). In this system all forages are compared to a reference grass pasture which is arbitrarily given a fill unit (FU) value of 1. Each forage is assumed to have an intrinsic fill value. Voluntary feed intake is then predicted in terms of fill units. Application of this system to practical diets is largely untried. However, it would be expected that ruminal conditions and the metabolic

status of the animals would be expected to change the fill value of a given forage.

Similar to using NDF, the intrinsic simplicity of the system has great appeal. However, even the authors admit it fails to account for the dynamics and differences that are commonly observed in voluntary dry matter intake.

Perhaps the major failing of all attempts to predict the voluntary feed intake is that they fail to remotely account for the dynamics of rumen fermentation and physiology. A complete recapitulation of all of these factors is beyond the scope of review. In fact, they are incompletely understood at best. Yet these interactions may so completely overshadow any effects of dietary constituents on dry matter intake, that the more important of these will be mentioned.

Cow Factors

Dry cows consume less feed than lactating cows (Emery, 1988). Larger body weight animals consume more feed than smaller animals, although growing animals consume more feed than mature animals at the same body weight (Allison, 1985).

In early lactation space within the digestive system may be limiting the amount of space available for feed. It is known that the digestive system and the liver increase in size 10% more within the first seven weeks of lactation than the size of the digestive tract in the dry period

(Barnes et al., 1986).

The physiology of the cow and her environment also affects dry matter intake. Animal factors identified as having an effect on DMI include: milk production, body size, stage of lactation, hormonal status, presence of disease, temperature, humidity, palatability of the ration and the number of times per day the ration is fed (NRC, Fox, ed., 1987). Although the importance of these factors on DMI is appreciated, a full review of them is beyond the scope of this thesis.

Neural, Hormonal and Metabolic Effects on Feed Intake

That there is neural, hormonal and metabolic control of intake in nonruminant species is not questioned (Forbes, 1988). Evidence of their role in regulating feed intake in the ruminant is more equivocal (Baile and Forbes, 1974). As in nonruminant species, electrical stimulation of the ventral-medial hypothesis will cause feeding behavior in sheep already full fed. Severing the vagus nerve of sheep will cause a cessation of eating to the point of starvation (Baile, 1975). Data have also been presented that indicate that stretch and osmolality receptors exist in the rumen wall and that stimulation of these receptors will depress feed intake. It is also well established that stimulation of the rumen wall by fibrous feedstuffs will result in increased rumination and remastication (Welch, 1982). All

of these factors argue for a large role of the neural system in the acute regulation of feed intake. Grovum (1986) has published a complete review of these factors. However, in all species and the ruminant in particular, the role of the nervous system in controlling dry matter intake has been better described than quantitated.

Hormonal regulation of metabolism is redirected in early lactation toward the production of milk as a dominant metabolic process (Bauman and Currie, 1980). Hormones have been investigated as regulators of feed intake because changing hormonal levels are associated with increasing dry matter intake in early lactation.

Ruminants experience an insulin surge after feeding (Chase et al. 1977a) suggesting a role for insulin in meal cessation. But sham fed sheep also undergo insulin release (Basset, 1975, cited by DeJong, 1986) suggesting the nervous system may play as great a role in insulin release as does nutrient supply. Propionate, ß-hydroxybutyrate and amino acids have all been shown to elicit an insulin release in ruminants (Brockman and Laarveld, 1986). Intravenous infusion of insulin will depress feed intake in sheep as will glucagon (Deetz and Wagesness, 1981). Although insulin has been shown to regulate glucose, fatty acid and ketone concentrations in ruminants (Heitman et al. 1986), the physiologic role of insulin as a feed intake regulator has been questioned (DeJong, 1987).

Glucose levels are inversely correlated with feed

intake in rats (Forbes, 1986). Blood levels of glucose, volatile fatty acids, ketones, nonesterified fatty acids and amino acids have all been studied as possible metabolic regulators of feed intake. In general the results are less than unequivocal (Chase et al., 1977a,b; Istasse et al., 1987; Sutton et al., 1988). Because of ruminal fermentation, little glucose as such is available for absorption (Baldwin, 1985) . Blood levels of glucose are low and relatively constant in the ruminant and arise almost entirely from continuous gluconeogenesis. Intravenous infusion of relatively high levels of glucose into sheep did not result in cessation of eating behavior. Physiological mechanisms allowed for the rapid clearance of glucose from the blood stream with no effects on the animals (Thye et al., 1970).

Monogastric species with lower blood sugar tend to eat more in order to maintain glucose homeostasis (Forbes, 1986). Sheep that were treated with phlorizin to increase urinary clearance of glucose experience only a short duration of lower blood glucose and no apparent effect on feeding behavior over the duration of these experiments. Apparently the animals were able to increase the rate of gluconeogenesis in order to maintain constant levels of blood glucose (Bergman, 1973).

Bovine ketosis is characterized by depressed appetite, low blood glucose and high blood ketones (Foster, 1988).

It has been suggested that high levels of blood ketones negatively affect intake overriding the effect of low blood glucose (Baird, 1982). Definitive experiments for proof of this theory are lacking although intravenous infusion of 3-hydroxy butyrate into normal dairy cows produced no decrease in dry matter consumption . Herdt et al. (1981) when studying metabolic profiles of peripartum cows were able to show a positive correlation between blood glucose and energy intake as well as an inverse relationship of blood 3-hydroxy butyrate with blood glucose. Blood free fatty acids were also negatively correlated with calculated energy intake.

Because cows in negative energy balance have elevated levels of serum bound nonesterified fatty acids, several studies have measured blood free fatty acid levels and attempted to correlate them with dry matter intake (Radloff et al., 1971) In general high levels of serum NEFA have been associated with lower feed intake although the relationship is less than perfect and no causal relationship has been demonstrated.

Because blood volatile fatty acids (VFA) rise immediately after a meal in direct response to the type and amount of feed consumed, they have also been investigated as short term regulators of feed intake in ruminants. Although acetate infused intraruminally has been shown to be a potent inhibitor of feed intake at pharmacological doses (Baile, 1975), no such inhibition occurs at

physiological doses (DeJong, 1986). Propionate infused intravenously also inhibits feeding at pharmacological doses (DeJong et al, 1981), but shows a variable response at physiological doses (Anil and Forbes, 1980). Although these experiments seem to preclude the VFA as acute regulators of feed intake, their potential role as long term regulators have not been adequately documented. This rise in blood VFA may be less important as ruminants that are not force fed show less blood VFA variation over the course of the day (Coggins and Field, 1976).

Intensive investigations with non-lactating cows over short time periods have shown no correlation between voluntary food intake and blood acetate or propionate (Bines and Morant, 1983). Blood butyrate and total blood ketones were negatively correlated with voluntary feed intake in immediate meals but were positively correlated with later meals. In these studies, blood NEFA level immediately preceding a meal was the single metabolite most positively and significantly correlated with voluntary dry matter intake. This has also been demonstrated in swine (Forbes, 1986), but is in disagreement with the data of Russel and Doney (1969) who found that blood levels of NEFA were strongly negatively correlated with the voluntary feed intake of sheep.

Belgian workers (Paquay et al., 1979) attempted to elucidate the long term regulation of feed intake of

mature, non-lactating sheep which were fed constant amounts of roughage and either grain restricted to meet maintenance requirements or grain ad libitum over a seven month period. In these experiments, the ad libitum fed sheep ate more total dry matter per day and gained more weight in the initial weeks of the experiment, but had returned to near maintenance levels by the end of the experiment. Initially blood glucose was higher, but blood ketone bodies and NEFA concentrations were lower in the sheep consuming more grain. These differences had disappeared by the end of the experimental period. Changes in the fatty acid composition of all blood lipids were noted. These alterations may represent changes due to dietary fatty acid composition rather than a role for fatty acid compositional changes in feed intake regulation, as suggested by these workers.

Daughters of sires with low production potential are known to have lower blood levels of FFA, glucose and ketone bodies as well as lower dry matter intakes than daughters of sires with higher genetic potential (Korver, 1988).

It is believed that dairy cattle that produce greater quantities of milk are in negative energy balance for longer periods of time (Coppock, 1985). It has also been suggested that dairy cows that are fatter at parturition have lower dry matter intakes but produce higher amounts of FCM (Treacher et al, 1986; Garnsworthy and Topps, 1982; Seymour and Polan, 1986; Kunz et al., 1985), although nearly identical experiments have yielded conflicting

results (Nocek et al., 1986; Boisclair et al, 1985; Garnsworthy and Gardner, 1987). The production increase of FCM is assumed to be due to more fat reserves which the animal can mobilize for milk production. The length of time spent in negative energy balance is associated with longer periods of anestrus. There is also a negative correlation between body condition at calving and days of anestrus (Butler et al.,1981). Increases in body score lower the number of days anestrus in most but not all studies. In all experiments, cows with greater body condition lost more body condition and body weight for a longer period of time during subsequent lactation. Fat cows had higher plasma NEFA levels after parturition (Reid and Roberts, 1983; Reid et al. 1986) and elevated blood ketones.

It is suggested that cows that calve in thinner condition are more energetically efficient (i.e., more of the feed energy is used directly for milk production) than those in fatter condition (Garnsworthy and Jones, 1987; Treacher et al. 1986). They may also lose less body protein (Reid et al., 1986). Beylea et al. (1986) found protein losses to be a relatively constant percent of total body tissue. Cows in fat body condition may also have more protein mass.

The disease condition known as "Fat Cow Syndrome" is characterized by the infiltration of fat into hepatic

tissue, decreased feed intake, greater incidences of ketosis, retained placenta and decreased reproductive performance (Emery et al, 1969; Reid and Roberts, 1983;) This condition is assumed to have excess body fat reserves as a predisposing condition. It appears that all dairy cows have some degree of hepatic fat infiltration immediately after parturition (Gerloff et al, 1986). Because of this, nutritionists have been reluctant to recommend higher body levels of fat at calving even though it appears that milk production and reproductive performance may be enhanced.

On a practical basis dairy farmers can manipulate the ration only slightly to increase dry matter intake. Increasing the amount of grain (NRC, 1988) and forage quality (Coppock, 1985) increase intake if the nutrient density of the ration is limiting. Either lack of or excess dietary protein has been shown to lower dry matter intake (Owens and Goetsch, 1986). Forages preserved as silage are known to reduce feed intake (Wilkinson et al, 1976) although the exact nature of this depression is not known (Shaver et al., 1985). Feeding more meals per day and/or milking more times per day (DePeters et al, 1985) has been shown to increase dry matter intake. Addition of buffering compounds to the ration has increased dry matter intake in studies with cows fed high grain, low forage diets but not when alfalfa makes up the major portion of the forage (Erdman, 1988). Addition of flavoring compounds has not resulted in increased feed intake because the cow

appears to have limited ability to discriminate flavors (Coppock, 1985).

In summary these conclusions can be drawn.

1. The integration of factors that regulate feed intake is still not well understood.
2. Dietary fiber has a role in regulating feed intake either by diluting out the energy content of the diet or by taking up space for more digestible dietary components.
3. The influence of the degree of body fatness on feed intake or milk production is not well understood.
4. At present there has not been identified a blood metabolite or group of metabolites that appear to have a dominate role in regulating feed intake.
5. At the present time practical recommendations for increasing dry matter intake on commercial farms are few.

MATERIALS AND METHODS

CATTLE HANDLING AND FEED SAMPLING

Thirty Holstein cows from the Michigan State University Campus (n=12) and Upper Peninsula herds (n=18) were utilized in a split block design with factorial arrangement of treatments. Cows were blocked by parity, location and date of expected calving. The campus

location had one block of primiparous and one block of multiparous cows. The Upper Peninsula location had two blocks of multiparous and one block of primiparous cows. Multiparous cows were all in either the second or third lactation. Within each block, two cows were assigned to each of three calculated ration formulations: 16% (ration 1), 20% (ration 2) and 24% ADF (ration 3) depending on body condition score so as to make a 3 by 2 factorial arrangement of treatments. Cows were designated either as fat or thin using the body condition scoring system of NIRD (Mulvany, 1979). Fat cows had body condition scores greater than 2.5 while thin cows had body condition scores less than or equal to 2.5. Rations were formulated to meet National Research Council (1978) guidelines for crude protein, minerals and vitamins for cows producing 40 kg of milk and weighing 550 kg.

Cows were placed on experiment three weeks before expected calving date and fed the herd dry cow ration. On day of parturition, cows were abruptly changed to experimental rations and continued on these rations until 11 weeks after parturition. Because there was no way to standardize calving day of the week, data from the first week of lactation was not used.

All cows were housed in comfort tie stalls and individually fed a total mixed ration offered twice daily. Feed was offered at 03:30 and 13:00 at the Campus location

(CL) and at 07:30 and 17:30 at the Upper Peninsula location (UP). Feed was weighed at feeding and offered to an approximate 10% refusal. Orts were collected and weighed once each day. All cows were milked twice daily with milk production recorded at each milking. Cows at CL were milked in a Boumatic walk through parlor with automatic production recording while those at UP were milked in their stalls with a DeLaval pipeline milker. Production at the UP station was measured with Michigan DHIA approved Waiko Milk Meters. Cows at both locations were weighed Monday of each week. Blood samples were obtained from coccygeal vessels 1 hour before feeding either on Monday (CL) or Wednesday (UP) of each week. Cows were body scored at the same time by experienced evaluators. Two evaluators were employed at the CL herd and three at the UP station. One evaluator was common to both locations. Body scores were recorded as the average of the evaluator's scores.

At each feeding a 0.45 kg sample was saved from the feed allocation of each cow. Samples were bagged in plastic bags, securely fastened and individual feed samples from a given feeding immediately frozen in large plastic bags at -30° C. At the end of each weekly feeding period, the fourteen samples were unfrozen, composited, completely mixed by hand and an approximately 1.5 kg sample saved for fiber analysis. Approximately 50 grams of the composited sample was retained for dry matter determination. Samples for dry matter were placed in tared 9 x 4 mm aluminum pans,

weighed and dried at 55° C for 72 hours. This weight was taken as the dry weight. Percent dry matter was determined by the formula:

Dry matter % = dry weight/ wet weight

Twenty-five percent of each feed refusal was retained, bagged, frozen and composited as for the feed samples. Samples were retained for dry matter determination and chemical analysis using the same protocol as for the feed samples.

All 1.5 kg samples for chemical determination were placed in 24 x 40 x 10 cm aluminum pans and oven dried at 55° C for 72 hours. These samples were removed from the oven and the entire contents of a pan ground by a Wiley Mill initially through a 3 mm screen and then subsequently through a 1 mm screen. After thoroughly mixing the finely ground sample, about 100 gm were retained in plastic collection vials until further compilation.

Individually ground samples were composited by adding 2 g of sample from each ground sample for all cows on a particular experimental diet within a given week. Composited feed samples for a given diet-week were analyzed sequentially in duplicate for NDF%, ADF%, lignin% and ash% by the method of Goering and Van Soest (1972). Reported values of feed fiber constituents are the average of duplicate analysis. If difference in NDF% between

duplicates was greater than 1.5 units, samples were rerun in duplicate and the average of the nearest three was reported. Orts were compiled proportionally by weight over a two week period for individual cows and analyzed sequentially for fiber fractions.

Crude protein was determined on samples composited over the whole experiment within diet and location as Kjeldahl nitrogen (AOAC, 1975) to verify adequate crude protein content.

BLOOD HANDLING AND ANALYSIS

Blood samples were obtained via 12 ml syringe and added to Vacutainers (Becton and Dickinson, Rutherford, N.J.). Three Vacutainers were filled as follows: a 4 ml tube with heparin and sodium fluoride added for glucose determination; and two 10 ml tubes with added sodium heparin for other blood analysis. All blood samples were kept immersed in ice immediately upon collection and kept there until removed for processing. Ketones were analyzed by the procedures of Williams, Mellanby and Krebs (1973) and Williams and Mellanby (1973). All chemicals were obtained from Sigma unless otherwise specified. Centrifugation of blood to obtain plasma as well as for ketone preparations was for 10 minutes after reaching maximum speed in either an IEC model K (CL) or a Sorvall model SS-1 (UP) centrifuge. Blood for glucose determination was spun immediately upon returning to the lab in the same

Plasma triglycerides were analyzed by adaptation of the Sigma Serum Triglyceride kit as follows. A 1 ml aliquot of blood plasma was extracted with 7 ml of 3:2 hexane:isopropanol. Three and one half ml of 7% sodium sulfate was added to the extraction mixture to facilitate separation of the aqueous and solvent phases. The solvent phase was pipetted off and added to 0.6 gm of Triglyceride Purifier (Sigma) to remove phospholipids. After shaking for 10 minutes, the purifier was separated from solvent by centrifugation and the supernatant pipetted into a clean 15 x 85 glass test tube. Five ml of 7:2 hexane isopropanol was added to the Triglyceride Purifier tube. The mixture was vortexed for 15 sec, recentrifuged and the solvent pipetted off into the sample tube.

The sample tube was evaporated to dryness in a sand bath under a continuous stream of N_2. One ml of isopropanol was used to dissolve the isolated lipid. Heating in a 60° C water bath was required to dissolve some samples. Analysis by thin layer chromatography showed that phosphorus containing lipids had been quantitatively removed. One half ml of 5 N potassium hydroxide was added to the sample and left standing overnight to saponify the sample. The next day, 0.5 ml of sodium periodate solution was added to the test tube. The periodate solution was prepared by dissolving 1.25 g of sodium m-periodate in 500 of 2 N acetic acid. After 10 minutes, color reagent was added. Color reagent was prepared by mixing 200 ml of a 2

M ammonium acetate solution with 400 ml of isopropanol and 1.5 ml of acetylacetone. Samples were incubated for 30 minutes in a 60° C water bath to fully develop color.

Because blood pigments were found to interfere with light absorption, the sample was washed with 2 ml of hexane before reading absorbance at 410 nm. Extraction of 10 standards of .2 mg of triolein, yielded at recovery of 99.8 ± 2.76%. Extraction and triglyceride readings on 10 separate 1 ml aliquot of a standard serum had a coefficient of variation of 5.12%. Addition of standards of 0.025, 0.05, 0.1, 0.2 and 0.3 mg of triolein to standard serum indicated linear recovery.

Plasma insulin was determined by specific double antibody radioimmunoassay using the method of Villa-Godoy (1987).

MILK COMPONENT ANALYSIS

Analysis of milk components was determined weekly. They were analyzed for fat%, protein%, and total solids% by Michigan DHIA. Reported butterfat %, protein % and totals solids % are the average of am and pm samples.

STATISTICAL ANALYSIS

Statistical analysis was performed using the general linear model (GLM) of SAS (SAS Institute Inc. Cary, N.C., release 5.18, 1986.) as a split block in time. The model was:

$Y_{ijklm} = u + a_i + \beta_j + (a\beta)_{ij} + C_k + D_l + + (aC)_{ik} + (\beta C)_{jk}{}^i + (a\beta C)_{ijk} + E_{ijklm}$

where Y_{jiklm} = observed variable of each individual cow for a given treatment in a given week of lactation in a given block.

u = sample mean

a_i = effects of diet

β_j = effects of body condition

C_k = effects of lactation week

D_l = effects of block

$(a\beta)_{ij}$ = diet x body condition interaction

$(aC)_{ik}$ = diet x lactation week interaction

$(\beta C)_{ij}$ = body condition x lactation week interaction

$(a\beta C)_{ijk}$ = ration x body condition x lactation week interaction

and E_{ijklm} = total pure error composed of

$(a\beta D)_{ijl}$ = ration x body condition x block interaction = whole plot error

$(a\beta CD)_{ijkl}$ = ration x body condition x lactation week x block interaction = subplot error

Correlations between dependent variables were generated using the GLM model of SAS. For variables with a significant week of lactation effect, regression equations were generated by cow using GLM of SAS. The model included:

$$Y = \beta_0 + \beta_1 x + \beta_2 x^2 + \beta_3 x^3$$

where Y = predicted variable value

β_0 = intercept

β_1 = coefficient of linear effect of lactation week

β_2 = coefficient of quadratic effect of lactation week

β_3 = coefficient of cubic effect of lactation week

x = lactation week

Univariate analysis of variance was performed on the generated intercept and coefficients to test differences for a given regression parameter among rations, body condition, blocks and interaction. The model for slope parameters included:

$$Y_i = u + a_i + \beta_j + (a\beta)_{ij} + C_k + E_{ijkl}$$

Where Y_{ijkl} = dependent slope parameter

u = mean slope parameter

a_i = fixed effect of diet

β_j = fixed effect of body condition

C_k = random effect of block

$(a\beta)_{ij}$ = ration by body condition interaction

and E_{ijkl} = the residual error

Overall differences between regression equations due to ration, body condition, block and interaction were tested using the multivariate analysis Procedure of SAS. The model included those terms above.

Tests for partitioning of the variance in dry matter intake and milk production were determined by using the

centrifuges and at the same speed as was reported for blood ketones. Plasma and deproteinized whole blood for ketone analysis were pipetted into blood dilution vials and held at -30° C until thawed for analysis. In all cases blood plasma for glucose was separated and frozen within 30 minutes of sampling. Ketone preparations were frozen within 2 hours of blood collection and blood plasma was frozen within 3 hours.

Glucose and creatinine were measured using diagnostic kits obtained from Sigma Chemical, St. Louis, Mo. Absorbance readings were obtained on a Guilford model 2400-S spectrophotometer. Nonesterified fatty acids (NEFA) were determined by using NEFA-C kits obtained from Wako Pharmaceutical (Dallas, Texas) after dilution by the method of McCutcheon and Bauman (1986). Absorbance of NEFA was read on a Guilford 2400 with a sipper attachment. Linearity was obtained on all analysis. Recovery of glucose, creatinine and NEFA were determined to be 102.4%, 96.8% and 100.7% with a coefficient of variation of 6.8%, 12.8% and 1.2% respectively. Determination of mMole of ketones, glucose, creatinine and NEFA in plasma was calculated by the following formula:

$$\frac{\text{Initial Absorbance of sample-Final Absorbance x of standard}}{\text{Initial Absorbance of standard - final absorbance standard}}$$

regression procedure in GLM of SAS in a stepwise elimination procedure. Variables with $R^2 < .20$ were dropped from the model. Variables were tested for linear, quadratic and cubic effects.

Comparison of means between primiparous and multiparous cows were determined using Student's t test for differences between treatment means of unequal replication. Specific comparisons among ration and body condition means over the first three treatment weeks were compared against the Bonferroni t statistic (Gill, 1978).

Calculation of ration energy (NE_l /kg) was from 1988 NRC (Sixth revised edition). Calculation of 4% fat corrected milk was also from NRC.

Energy Balance was calculated as from Villa-Godoy (1987).

RESULTS

PREPARTUM COWS

Prepartum cows showed no significant differences due to ration in any blood variables except for plasma concentrations of triacylglycerol (ration 1 less than ration 2 and ration 1 less than ration 3, $P<.01$). Dry cow diet formulation is presented in Table 1. Means and contrast significances for all dry period variables are presented in Table 2. Because experimental diets were not offered until day of parturition, the finding of lower plasma triacylglycerol for cows fed ration 1 was considered

Table 1. Feed composition of prepartum rations (percent of dry matter basis).

Location	Feed	Percent
Campus	Haylage	18.8 %
	Cornsilage	65.4 %
	Shelled corn	6.5 %
	Soybean meal (44%)	7.2 %
	Trace mineral salt	0.4 %
	Vitamin-mineral premix *	0.4 %
Upper Penninsula		
	Haylage	88.8 %
	Shelled corn	10.6 %
	Trace mineral salt	0.2 %
	Vitamin-mineral premix *	0.4 %

* Formulated to provide 0.25% calcium, 0.18% phosporus, 0.25% magnesium of total ration dry matter as well as 1000 IU of vitamin A, 125 IU of vitamin D and 12 IU of vitamin E per 0.45 kg of ration dry matter.

Table 2. Effect of three ADF levels and two body conditions on selected contrasts for dry matter intake, feed and blood variables in the prepartum period.

Variable	Treatment	Selected Contrast	Means	Mean	SED	Units	P	Significant Interaction
Dry matter intake	Body Condition	Thin v fat	82.80	93.40	6.59	kg		
	Ration	Ration 1 v 3	86.70	91.20	1.25	kg		
		Ration 1 v 2	86.70	85.80	1.25	kg		
		Ration 2 v 3	85.80	91.20	1.25	kg		
		1st lactation v later	77.90	93.10	5.66	kg	0.01	
DMI/100 kg body weight	Body Condition	Thin v fat	13.34	13.86	0.68	kg/100 kg		
	Ration	Ration 1 v 3	13.36	13.19	0.19	kg/100 kg		
		Ration 1 v 2	13.36	13.22	0.19	kg/100 kg		
		Ration 2 v 3	13.22	13.19	0.19	kg/100 kg		
		1st lactation v later	6.28	6.10	1.10	kg/100 kg	0.01	
Body weight	Body Condition	Thin v fat	626.9	683.7	17.98	kg		
	Ration	Ration 1 v 3	652.6	646.3	3.32	kg		
		Ration 1 v 2	652.6	662.9	3.32	kg		
		Ration 2 v 3	662.9	646.3	3.32	kg		
		1st lactation v later	565.3	693.4	51.52	kg		

Continued

Table 2. (continued)

Variable	Treatment	Selected Contrast	Means	Mean	SED	Units	P	Significant Interaction
Gain in body weight	Body Condition	Thin v fat	62.9	61.7	0.25	kg		
	Ration	Ration 1 v 3	77.8	47.4	8.81	kg		
		Ration 1 v 2	77.8	61.0	8.81	kg		
		Ration 2 v 3	61.0	47.4	8.81	kg		
		1st lactation v later	57.9	63.5	8.78	kg		
Body condition score	Body Condition	Thin v fat	2.4	3.3	0.337			
	Ration	Ration 1 v 3	2.91	2.76	0.049			
		Ration 1 v 2	2.91	2.51	0.049			
		Ration 2 v 3	2.51	2.76	0.049			
		1st lactation v later	3.05	2.85	0.375			
Gain in body condition score	Body Condition	Thin v fat	0.19	0.49	0.144			
	Ration	Ration 1 v 3	0.37	0.34	0.033			
		Ration 1 v 2	0.37	0.29	0.033			
		Ration 2 v 3	0.29	0.34	0.033			
		1st lactation v later	0.28	0.35	0.118			

Continued

Table 2. (continued)

Variable	Treatment	Selected Contrast	Means	Mean	SED	Units	P	Significant Interaction
Ration NDF	Body Condition	Thin v fat	41.1	42.5	0.15	%		
	Ration	Ration 1 v 3	43.17	41.47	0.97	%		
		Ration 1 v 2	43.17	40.70	0.97	%		
		Ration 2 v 3	40.70	41.47	0.97	%		
		1st lactation v later	40.81	41.28	4.47	%		
Ration ADF	Body Condition	Thin v fat	25.01	25.99	0.04	%		
	Ration	Ration 1 v 3	25.89	25.57	0.49	%		
		Ration 1 v 2	25.89	24.95	0.49	%		
		Ration 2 v 3	24.95	25.57	0.49	%		
		1st lactation v later	24.37	25.08	3.74	%		
Ration lignin	Body Condition	Thin v fat	4.48	4.69	0.01	%		
	Ration	Ration 1 v 3	4.65	4.54	0.04	%		
		Ration 1 v 2	4.65	4.53	0.04	%		
		Ration 2 v 3	4.53	4.54	0.04	%		
		1st lactation v later	4.19	4.55	0.84	%		
Ration ash	Body Condition	Thin v fat	6.99	7.17	0.034	%		
	Ration	Ration 1 v 3	7.04	7.01	0.042	%		
		Ration 1 v 2	7.04	7.18	0.042	%		
		Ration 2 v 3	7.18	7.01	0.042	%		
		1st lactation v later	6.56	7.12	0.823	%		

Continued

Table 2. (continued)

Variable	Treatment	Selected Contrast	Means	Mean	SED	Units	P	Significant Interaction
NDF consumed	Body Condition	Thin v fat	33.80	39.80	3.04	kg		
	Ration	Ration 1 v 3	37.80	36.90	1.13	kg		
		Ration 1 v 2	37.80	35.10	1.13	kg		
		Ration 2 v 3	35.10	36.90	1.13	kg		
		1st lactation v later	32.00	38.22	3.4	kg	0.01	
NDF consumed % of body weight	Body Condition	Thin v fat	5.45	5.89	0.33	kg/100 kg		
	Ration	Ration 1 v 3	5.80	5.77	0.16	kg/100 kg		
		Ration 1 v 2	5.80	5.40	0.16	kg/100 kg		
		Ration 2 v 3	5.40	5.77	0.16	kg/100 kg		
		1st lactation v later	5.75	5.51	0.60	kg/100 kg	0.01	
ADF consumed	Body Condition	Thin v fat	20.40	24.30	1.83	kg		
	Ration	Ration 1 v 3	22.70	22.60	0.68	kg	0.10	
		Ration 1 v 2	22.70	21.40	0.68	kg		
		Ration 2 v 3	21.40	22.60	0.68	kg		
		1st lactation v later	19.03	23.14	2.84	kg	0.01	
ADF consumed % of body weight	Body Condition	Thin v fat	3.30	3.60	0.20	kg/100 kg		
	Ration	Ration 1 v 3	3.47	3.54	0.09	kg/100 kg		
		Ration 1 v 2	3.47	3.31	0.09	kg/100 kg		
		Ration 2 v 3	3.31	3.51	0.09	kg/100 kg		
		1st lactation v later	3.64	3.33	0.49	kg/100 kg	0.01	

Continued

Table 2. (continued)

Variable	Treatment	Selected Contrast	Means	Mean	SED	Units	P	Significant Interaction
Lignin consumed	Body Condition	Thin v fat	3.66	4.39	0.314	kg		
	Ration	Ration 1 v 3	4.08	4.04	0.112	kg	0.05	
		Ration 1 v 2	4.08	3.88	0.112	kg		
		Ration 2 v 3	3.88	4.04	0.112	kg		
						kg		
		1st lactation v later	3.27	4.19	0.665	kg	0.01	
Ash consumed	Body Condition	Thin v fat	5.75	6.73	0.515	kg		
	Ration	Ration 1 v 3	6.19	6.33	0.050	kg		
		Ration 1 v 2	6.19	6.13	0.050	kg		
		Ration 2 v 3	6.13	6.33	0.050	kg		
		1st lactation v later	5.14	6.59	0.648	kg	0.01	
Plasma BHBA concentration	Body Condition	Thin v fat	0.474	0.429	0.03	mM/ml		
	Ration	Ration 1 v 3	0.508	0.427	0.046	mM/ml		
		Ration 1 v 2	0.508	0.416	0.046	mM/ml		
		Ration 2 v 3	0.416	0.427	0.046	mM/ml		
		1st lactation v later	0.482	0.449	0.052	mM/ml		
Plasma ACAC concentration	Body Condition	Thin v fat	0.009	0.020	0.009	mM/ml		
	Ration	Ration 1 v 3	0.015	0.008	0.012	mM/ml	0.01	
		Ration 1 v 2	0.015	0.022	0.012	mM/ml	0.01	
		Ration 2 v 3	0.022	0.008	0.012	mM/ml	0.01	
		1st lactation v later	0.010	0.015	0.013	mM/ml		

Continued

Table 2. (continued)

Variable	Treatment	Selected Contrast	Means	Mean	SED	Units	P	Significant Interaction
Plasma NEFA concentration	Body Condition	Thin v fat	0.244	0.296	0.027	mM/ml		
	Ration	Ration 1 v 3	0.272	0.206	0.042	mM/ml	0.01	
		Ration 1 v 2	0.272	0.336	0.042	mM/ml	0.01	
		Ration 2 v 3	0.336	0.206	0.042	mM/ml	0.01	
		1st lactation v later	0.211	0.256	0.091	mM/ml	0.10	
Plasma Triacyl-glycerol concentration	Body Condition	Thin v fat	3.610	3.590	0.0016	mM/ml		
	Ration	Ration 1 v 3	3.000	4.240	0.0035	mM/ml	0.01	
		Ration 1 v 2	3.000	3.550	0.0035	mM/ml	0.01	
		Ration 2 v 3	3.550	4.240	0.0035	mM/ml	0.01	
		1st lactation v later	3.590	3.600	0.0030	mM/ml		
Plasma creatinine concentration	Body Condition	Thin v fat	0.164	0.173	0.005	mM/ml		
	Ration	Ration 1 v 3	0.173	0.164	0.001	mM/ml	0.01	
		Ration 1 v 2	0.173	0.168	0.001	mM/ml	0.01	
		Ration 2 v 3	0.168	0.164	0.001	mM/ml	0.01	
		1st lactation v later	0.165	0.171	0.009	mM/ml		
Plasma glucose concentration	Body Condition	Thin v fat	0.410	0.393	0.010	mM/ml		
	Ration	Ration 1 v 3	0.395	0.407	0.010	mM/ml		
		Ration 1 v 2	0.395	0.403	0.010	mM/ml		
		Ration 2 v 3	0.403	0.407	0.010	mM/ml		
		1st lactation v later	0.415	0.396	0.017	mM/ml		

Continued

Table 2. (continued)

Variable	Treatment	Selected Contrast	Means	Mean	SED	Units	P	Significant Interaction
Plasma insulin concentration	Body Condition	Thin v fat	0.269	0.395	0.064	ng/ml		
	Ration	Ration 1 v 3	0.292	0.429	0.021	ng/ml		
		Ration 1 v 2	0.292	0.271	0.021	ng/ml		
		Ration 2 v 3	0.271	0.429	0.021	ng/ml		
		1st lactation v later	0.345	0.315	0.082	ng/ml		

due to random differences between cows selected for ration 1. There was also significantly less ($P<.05$) ADF in the rations fed at the CL station. There was also a trend ($P<.10$) toward lower NDF content in the dry cow rations of the CL herd. This may have been caused by the inclusion of corn silage in the dry cow ration at the CL location. Consumption of ADF ($P<.01$) but not NDF ($P>.80$) was greater at the UP location.

Prepartum body condition, however, resulted in several significantly different variables. Cows in fat body condition prepartum had a significantly higher body condition score ($P<.01$), gained significantly more body condition ($P<.05$) in the weeks prior to parturition and tended ($P<.10$) to weigh more than those in thin body condition. They tended to eat more ($P<.10$) which resulted in a tendency to consume more NDF, ADF and acid detergent lignin ($P<.10$). Fatter dry cows had higher levels of plasma insulin ($P<.05$) but tended to have lower blood BHBA concentrations ($P < .10$).

COWS

Although 30 cows initially began on trial, two cows were removed from the data set. Both were first lactation cows on ration 1 and assigned to fat body condition. One was from the UP herd and one from the CL herd. The UP heifer had a severe case of mastitis at parturition resulting in a loss of one quarter. Although she

subsequently recovered, her milk production was so abnormally low as to bias the data set. The CL heifer was diagnosed with a displaced abomasum at 3 weeks of lactation. Corrective surgery was performed, and she was placed back on trial. However, 3 weeks later she was again diagnosed with a displaced abomasum. Because these incidents resulted in prolonged periods of reduced dry matter intake, she was also dropped from the data set.

Additionally, two other cows, both assigned to ration 2 from the UP Experiment Station, were also diagnosed with displaced abomasums upon parturition. The displacements were corrected surgically, and the cows remained on trial and continued without further incidence.

All four primiparous cows on ration 1 showed some evidence of laminitis. Two of these, one at the UP and one at CL herds, were severe enough so as to interfere with walking. No founder symptoms were detected in multiparous cows on ration 1 or in the cows fed any other diet.

DIET

Diet composition for lactating cows is presented in Table 3 and nutrient composition for these diets is presented in Table 4. Although total mixed diets were calculated to contain 16, 20 and 24% ADF, actual mean dietary ADF levels were 17.36, 20.25 and 22.77% (+0.33). These differences were significant, however, (ration 1 vs ration 2; ration 1 vs ration 3; and ration 2 vs ration 3,

Table 3. Approximate average ingredient composition of experimental diets (percent of dry matter basis).

Location	Ingredient	Diet 1	2	3
Campus	Haylage	23.3	33.2	42.8
	Shelled Corn	53.0	43.2	35.2
	Soybean Meal (44%)	22.1	22.1	20.5
	TM salt	.45	.45	.45
	Limestone	.35	.35	.35
	Dicalcium phosphate	.55	.55	.55
	Vitamin-trace mineral mix	.19	.19	.19
	Forage:concentrate	23:77	33:67	43:57
Upper Penninsula				
	Haylage	29.0	39.6	49.2
	Shelled corn	49.2	39.6	32.0
	Soybean meal (44%)	20.7	19.5	17.7
	TM salt	.41	.41	.41
	Sodium mono-phosphate	.40	.39	.39
	Vitamin-trace mineral mix	.41	.41	.41
	Forage:concentrate	29:71	40:60	43:57

Table 4. Nutrient composition of experimental diets (percent of dry matter basis).

Fraction	DIETS 1	2	3
Neutral detergent fiber	33.38	36.15	38.19
Acid detergent fiber	17.36	20.25	22.77
Acid detergent lignin	3.00	3.55	4.24
Ash	6.23	6.75	7.32
Net energy* lactation (MCal/kg)	1.73	1.67	1.63
		ORTS	
Neutral detergent fiber	34.98	38.15	39.22
Acid detergent fiber	18.08	21.63	23.98
Acid detergent lignin	3.05	3.85	4.41
Ash	6.51	6.90	7.48

* Calculated value from ADF

P<.01) (Table 5). Average crude protein content of the diets were 17.96, 18.13 and 18.22% for the respective diets. All diets contained significantly different amounts of energy (P < .01), NDF (P < .01) and lignin (P < .01) (Table 5), but not ash. Percent fiber composition of orts was numerically higher than the ration for all fiber fractions although this difference was not significantly different from the ration (Table 6; P > .10). Because of changes in the composition of the haylage, the fiber fractions of the total diet changed significantly over time. This data is presented in Appendix Tables 11-14. This resulted in significant individual variation of feed composition among cow blocks depending on date of parturition.

Caution must be applied to the summary statistics used in the analysis of feed constituents. The statistical model selected included lactation week. This is an adequate model for most dependent variables, but as already noted, experimental cows did not all calve in the same week. In fact week of parturition covered a 16-week time span. The percent fiber in the diet, both ADF and NDF varied over this time span as noted above. Use of lactation week in the model, therefore, resulted in an inflated error term. Realizing this could bias interpretation of the experiment, the percent of fiber in the diet and DMI were reanalyzed by replacing the lactation week term in the model with actual calendar week. The

Table 5. Weekly means and selected contrasts for various feed variables for cows fed three levels of ADF and at two body conditions.

Variable	Treatment	Selected Contrast	Means	Mean	SED	Units	P[a]	Significant Interactions
Ration NDF content	Body Condition	Thin v fat	36.08	35.67	0.66	%		
	Ration	Ration 1 v 3	33.37	38.19	0.78	%	0.01	
		Ration 1 v 2	33.37	36.15	0.83	%	0.01	
		Ration 2 v 3	36.15	38.19	0.83	%	0.01	
		1st lactation v later	35.82	36.42	0.69	%		
						%		
Ration ADF content	Body Condition	Thin v fat	20.19	20.03	0.36	%		
	Ration	Ration 1 v 3	17.36	22.77	0.42	%	0.01	
		Ration 1 v 2	17.36	20.25	0.45	%	0.01	
		Ration 2 v 3	20.25	22.77	0.45	%	0.01	
		1st lactation v later	19.63	20.38	0.38	%		
Ration lignin content	Body Condition	Thin v fat	3.61	3.59	0.05	%		
	Ration	Ration 1 v 3	3.00	4.24	0.06	%	0.01	
		Ration 1 v 2	3.00	3.55	0.07	%	0.01	
		Ration 2 v 3	3.55	4.24	0.07	%	0.01	
		1st lactation v later	3.59	3.60	0.06	%		
Ration ash content	Body Condition	Thin v fat	6.74	6.8	0.11	%		
	Ration	Ration 1 v 3	6.23	7.32	0.13	%	0.01	
		Ration 1 v 2	6.23	6.75	0.14	%	0.01	
		Ration 2 v 3	6.75	7.32	0.14	%	0.01	
		1st lactation v later	3.59	3.61	0.12	%		

Continued

Table 5. (Continued)

Variable	Treatment	Selected Contrast	Means	Mean	SED	Units	P[a]	Significant Interactions
ORTS NDF content	Body Condition	Thin v fat	37.54	37.26	1.01	%		Body condition * lactation week (P<.01)
	Ration	Ration 1 v 3	34.98	39.22	1.19	%		
		Ration 1 v 2	34.98	38.15	1.20	%		
		Ration 2 v 3	38.15	39.21	1.20	%		
		1st lactation v later	36.28	38.02	1.05	%		
						%		
ORTS ADF content	Body Condition	Thin v fat	21.22	21.19	0.58	%		
		Ration 1 v 3	18.08	23.98	0.69	%		
	Ration	Ration 1 v 2	18.08	21.63	0.73	%		
		Ration 2 v 3	21.63	23.98	0.73	%		
		1st lactation v later	20.37	21.67	0.60	%		
ORTS lignin content	Body Condition	Thin v fat	3.77	3.76	0.37	%		
		Ration 1 v 3	3.05	4.41	0.43	%		
	Ration	Ration 1 v 2	3.04	3.85	0.46	%		
		Ration 2 v 3	3.85	4.41	0.46	%		
		1st lactation v later	3.78	3.76	0.38	%		
ORTS ash content	Body Condition	Thin v fat	6.97	6.96	0.16	%		
		Ration 1 v 3	6.51	7.48	0.19	%		
	Ration	Ration 1 v 2	6.51	6.90	0.20	%		
		Ration 2 v 3	6.90	7.43	0.20	%		
		1st lactation v later	7.12	6.88	0.17	%		

Continued

Table 5. (Continued)

Variable	Treatment	Selected Contrast	Means	Mean	SED	Units	P[a]	Significant Interactions
Difference in ration and ORTS ash	Body Condition	Thin v fat	-0.23	-0.16	0.07	%		
		Ration 1 v 3	-0.28	-0.16	0.08	%		
	Ration	Ration 1 v 2	-0.28	-0.15	0.09	%		
		Ration 2 v 3	-0.16	-0.15	0.09	%		
		1st lactation v later	-0.10	-0.26	0.07	%		

[a] Contrasts not listed are not significantly different (P > .10).

Table 6. Weekly means and selected contrasts for the difference between the composition of the ration and the ORTS.

Variable	Treatment	Selected Contrast	Means	Mean	SED	Units	P[a]	Significant Interactions
Difference in ration and ORTS NDF	Body Condition	Thin v fat	-1.46	-1.55	0.68	%		Body condition * lactation week (P<.01)
	Ration	Ration 1 v 3	-1.58	-1.03	0.80	%		
		Ration 1 v 2	-1.58	-2.00	0.84	%		
		Ration 2 v 3	-2.00	-1.03	0.84	%		
		1st lactation v later	-1.43	-1.52	0.70	%		
Difference in ration and ORTS ADF	Body Condition	Thin v fat	-1.03	-1.15	0.43	%		Body condition * lactation week (P<.10)
	Ration	Ration 1 v 3	-0.72	-1.21	0.51	%		
		Ration 1 v 2	-0.72	-1.39	0.54	%		
		Ration 2 v 3	-1.39	-1.21	0.54	%		
		1st lactation v later	-0.73	-1.28	0.45	%		
Difference in ration and ORTS lignin	Body Condition	Thin v fat	-0.16	-0.16	0.08	%		Body condition * lactation week (P<.01)
	Ration	Ration 1 v 3	-0.05	-0.17	0.09	%		
		Ration 1 v 2	-0.05	-0.29	0.10	%		
		Ration 2 v 3	-0.29	-0.17	0.10	%		
		1st lactation v later	-0.18	-0.15	0.08	%		
Difference in ration and ORTS ash	Body Condition	Thin v fat	-0.23	-0.16	0.07	%		
	Ration	Ration 1 v 3	-0.28	-0.16	0.08	%		
		Ration 1 v 2	-0.28	-0.15	0.09	%		
		Ration 2 v 3	-0.16	-0.15	0.09	%		
		1st lactation v later	-0.10	-0.26	0.07	%		

[a]Contrasts not listed are not significantly different (P > .10).

model for DMI was also run using the actual ADF level of the ration as a covariate.

The model using lactation week explained 79% of the variation in ADF percent of the ration (Table 7). In contrast to this model, the model with calendar week explained 95% of the total variation for ADF percent of the ration. There was a significant block effect when analyzing ADF percent in the rations if the model contained either lactation week or experimental week because blocks were confounded with date of parturition to some extent. Thus, blocks were somewhat confounded with calendar week. In both cases ADF percent of the ration was significantly different ($P<.0001$) among diets (Table 7).

Significance level of dry matter intake was not affected by the replacement of lactation week with calendar week or by use of ADF as a covariate.

PRODUCTION

Milk production was significantly greater ($P<.05$) for cows fed ration 1 than those fed ration 3. Ration 2 was not significantly different from the other two ($P>.10$, Table 8), although ration 2 was almost numerically equal to ration 1. Production of 4% fat corrected milk (4 FCM) per 100 kg of body weight was higher for ration 1 than ration 3 ($P<.05$). This difference was more tentative ($P < .10$) based on total weekly 4% FCM production. Milk production, milk composition and component yield were unaffected by

Table 7. Source of variation of ADF levels in the ration for experimental designs employing either lactation week or calendar week in the model (Type III sum of squares).

Model: Lactation Week

Source of Variation	Degrees of Freedom	Sum of Squares
Ration	2	1464.3475
Body Condition	1	2.2728
Ration X Body Condition	2	6.2810
Block	4	246.7486
Ration X Body Condition X Block	18	160.6890
Lactation Week	9	155.5199
Ration X Lactation Week	18	35.8975
Body Condition X Lactation Week	9	24.3830
Ration X Body Condition X Lactation Week	18	25.2208
Error	198	595.9665
Total	279	2718.6499

Model: Experimental Week

Source of Variation	Degrees of Freedom	Sum of Squares
Ration	2	722.4887
Body Condition	1	.0450
Ration X Body Condition	2	.8514
Block	4	220.5189
Ration X Body Condition X Block	18	39.5602
Experimental Week	22	408.4732
Ration X Experimental Week	39	69.7884
Body Condition X Experimental Week	21	4.7287
Ration X Body Condition X Experimental Week	30	6.1325
Error	139	256.8861
Total	279	2718.6499

Table 8. Effect of three ADF levels and two body conditions on selected contrasts for means of weekly milk production variables.

Variable	Treatment	Selected Contrast	Means	Mean	SED	Units	P[a]	Significant Interaction
Milk production	Body Condition	Thin v fat	256.50	251.40	12.4	kg		
	Ration	Ration 1 v 3	269.20	230.00	14.6	kg	0.05	
		Ration 1 v 2	269.20	265.60	15.5	kg		
		Ration 2 v 3	265.60	230.00	15.5	kg		
		1st lactation v later	198.80	284.90	28.4	kg	0.01	
4% FCM production	Body Condition	Thin v fat	237.40	245.40	14.0	kg	0.96	
	Ration	Ration 1 v 3	256.10	217.60	16.5	kg		
		Ration 1 v 2	256.10	252.00	17.7	kg		
		Ration 2 v 3	252.00	217.60	17.7	kg		
		1st lactation v later	176.20	610.00	14.9	kg	0.01	
4FCM/100 kg body	Body Condition	Thin v fat	19.70	19.20	1.05	kg/100 kg		
	Ration	Ration 1 v 3	21.10	17.54	1.23	kg/100 kg	0.05	
		Ration 1 v 2	21.10	20.00	1.33	kg/100 kg		
		Ration 2 v 3	20.00	17.50	1.33	kg/100 kg		
		1st lactation v later	16.40	21.30	1.10	kg/100 kg	0.01	
Milk fat %	Body Condition	Thin v fat	3.47	3.79	0.17	%		
	Ration	Ration 1 v 3	3.64	3.64	0.20	%		
		Ration 1 v 2	3.64	3.58	0.22	%		
		Ration 2 v 3	3.58	3.64	0.22	%		
		1st lactation v later	3.28	3.81	0.18	%	0.01	

Continued

Table 8. (Continued)

Variable	Treatment	Selected Contrast	Means	Mean	SED	Units	P[a]	Significant Interaction
Milk protein %	Body Condition	Thin v fat	3.07	3.13	0.07	%		
		Ration 1 v 3	3.12	3.12	0.08	%		
	Ration	Ration 1 v 2	3.12	3.04	0.08	%		
		Ration 2 v 3	3.04	3.12	0.08	%		
		1st lactation v later	3.11	3.10	0.07	%		
Milk solids %	Body Condition	Thin v fat	12.30	12.54	0.22	%		
		Ration 1 v 3	12.48	12.34	0.25	%		
	Ration	Ration 1 v 2	12.48	12.41	0.27	%		
		Ration 2 v 3	12.41	12.34	0.27	%		
		1st lactation v later	12.18	12.54	0.22	%	0.01	
Milk fat production	Body Condition	Thin v fat	8.95	9.64	0.65	kg		
		Ration 1 v 3	9.88	8.36	0.76	kg		
	Ration	Ration 1 v 2	9.88	9.66	0.82	kg		
		Ration 2 v 3	9.66	8.36	0.82	kg		
		1st lactation v later	7.54	10.60	0.68	kg	0.01	
Milk protein production	Body Condition	Thin v fat	7.91	7.78	0.38	kg		
		Ration 1 v 3	8.41	7.10	0.45	kg	0.05	
	Ration	Ration 1 v 2	8.41	8.10	0.48	kg		
		Ration 2 v 3	8.10	7.10	0.48	kg		
		1st lactation v later	6.12	8.81	0.40	kg	0.01	

Continued

Table 8. (Continued

Variable	Treatment	Selected Contrast	Means	Mean	SED	Units	P[a]	Significant Interaction
Milk solids production	Body Condition	Thin v fat	31.75	31.60	0.22	kg		
		Ration 1 v 3	33.73	28.37	0.25	kg		
	Ration	Ration 1 v 2	33.73	33.30	0.27	kg		
		Ration 2 v 3	33.30	28.37	0.27	kg		
		1st lactation v later	24.14	35.91	0.22	kg	0.01	

[a]Contrasts not listed are not significantly different (P > .10).

body condition (P>.10). Milk composition was also unaffected by ration (P>.10). Total weekly production of milk protein was greater for cows fed ration 1 than 3 (P<.05). There was a trend (P<.10) for cows on ration 1 to produce more kg of total weekly milk solids. Weekly milk fat yield was not affected by either body condition or ration. Weekly production variables are presented in Appendix Tables 1-6.

Primiparous cow blocks produced less milk (P<.01) than multiparous cows. As a result, they produced less 4% FCM, less kg 4% FCM per 100 kg of body weight, less kg milk fat and less kg of milk protein (P<.01). Percent of milk components was not different between older and first lactation cows (P>.10).

Obviously week of lactation had a strong effect (P<.01) on the amount of milk produced (Figure 1) and, as a result, had a corresponding effect on kg of milk components produced (P<.01).

Analysis of coefficients of individual lactation curves generated by regression (mean R^2=.82) to gain insight into how the ration was affecting production indicated that the intercept parameter was not different among diets (P>.10). There were, however, significant differences between linear, quadratic and cubic effects of lactational week and treatment (ration 1 vs ration 2, ration 1 vs ration 3 and ration 2 vs ration 3, P<.01) for

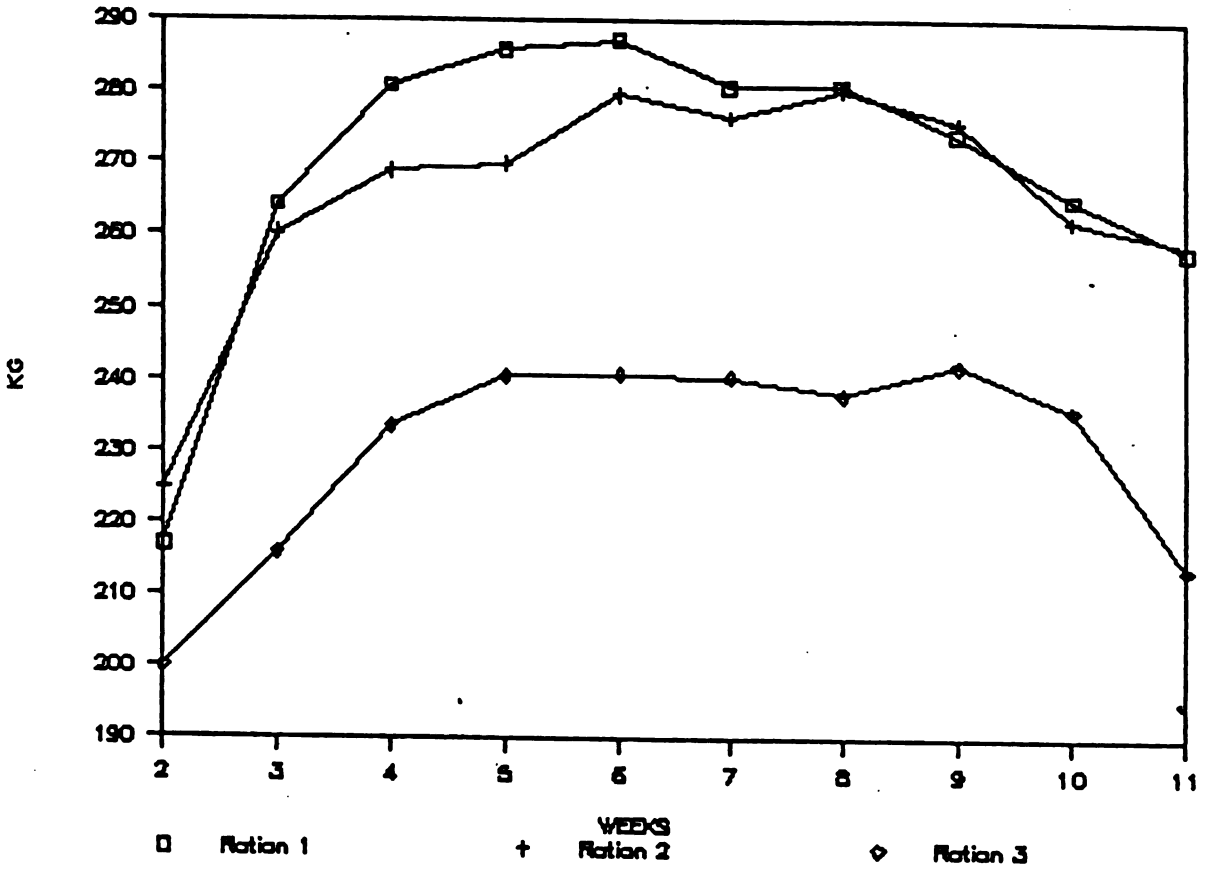

Figure 1. Mean weekly milk production of cows fed three different levels of ADF.

all coefficients (Figure 2).

Similar analysis on regression equations on kg of milk fat produced differences in intercept and linear coefficients as well as trends for quadratic and cubic coefficients (Figure 3). Milk fat percent was not affected differently ($P>.10$).

Analysis of regression equations for weekly milk protein percent, total kg of milk protein, milk solids percent and total solids production produced no evidence that rations were affecting slope parameters ($P>.10$).

Neither univariate or multivariate analysis indicated that body condition had any effect on coefficients of either milk or milk constituents ($P>.10$).

A word of caution must be applied to the interpretation of these regression equations. The intercept parameter can be interpreted as the starting point assuming the equation adequately describes the relationship. The linear slope approximates the initial increase or decline from the intercept while the quadratic coefficient describes the rate of change when the equation reaches its maximum or minimum. Cubic effects may be viewed as reflecting lack of symmetry in the curve since a pure second degree curve is necessarily symmetrical about the maximum or minimum.

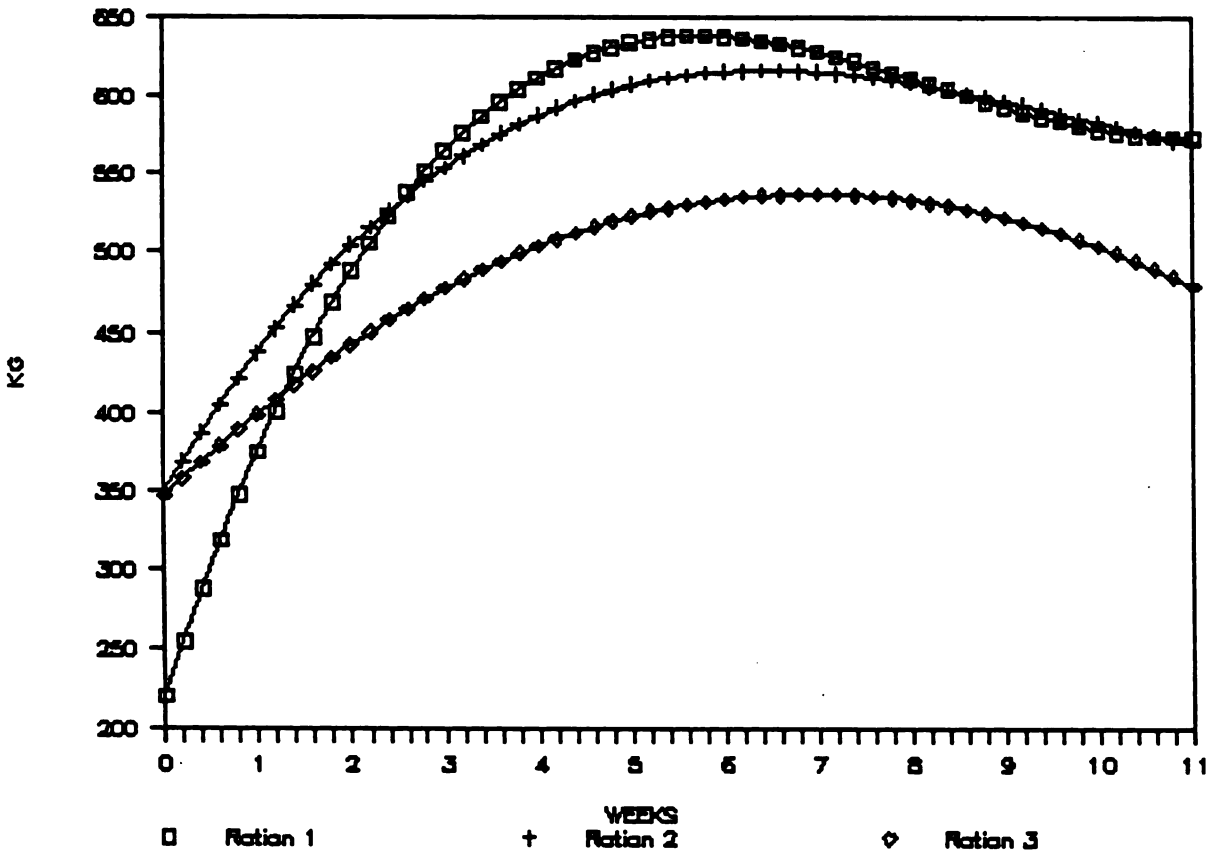

Figure 2. Regression plots of milk production of cows fed three different levels of ADF.

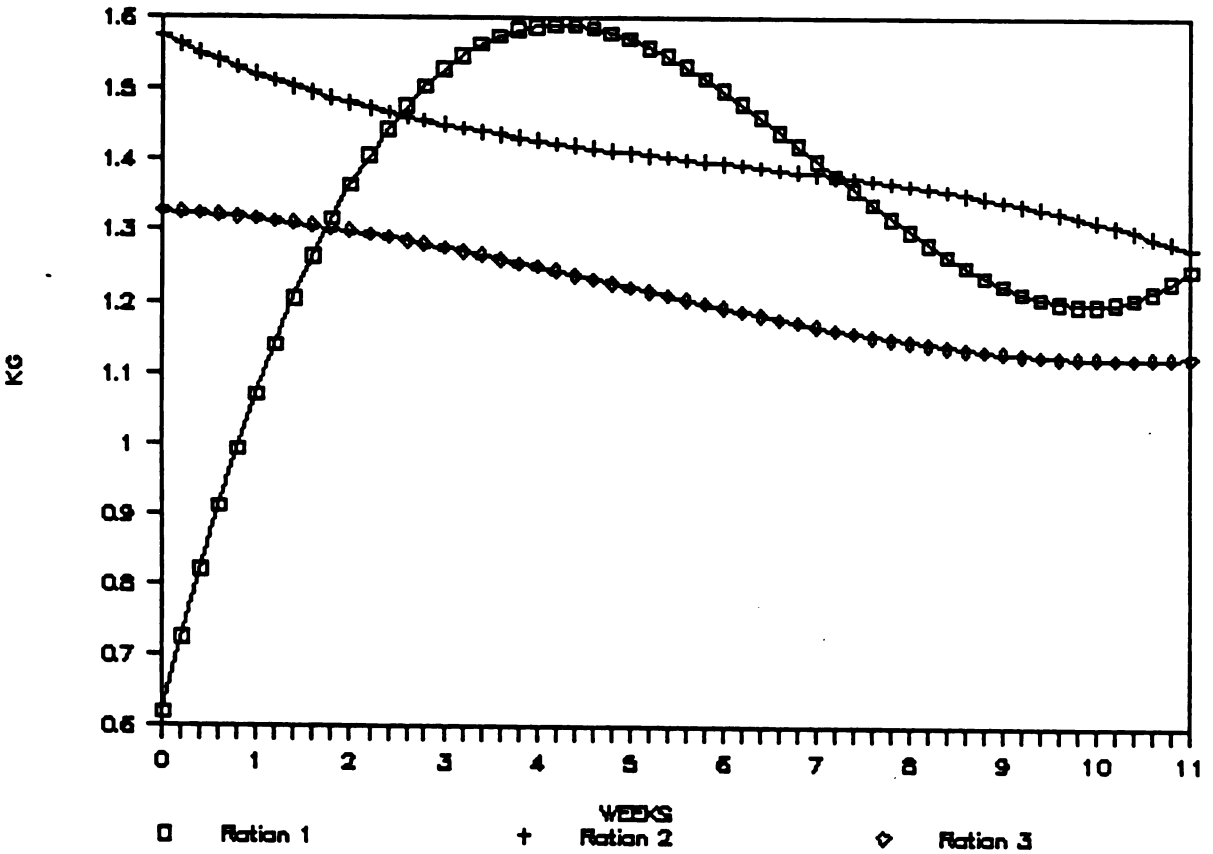

Figure 3. Regression plots of milk fat production of cows fed three different levels of ADF.

BODY WEIGHT AND BODY CONDITION

Body weight, body weight loss, body condition score and loss of body condition were not affected by the ration consumed ($P>.10$) (Table 9). Fat cows weighed more ($P<.05$) and lost more body weight than thin cows ($P<.05$) but there was no difference between fat or thin cows in body condition score or change in body condition score ($P>.10$). Because the fat cows had significantly higher body condition scores prepartum, a majority of the loss of body condition must have occurred in the week of and in the first week after parturition which was not measured. This implies that loss of body condition is quite rapid.

There was a strong effect of time on body weight, body weight loss, body condition score and change in body condition score ($P<.01$). Analysis of the cubic regression equation for effects of body condition on body weight revealed that the intercept was the only significantly different parameter among rations ($P<.05$, Figure 4). Multivariate analysis of variance revealed a trend for an interaction of body condition and ration ($P<.10$). These interactions are represented in Figures 5, 6 and 7. Visual analysis leads one to conclude that the cows consuming ration 2 and in heavy body condition lost weight at a slower rate than those cows fed ration 1 or 3.

As would be expected, body condition had a significant effect on body condition score ($P<.05$); that is fat cows had higher body condition score than thin cows. But the

Table 9. Treatment means and selected contrasts for cows fed three ADF levels and at two body conditions for body measurement variables.

Variable	Treatment	Selected Contrast	Means	Mean	Units	SED	P[a]	Significant Interactions
Body weight	Body Condition	Thin v fat	543.00	571.00	kg	11.2	0.04	Ration * body condition (P<.01)
		Ration 1 v 3	548.00	558.00	kg	13.2		
	Ration	Ration 1 v 2	548.00	565.00	kg	14.0		Body condition *lactation week (P<.10)
		Ration 2 v 3	565.00	558.00	kg	14.0		
		1st lactation v later	490.00	593.00	kg	11.6	0.01	
Loss of body weight	Body Condition	Thin v fat	-16.60	-36.80	kg	9.1	0.04	Body condition *lactation week (P<.05)
		Ration 1 v 3	21.70	28.80	kg	10.8		
	Ration	Ration 1 v 2	21.70	27.80	kg	11.4		
		Ration 2 v 3	27.80	28.80	kg	11.4		
		1st lactation v later	18.50	30.12	kg	9.5	0.05	
Body condition score	Body Condition	Thin v fat	1.60	2.00		0.20	0.05	Body condition *lactation week (P<.05)
		Ration 1 v 3	1.83	1.89		0.23		
	Ration	Ration 1 v 2	1.83	1.68		0.24		
		Ration 2 v 3	1.68	1.89		0.24		Ration * body condition (P<.10)
		1st lactation v later	1.96	1.85		0.20		
Loss of body condition score	Body Condition	Thin v fat	-0.60	-0.75		0.18		Body condition *lactation week (P<.10)
		Ration 1 v 3	0.81	0.62		0.21		
	Ration	Ration 1 v 2	0.81	0.57		0.22		
		Ration 2 v 3	0.57	0.62		0.22		
		1st lactation v later	0.80	0.60		0.18		

[a]Contrasts not listed are not significantly different (P > .10).

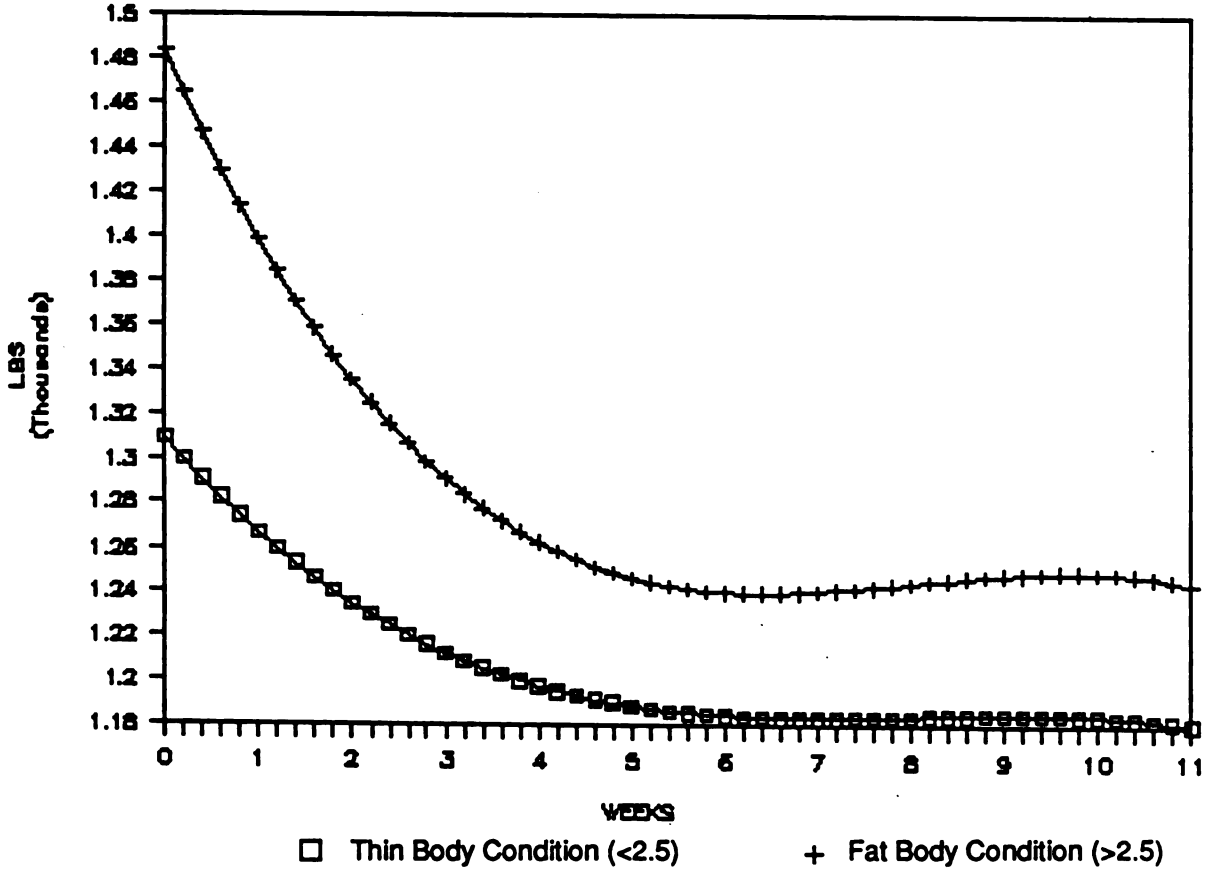

Figure 4. Regression plots of the body weight of cows at two different body conditions.

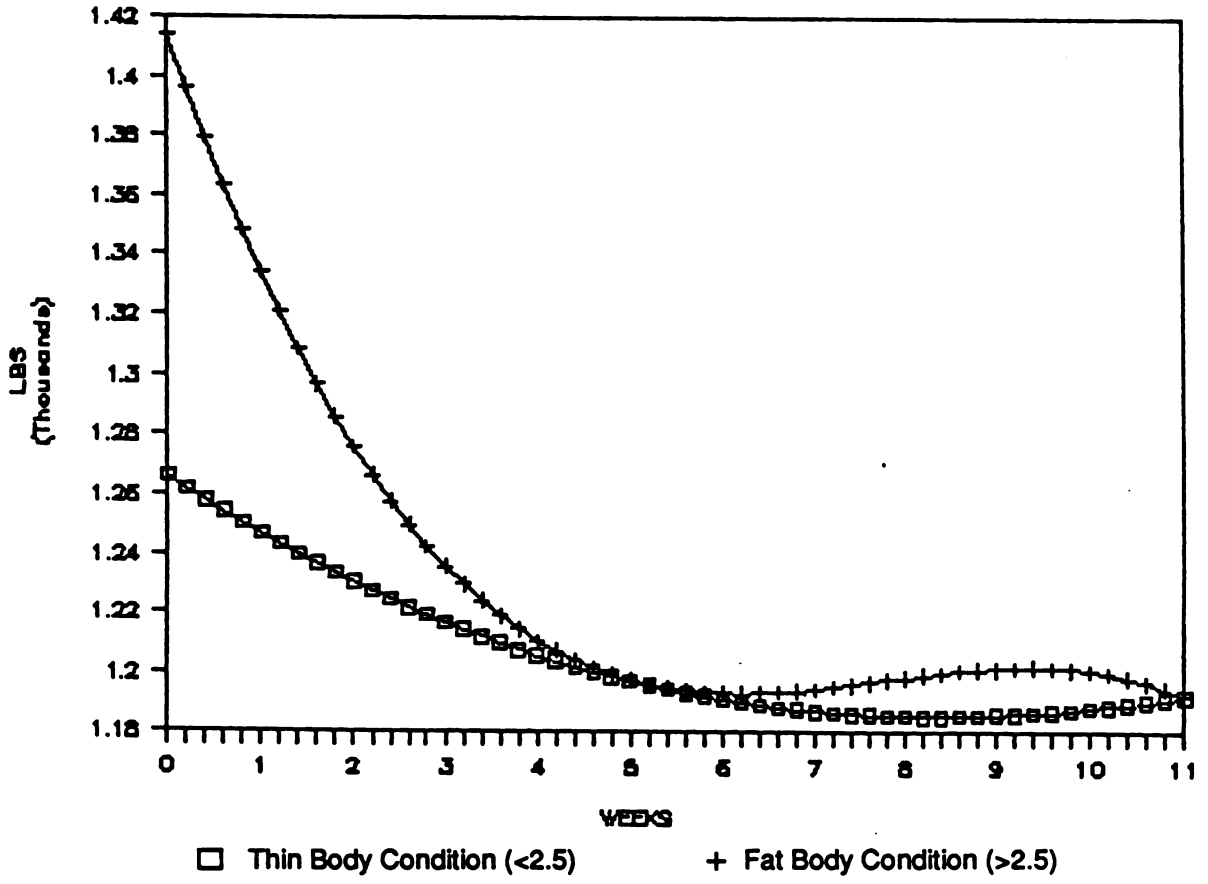

Figure 5. Regression plots of the effect of interaction between ration 1 and body condition on body weight.

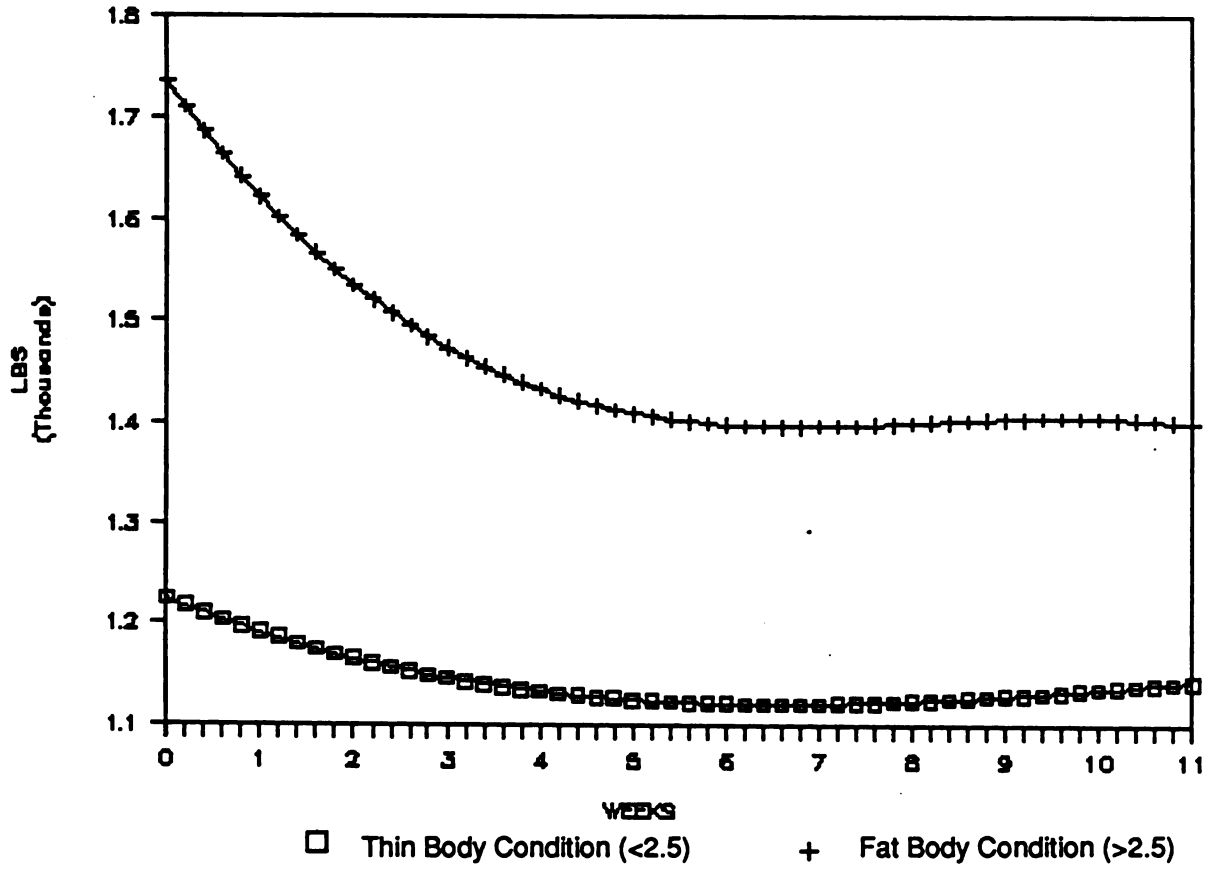

Figure 6. Regression plots of the effect of interaction between ration 2 and body condition on body weight.

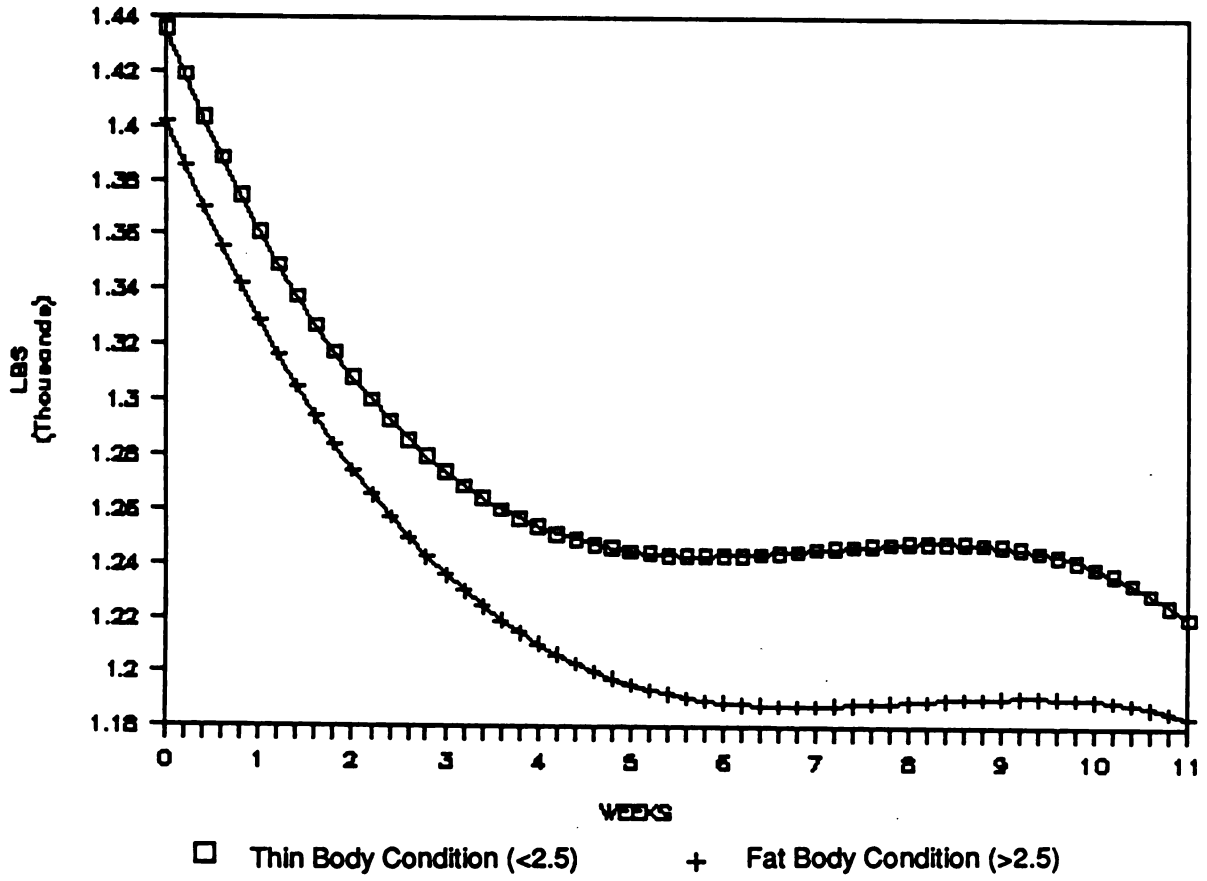

Figure 7. Regression plots of the effect of interaction between ration 3 and body condition on body weight.

loss of body condition was not different between fat and thin cows (P>.10) . Week of lactation had a significant effect on body condition score and change in body condition score. A significant body condition by time interaction was also detected (P<.05). Additionally, there tended to be interaction between week of lactation and body condition for body weight, body condition score and change in body condition score (P<.10).

Univariate analysis of the regression equations for body condition score (mean R^2=.66) revealed that the intercept was the only parameter that was affected by body condition. Also revealed by MANOVA was a significant diet by body condition interaction for the regression equations (P<.05, Figures 8, 9, 10, 11, 12). Visual analysis of regression plots revealed that this was due to the fat cows on ration 1 which fattened in the last weeks of the experiment. This fattening was detected as an increase in body weight.

DRY MATTER INTAKE

Total dry matter intake was not significantly affected by ration (Figure 13) or body condition (Figure 14) (P>.10) (see also Table 10 and Appendix Tables 11-20). There was a large effect of lactation week (P<.01) as well as a highly significant difference in the DMI between primiparous and multiparous cows (P<.01). In this experiment, multiparous cows ate almost 38% more.

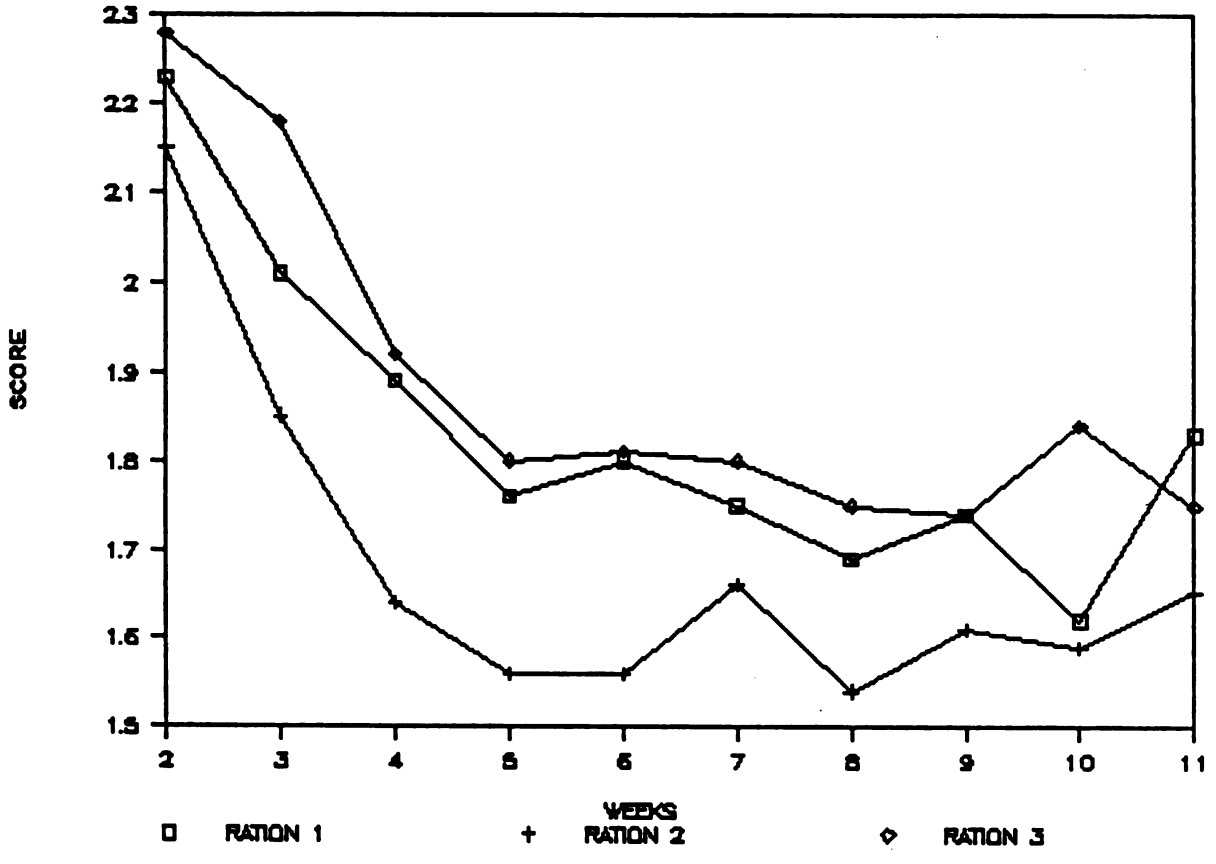

Figure 8. Mean weekly body condition score of cows fed three different levels of ADF.

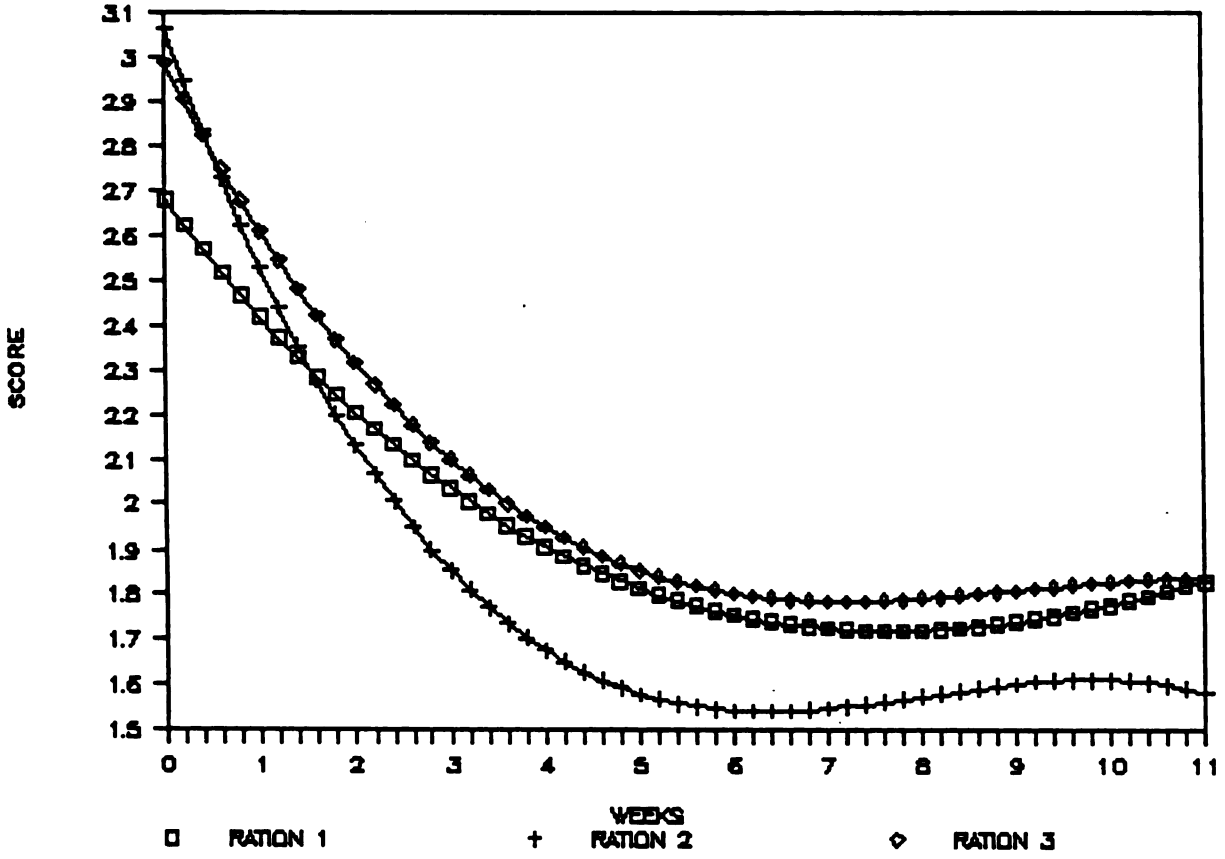

Figure 9. Regression plot of body condition score of cows fed three different levels of ADF.

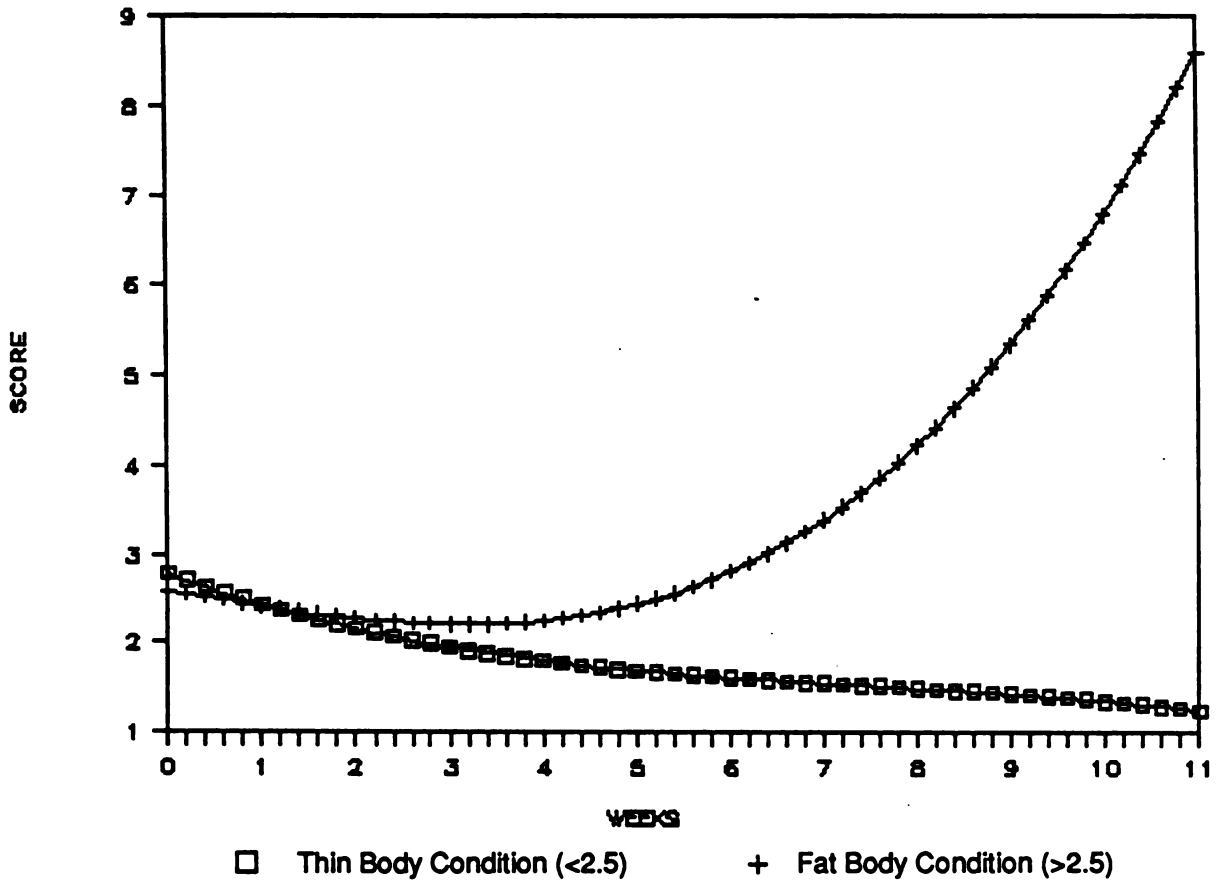

Figure 10. Regression plots of the interaction of ration 1 and body condition on body condition score.

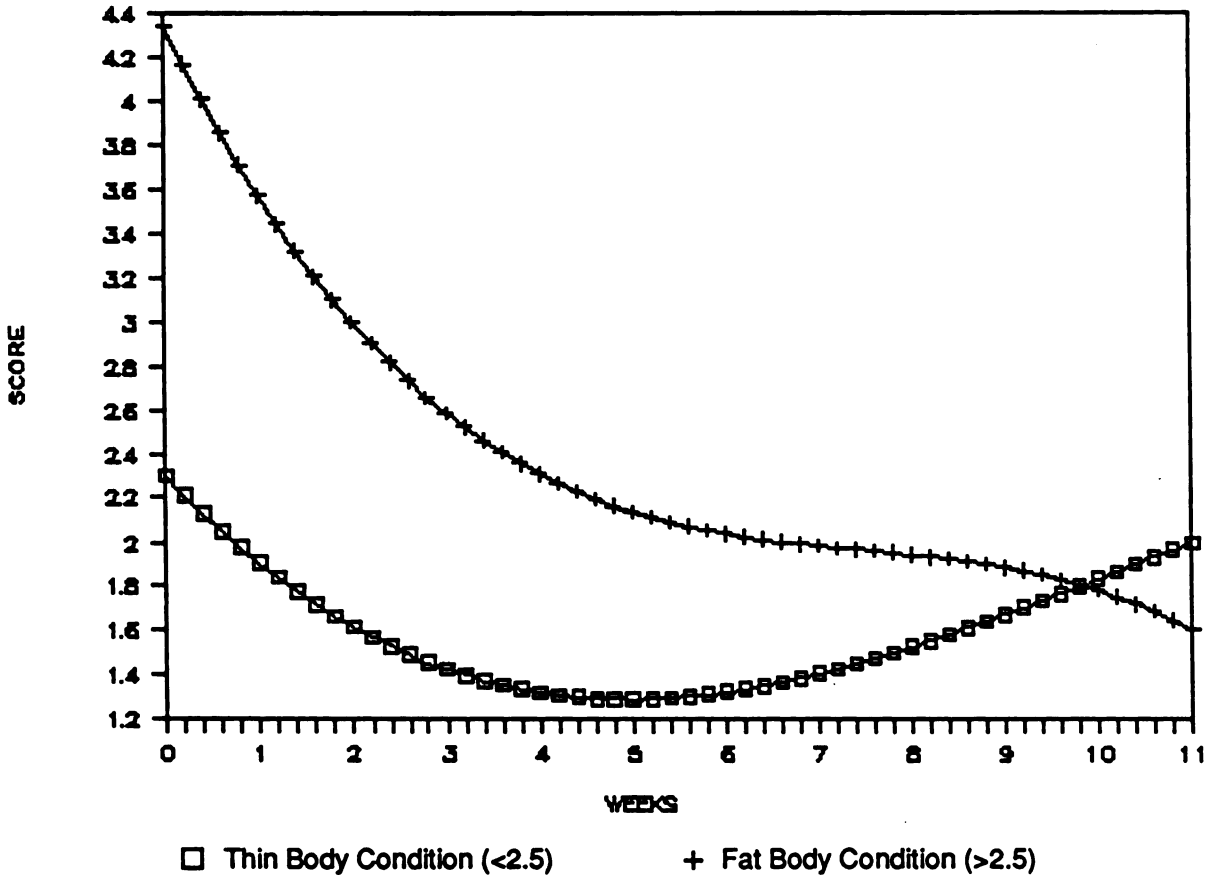

Figure 11. Regression plots of the interaction of ration 2 and body condition on body condition score.

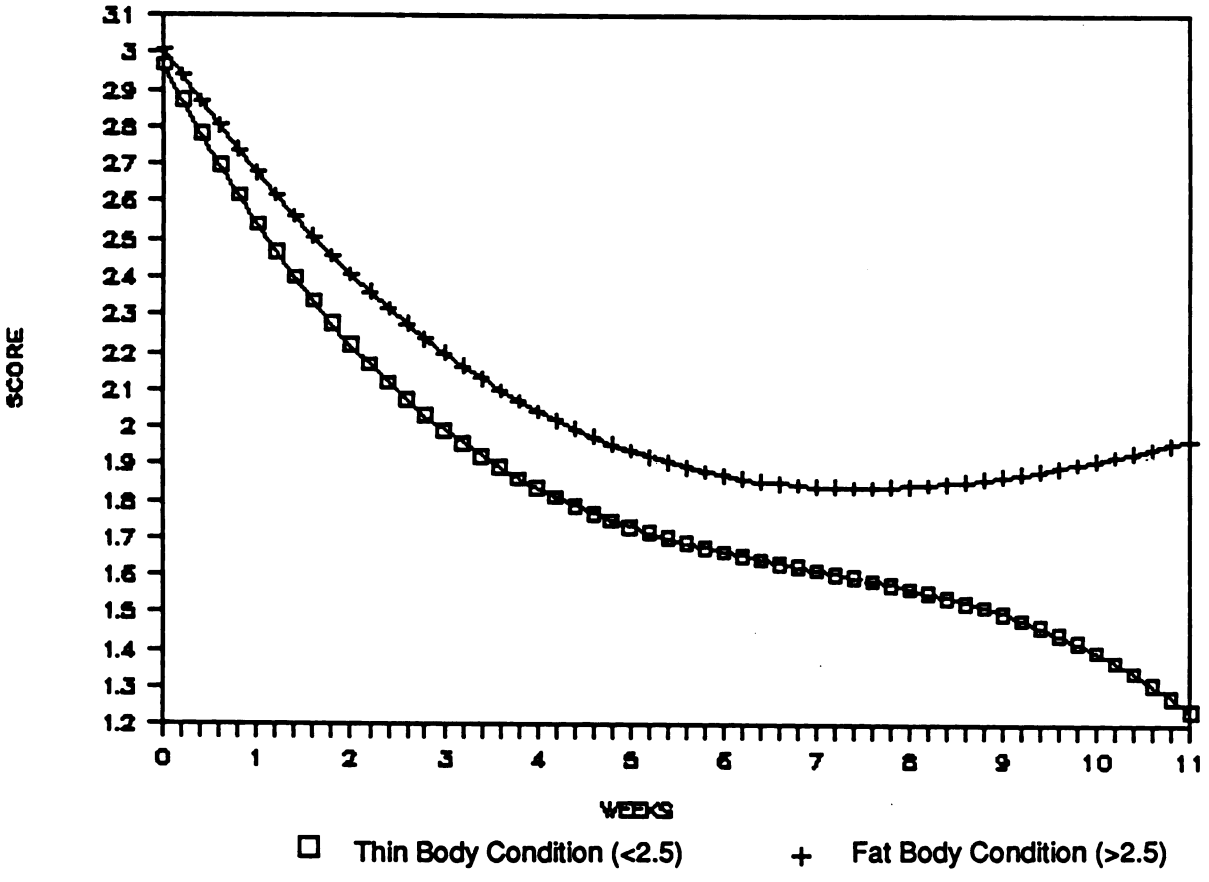

Figure 12. Regression plots of the interaction of ration 3 and body condition on body condition score.

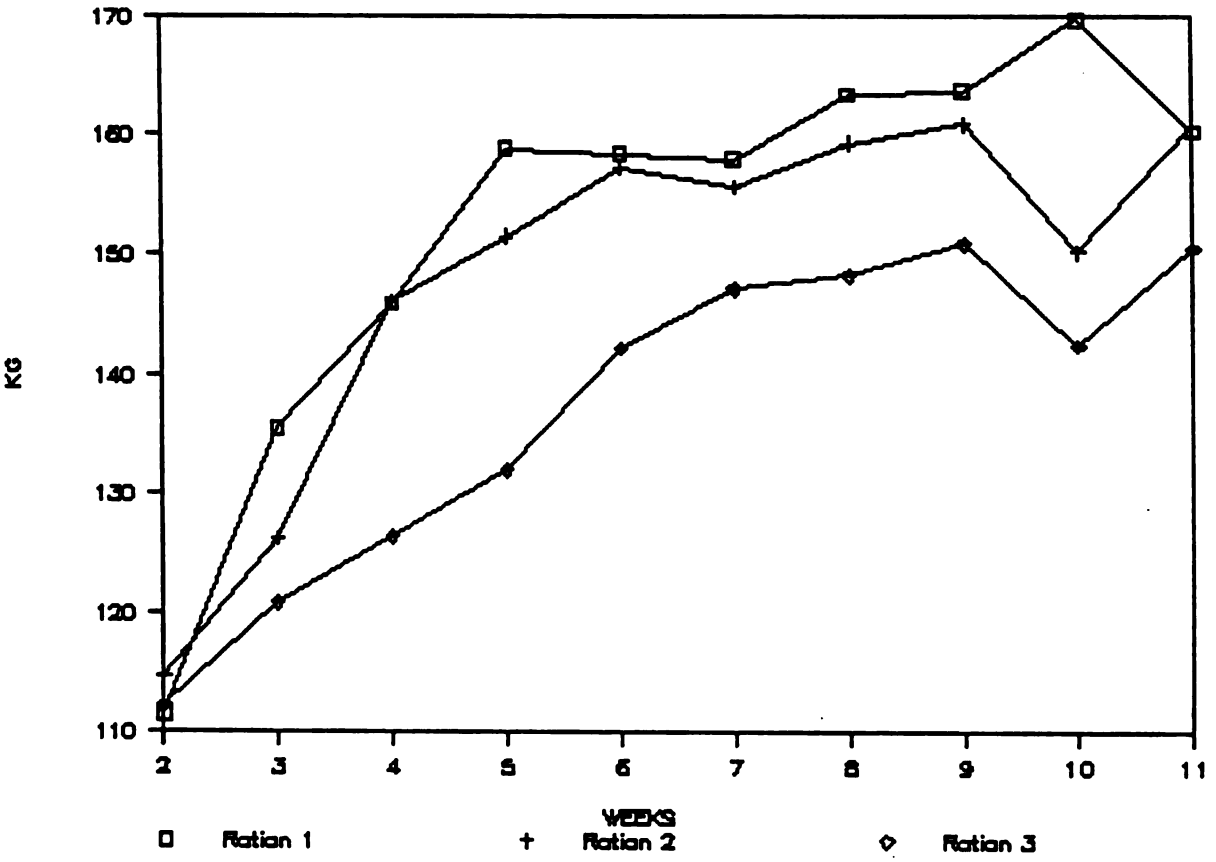

Figure 13. Mean weekly dry matter intake of cows fed three different levels of ADF.

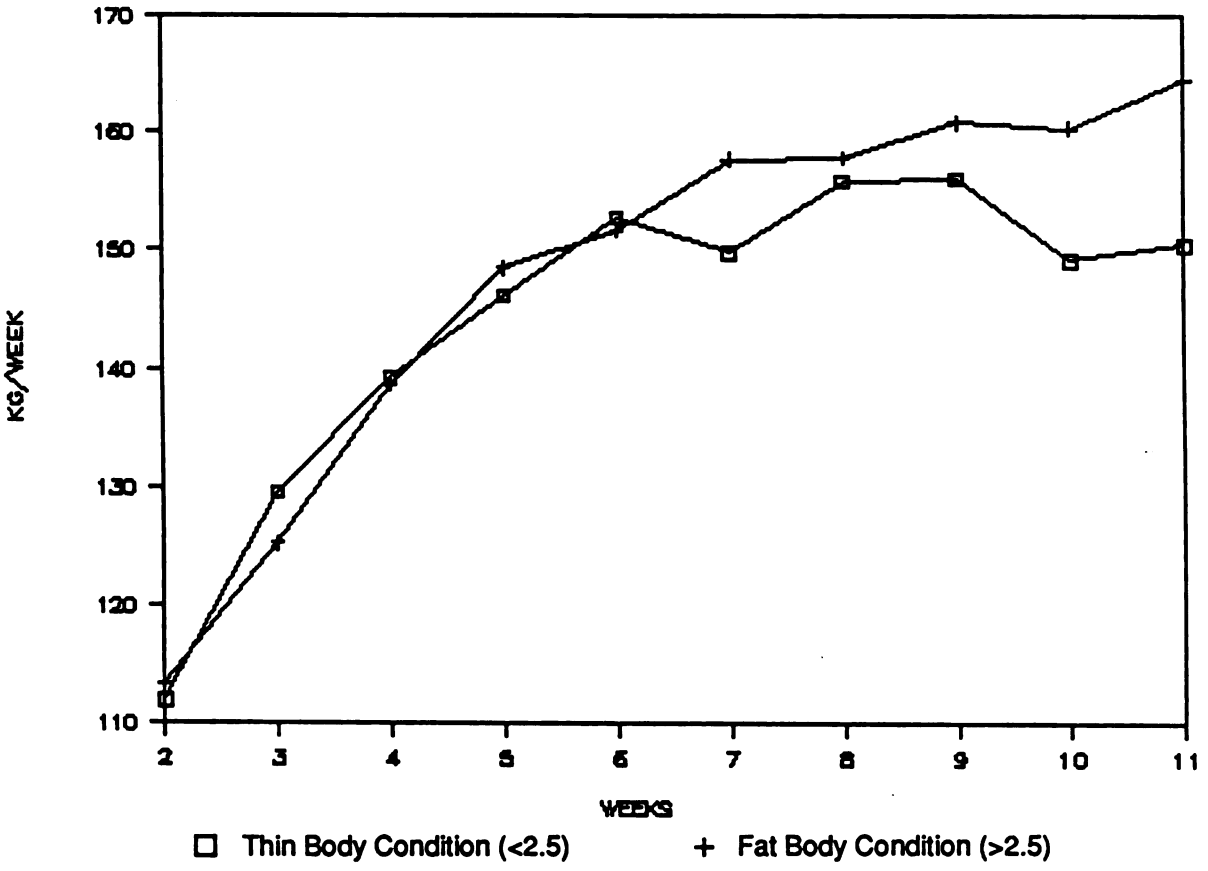

Figure 14. Mean weekly dry matter intake of cows at two different body condition scores.

Table 10. Treatment means and selected contrasts for cows fed three ADF levels and at two body conditions for feed intake variables.

Variable	Treatment	Selected Contrast	Means	Mean	SED	Units	P[a]	Significant Interactions
Dry matter intake	Body Condition	Thin v fat	144.10	147.90	14.6	kg		
	Ration	Ration 1 v 3	152.50	137.30	17.3	kg		
		Ration 1 v 2	152.50	148.30	18.3	kg		
		Ration 2 v 3	148.30	137.30	18.3	kg		
		1st lactation v later	116.90	162.00	15.2	kg	0.01	
DMI/100 kg body weight	Body Condition	Thin v fat	26.50	25.80	1.14	kg/100 kg		
		Ration 1 v 3	27.78	24.46	1.34	kg/100 kg	0.10	
	Ration	Ration 1 v 2	27.78	26.37	1.43	kg/100 kg		
		Ration 2 v 3	26.37	24.46	1.43	kg/100 kg		
		1st lactation v later	23.93	27.40	1.18	kg/100 kg	0.01	
NDF consumed	Body Condition	Thin v fat	51.60	52.45	2.7	kg		
		Ration 1 v 3	50.90	52.10	3.2	kg		
	Ration	Ration 1 v 2	50.90	53.30	3.4	kg		
		Ration 2 v 3	53.30	52.10	3.4	kg		
		1st lactation v later	40.10	58.50	2.8	kg	0.01	
NDF consumed % of body weight	Body Condition	Thin v fat	9.46	9.13	0.47	kg/100 kg		
		Ration 1 v 3	9.24	9.26	0.55	kg/100 kg		
	Ration	Ration 1 v 2	9.24	9.43	0.58	kg/100 kg		
		Ration 2 v 3	9.43	9.26	0.58	kg/100 kg		
		1st lactation v later	8.22	9.90	0.49	kg/100 kg	0.01	

Continued

Table 10. (Continued)

Variable	Treatment	Selected Contrast	Means	Mean	SED	Units	P	Significant Interactions
ADF consumed	Body Condition	Thin v fat	28.80	29.20	1.5	kg		
		Ration 1 v 3	26.40	30.90	1.8	kg	0.10	
	Ration	Ration 1 v 2	26.40	29.80	1.9	kg		
		Ration 2 v 3	29.80	30.90	1.9	kg		
		1st lactation v later	22.60	32.60	1.6	kg	0.01	
ADF consumed % of body weight	Body Condition	Thin v fat	5.27	5.10	0.26	kg/100 kg		
		Ration 1 v 3	4.81	5.50	0.30	kg/100 kg		
	Ration	Ration 1 v 2	4.81	5.28	0.32	kg/100 kg		
		Ration 2 v 3	5.28	5.50	0.32	kg/100 kg		
		1st lactation v later	4.63	5.50	0.27	kg/100 kg	0.01	
Lignin consumed	Body Condition	Thin v fat	5.10	5.20	0.26	kg		Body condition * lactation week
		Ration 1 v 3	4.58	5.75	0.32	kg	0.05	(P<.01)
	Ration	Ration 1 v 2	4.58	5.18	0.34	kg		
		Ration 2 v 3	5.18	5.75	0.34	kg		
		1st lactation v later	4.12	5.75	0.28	kg	0.01	
Lignin consumed % of body weight	Body Condition	Thin v fat	0.94	0.92	0.04	kg/100 kg		Body condition * lactation week
		Ration 1 v 3	0.83	1.02	0.05	kg/100 kg	0.01	(P<.01)
	Ration	Ration 1 v 2	0.83	0.92	0.06	kg/100 kg		
		Ration 2 v 3	0.92	1.02	0.06	kg/100 kg		
		1st lactation v later	0.84	0.97	0.05	kg/100 kg	0.01	

Continued

Table 10. (Continued)

Variable	Treatment	Selected Contrast	Means	Mean	SED	Units	P	Significant Interactions
Ash consumed	Body Condition	Thin v fat	9.60	9.96	0.49	kg		Body condition * lactation week
		Ration 1 v 3	9.44	9.99	0.57	kg		(P<.05)
	Ration	Ration 1 v 2	9.44	9.91	0.61	kg		
		Ration 2 v 3	9.91	9.99	0.61	kg		
		1st lactation v later	8.22	10.64	0.50	kg	0.01	
Ash consumed % of body weight	Body Condition	Thin v fat	1.77	1.74	0.09	kg/100 kg		Body condition * lactation week
		Ration 1 v 3	1.72	1.78	0.10	kg/100 kg		(P<.01)
	Ration	Ration 1 v 2	1.72	1.77	0.11	kg/100 kg		
		Ration 2 v 3	1.77	1.78	0.11	kg/100 kg		
		1st lactation v later	1.68	1.80	0.09	kg/100 kg		

[a]Contrasts not listed are not significantly different (P > .10).

Regression equation analysis revealed no differences in intercept or slope parameters (P>.10) among diets or between body conditions.

Dry matter intake as a percent of body weight did tend to be higher (P<.10) for ration 1 than ration 3. Primiparous cows consumed less dry matter as a percent of body weight than did multiparous cows (P<.01). Analysis of parameters for regression equations revealed no differences due to ration or body condition (P>.10).

Ingested amount of NDF and ash were not different for either rations or body condition (P>.10). ADF intake tended to be greater for cows consuming ration 3 than ration 1 (P<.10) while lignin intake was significantly higher for cows fed ration 3 than ration 1 (P<.01). First lactation cows, because of lower dry matter intake, ate significantly less NDF, ADF, lignin and ash (P<.01). For all rations, consumption of all fiber fractions as a percent of body weight was only slightly different, but less significantly so than that of total fiber intake (Table 10). As a percent of body weight, primiparous blocks ate less fiber constituents than mature cows (P<.05).

Univariate analysis of the regression equation parameters for amounts of ingested NDF among rations indicated that there were no differences in intercept or slopes of the regression line (P<.10). There was no

evidence from the Manova of any differences in NDF intake (P>.10). That is, the regression equation confirmed that the cows all consumed the same amount of NDF. There was evidence for a body condition by ration interaction (Figures 15, 16 and 17). Visual analysis of the regression plots indicated that fat cows eating ration 2 consumed more NDF than the thin cows. For cows consuming rations 1 and 3, the thin cows consumed more NDF than did fat cows. Similar analysis of the regression equations for ingestion of ADF indicated a significant effect of body condition (P <.05) on ADF consumption (Figure 18). Fat cows consumed more ADF than thin cows.

BLOOD METABOLITES

Blood metabolite and insulin concentrations were unaffected by ration (P>.10, Table 11) except for ß-hydroxy butyric acid (BHBA) (ration 1 less than ration 3, P<.05; ration 2 less than ration 3, P<.10) (Figure 19). There was a trend for TG to be affected by diet (ration 1 less than ration 3, P<.10). Ratio of BHBA:acetoacetic acid was significantly affected by body condition with thin cows having significantly (P<.05) higher ratios than fat cows.

All blood metabolites showed significant differences with advancing lactation (P<.05) except ketone ratios and plasma insulin (P>.10, Figures 20, 21, 22, 23, 24 and 25).

Analysis of regression coefficients and MANOVA testing revealed no effect of diet or body condition on any blood variable except NEFA. Univariate analysis of the

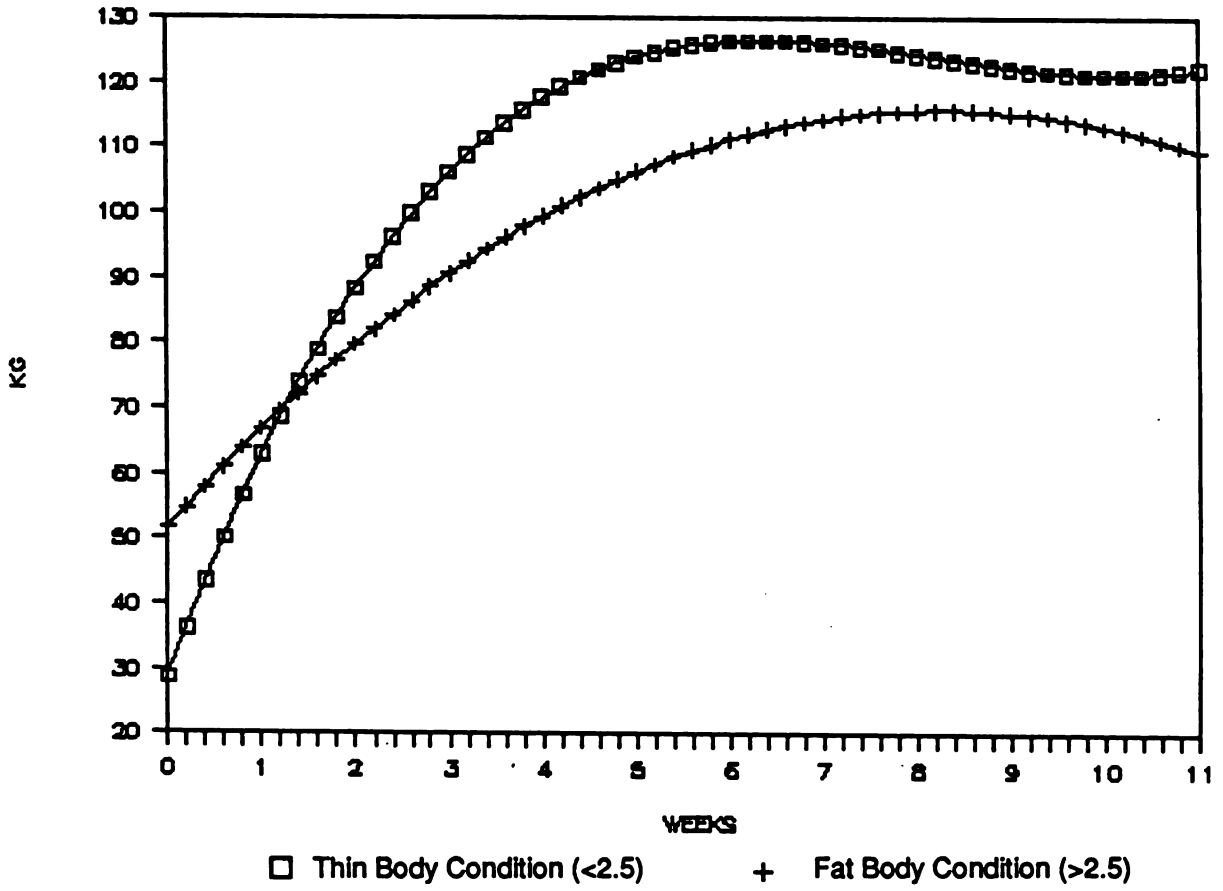

Figure 15. Regression plots of the effect of the NDF consumption in ration 1 and body condition on body weight.

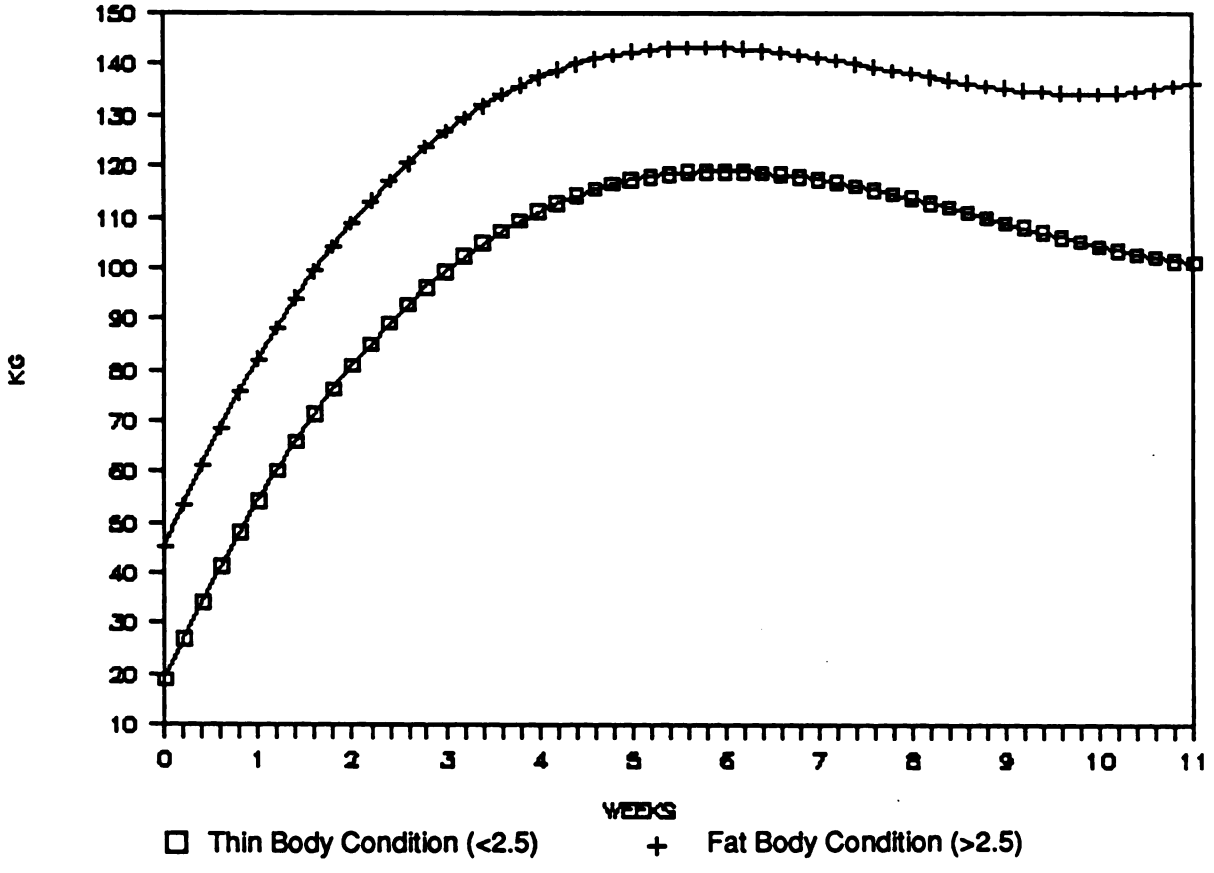

Figure 16. Regression plots of the effect of the NDF consumption in ration 2 and body condition on body weight.

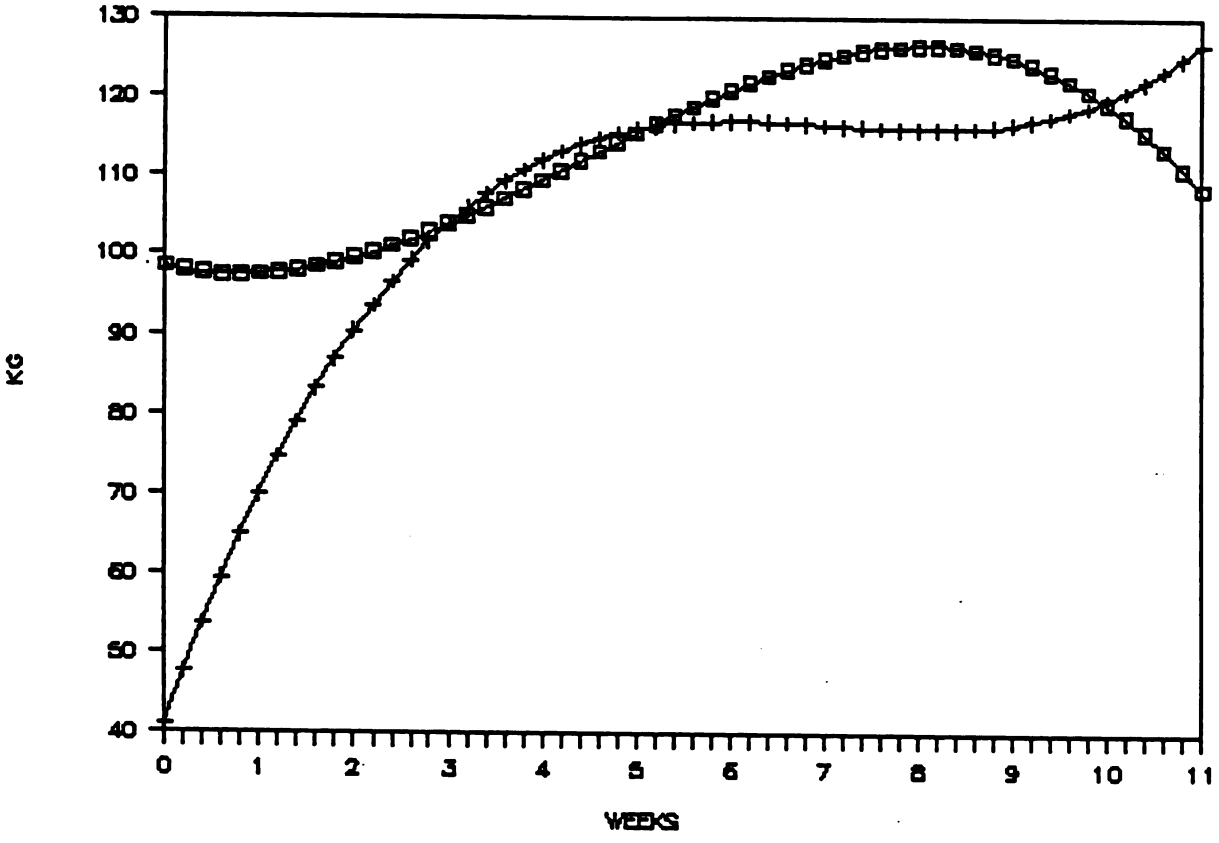

Figure 17. Regression plots of the effect of the NDF consumption in ration 3 and body condition on body weight.

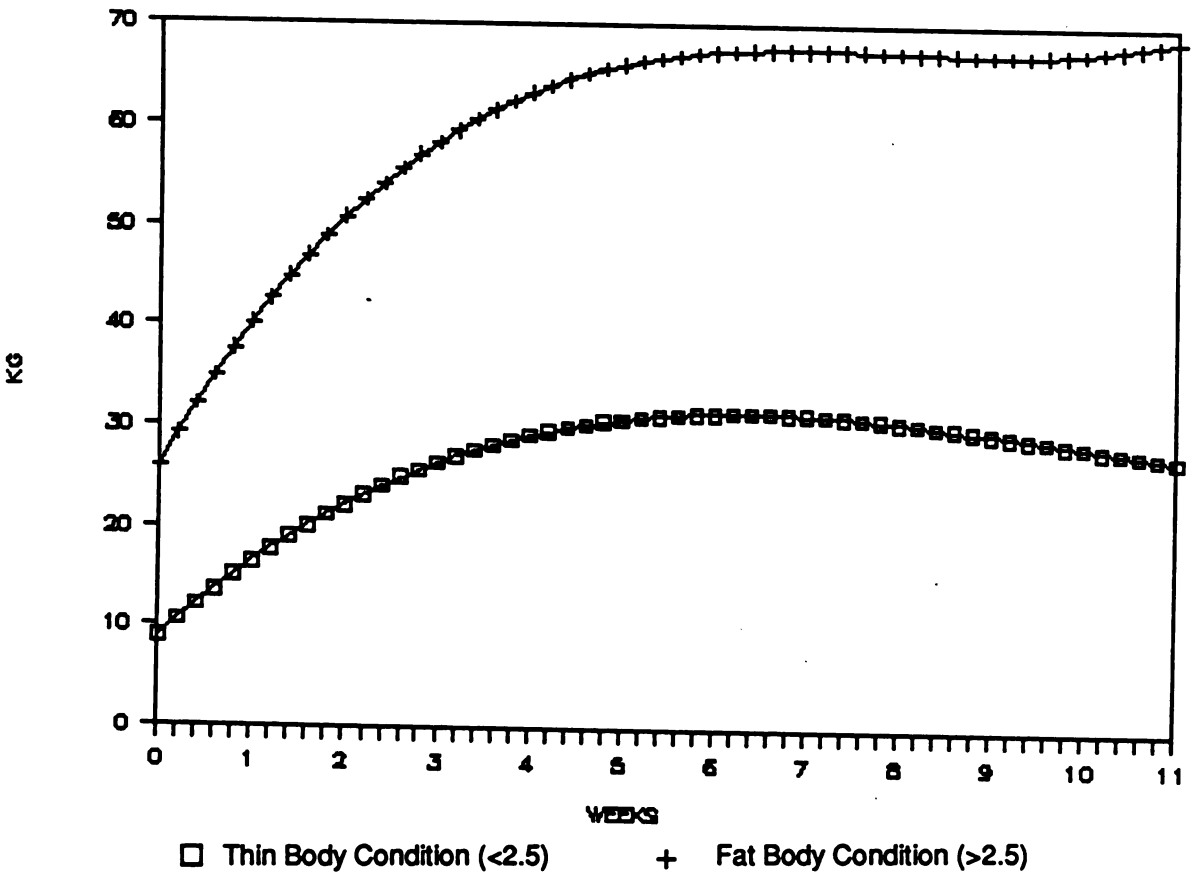

Figure 18. Regression plots of the effect of body condition on ADF consumption.

Table 11. Weekly means and selected contrasts of blood metabolites and plasma insulin among cows fed three levels of ADF and at two body conditions.

Variable	Treatment	Selected Contrast	Means	Mean	SED	Units	P[a]	Significant Interaction
Blood BHBA concentration	Body Condition	Thin v fat	0.565	0.537	0.044	mM		
	Ration	Ration 1 v 3	0.503	0.636	0.052	mM	0.05	
		Ration 1 v 2	0.503	0.508	0.056	mM		
		Ration 2 v 3	0.508	0.636	0.056	mM	0.10	
		1st lactation v later	0.485	0.552	0.046	mM		
Blood ACAC concentration	Body Condition	Thin v fat	0.023	0.013	0.006	mM	0.11	
		Ration 1 v 3	0.016	0.024	0.007	mM		
	Ration	Ration 1 v 2	0.016	0.016	0.008	mM		
		Ration 2 v 3	0.016	0.024	0.008	mM		
		1st lactation v later	0.019	0.018	0.006	mM		
Ratio BHBA:ACAC	Body Condition	Thin v fat	0.036	0.023	0.006		0.04	
		Ration 1 v 3	0.030	0.030	0.007			
	Ration	Ration 1 v 2	0.030	0.029	0.007			
		Ration 2 v 3	0.029	0.030	0.007			
		1st lactation v later	0.032	0.029	0.006			
Plasma NEFA concentration	Body Condition	Thin v fat	0.328	0.348	0.038	mM		
		Ration 1 v 3	0.322	0.370	0.044	mM		
	Ration	Ration 1 v 2	0.322	0.317	0.047	mM		
		Ration 2 v 3	0.317	0.370	0.047	mM		
		1st lactation v later	0.304	0.357	0.039	mM	0.05	

Continued

Table 11. (Continued)

Variable	Treatment	Selected Contrast	Means	Mean	SED	Units	P[a]	Significant Interaction
Plasma triacyl-glycerol concentration	Body Condition	Thin v fat	0.0071	0.0077	0.0006	mM		
	Ration	Ration 1 v 3	0.0065	0.0080	0.0007	mM	0.10	
		Ration 1 v 2	0.0065	0.0077	0.0008	mM		
		Ration 2 v 3	0.0077	0.0080	0.0008	mM		
		1st lactation v later	0.0070	0.0075	0.0006	mM		
Plasma creatinine concentration	Body Condition	Thin v fat	0.146	0.146	0.006	mM		
	Ration	Ration 1 v 3	0.143	0.148	0.007	mM		
		Ration 1 v 2	0.143	0.147	0.007	mM		
		Ration 2 v 3	0.147	0.146	0.007	mM		
		1st lactation v later	0.144	0.147	0.006	mM		
Plasma glucose concentration	Body Condition	Thin v fat	0.373	0.379	0.009	mM	0.12	
	Ration	Ration 1 v 3	0.386	0.364	0.010	mM	0.10	
		Ration 1 v 2	0.386	0.379	0.011	mM		
		Ration 2 v 3	0.379	0.364	0.011	mM		
		1st lactation v later	0.395	0.365	0.009	mM	0.01	
Plasma insulin concentration	Body Condition	Thin v fat	0.330	0.309	0.032	ng/ml		
	Ration	Ration 1 v 3	0.307	0.365	0.037	ng/ml		
		Ration 1 v 2	0.307	0.281	0.040	ng/ml		
		Ration 2 v 3	0.281	0.365	0.040	ng/ml	0.10	
		1st lactation v later	0.367	0.305	0.033	ng/ml	0.05	

Continued

Table 11. (Continued)

Variable	Treatment	Selected Contrast	Means	Mean	SED	Units	P[a]	Significant Interaction
Ratio glucose: insulin	Body Condition	Thin v fat	1.130	1.230	0.104			
	Ration	Ration 1 v 3	1.260	1.190	0.122			
		Ration 1 v 2	1.260	1.350	0.130			
		Ration 2 v 3	1.350	1.190	0.130			
		1st lactation v later	1.140	1.200	0.108			

[a]Contrasts not listed are not significantly different (P > .10).

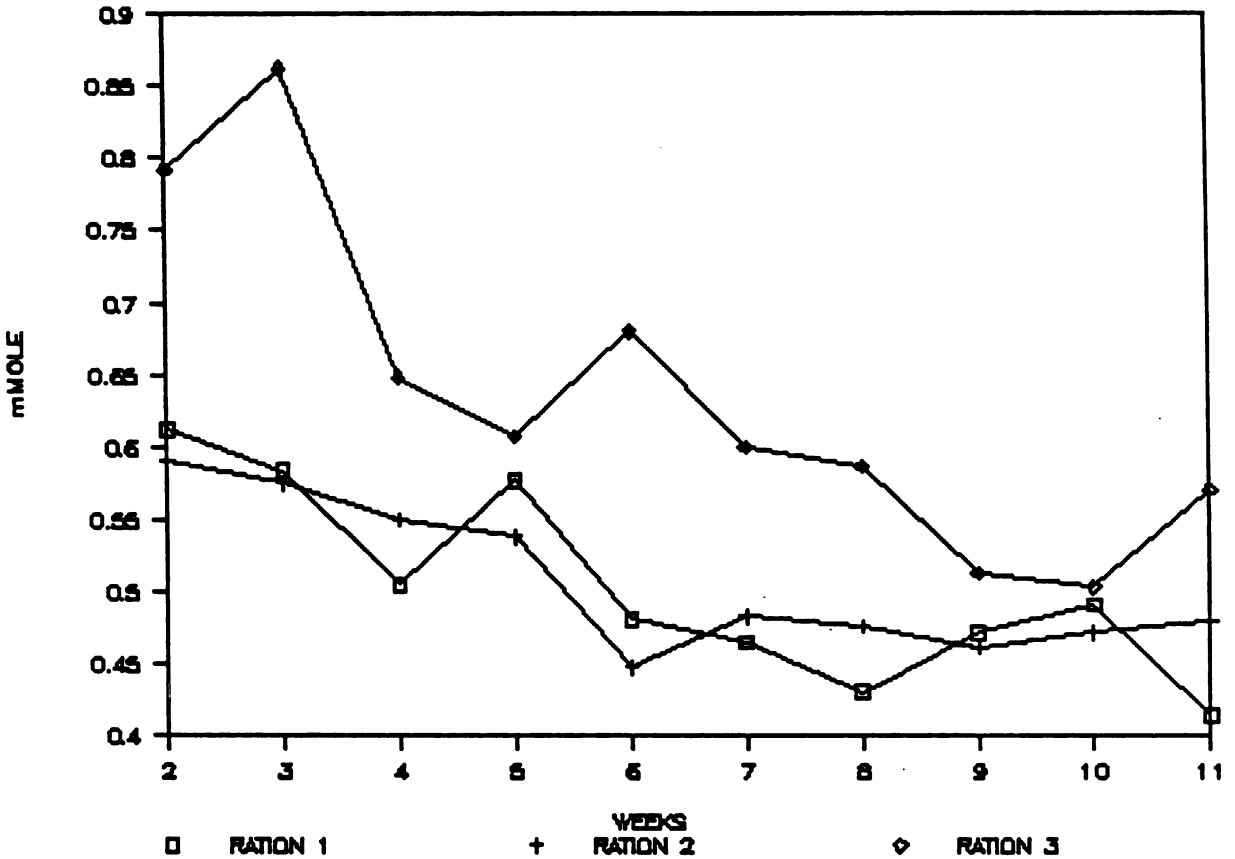

Figure 19. Mean weekly concentration of ß-hydroxybutyric acid (mMoles)in the whole blood of cows fed three different levels of ADF.

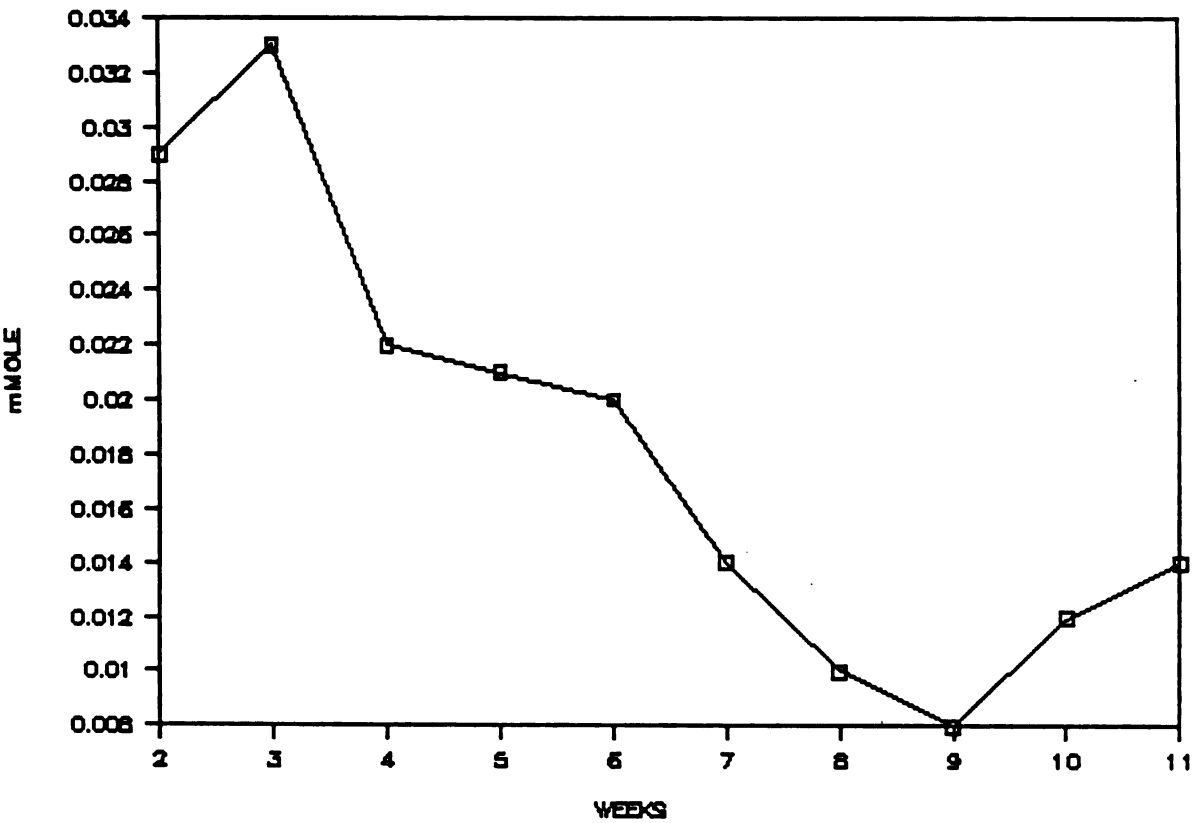

Figure 20. Mean weekly concentration of acetoacetic acid (mMoles) in the whole blood of experimental cows.

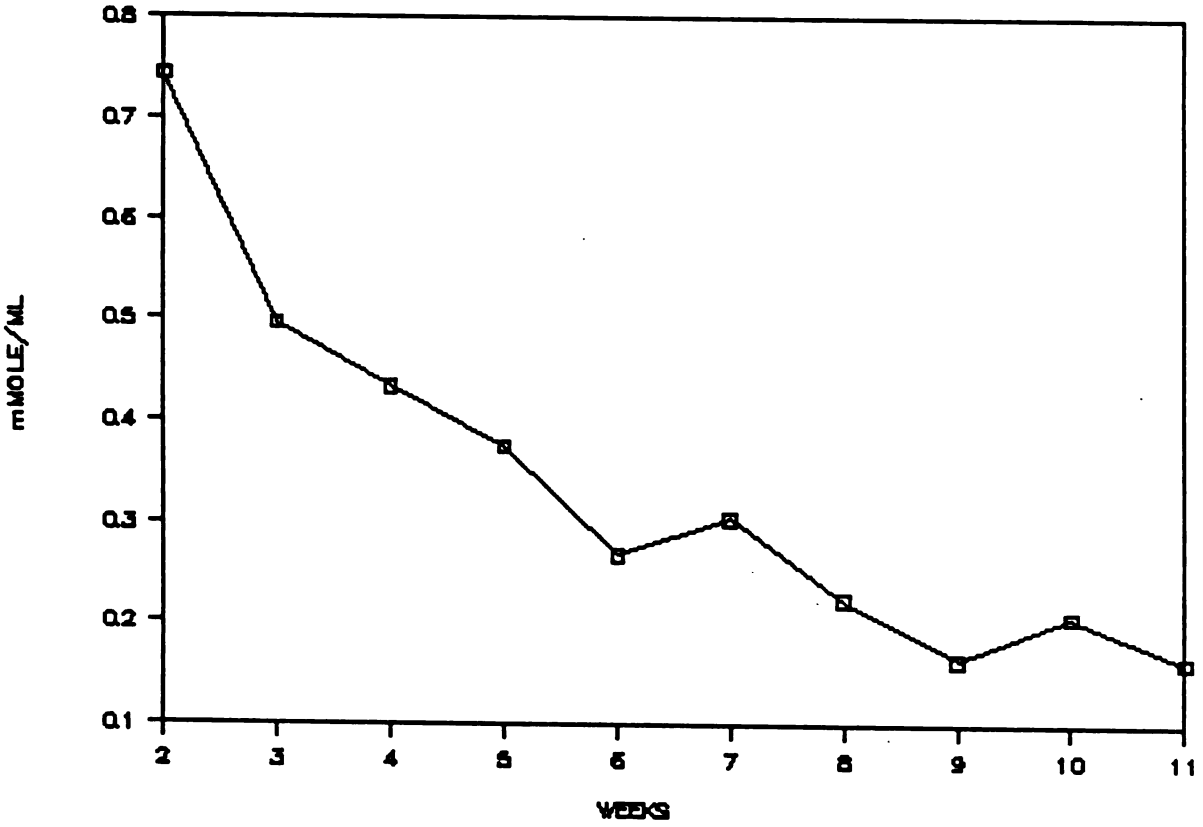

Figure 21. Mean weekly concentration of plasma nonesterified fatty acids (mMoles) of experimental cows.

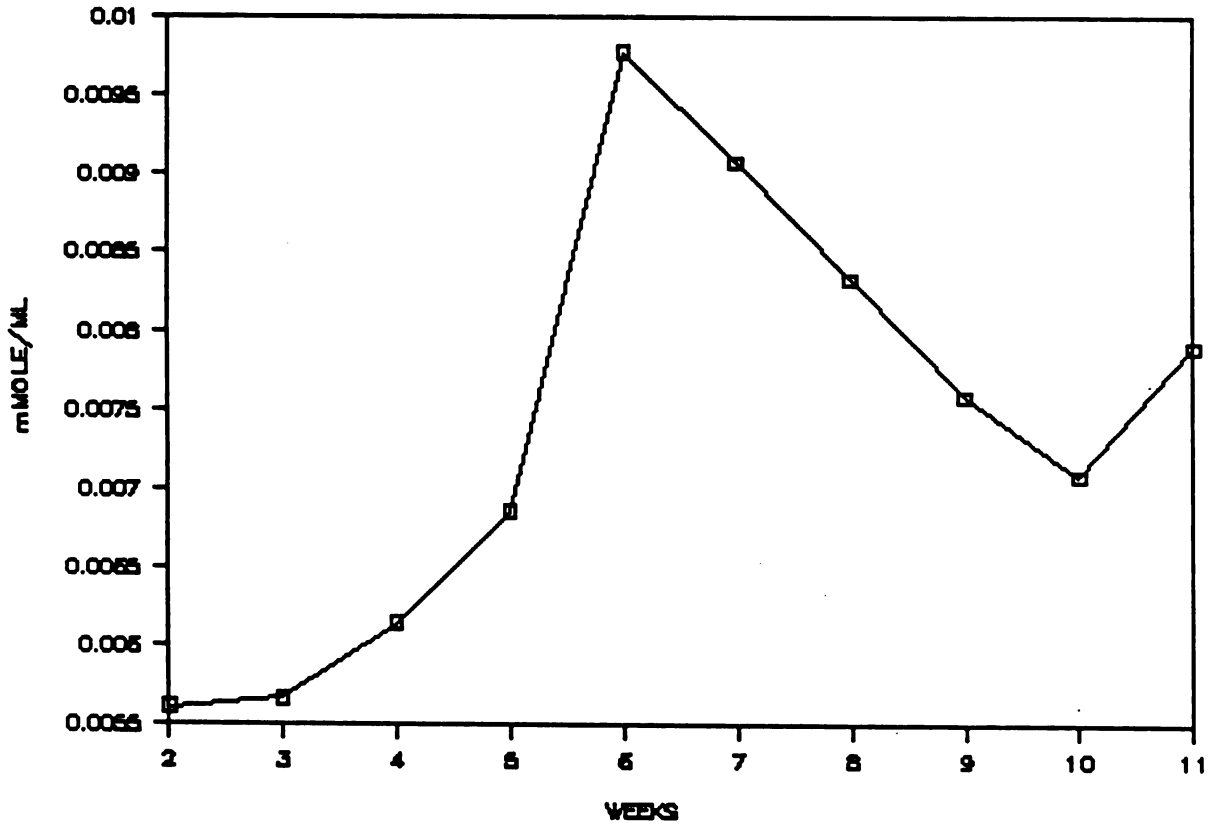

Figure 22. Mean weekly concentration of plasma triacylglycerol (mMoles) of experimental cows.

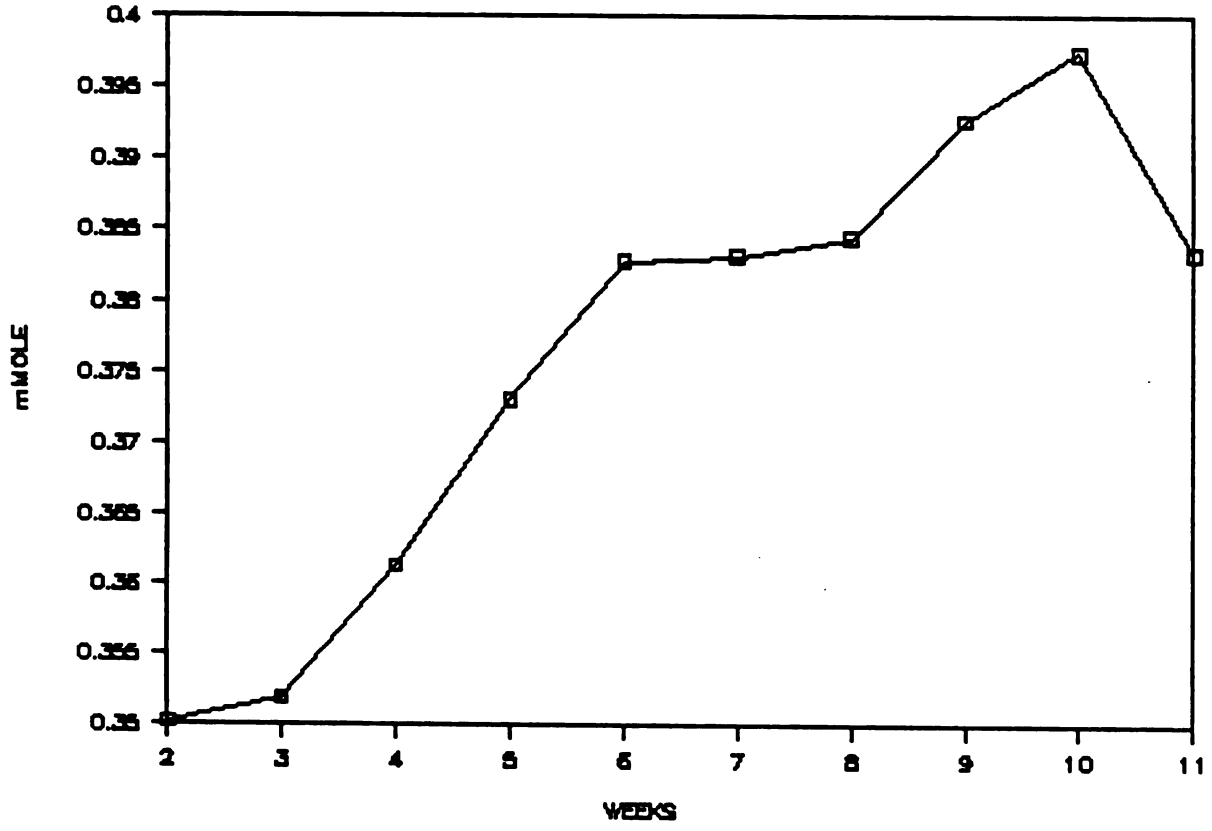

Figure 23. Mean weekly concentration of plasma glucose (mMoles) of experimental cows.

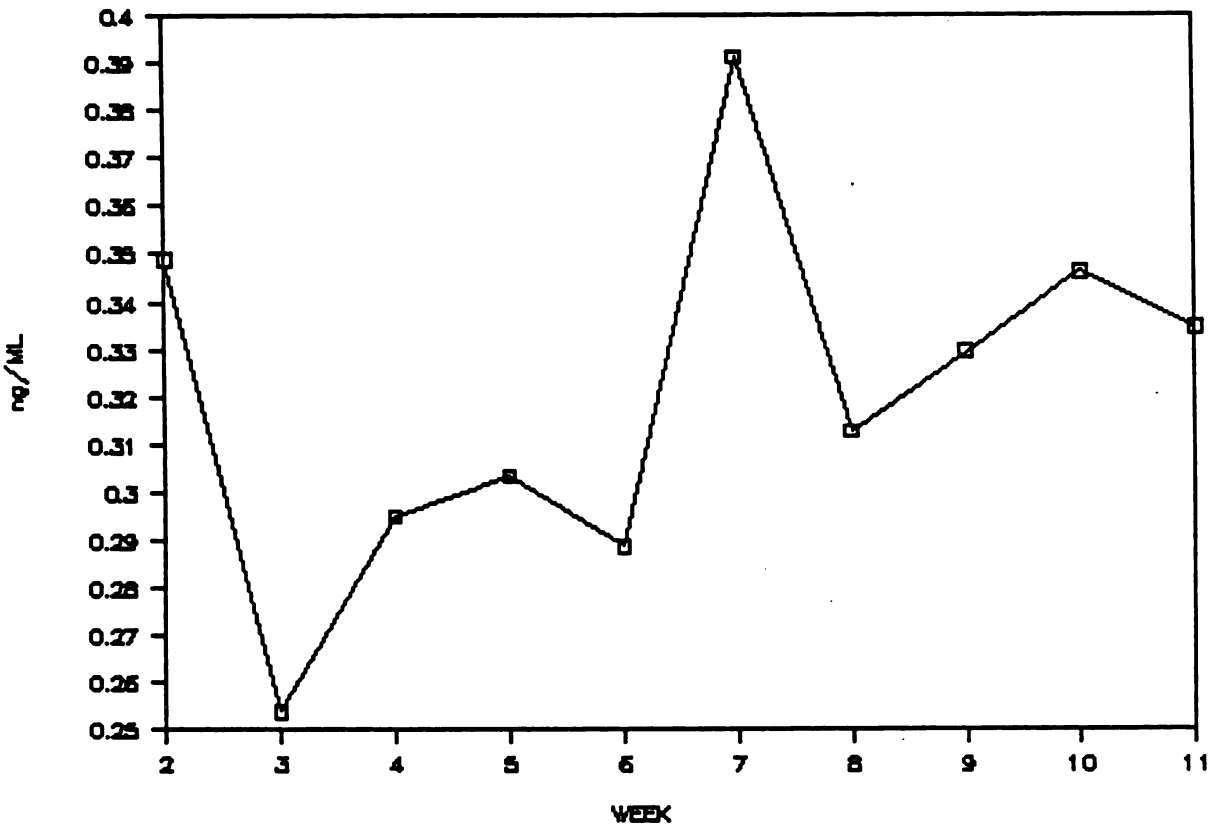

Figure 24. Mean weekly concentration of plasma insulin (ng/ml) of experimental cows.

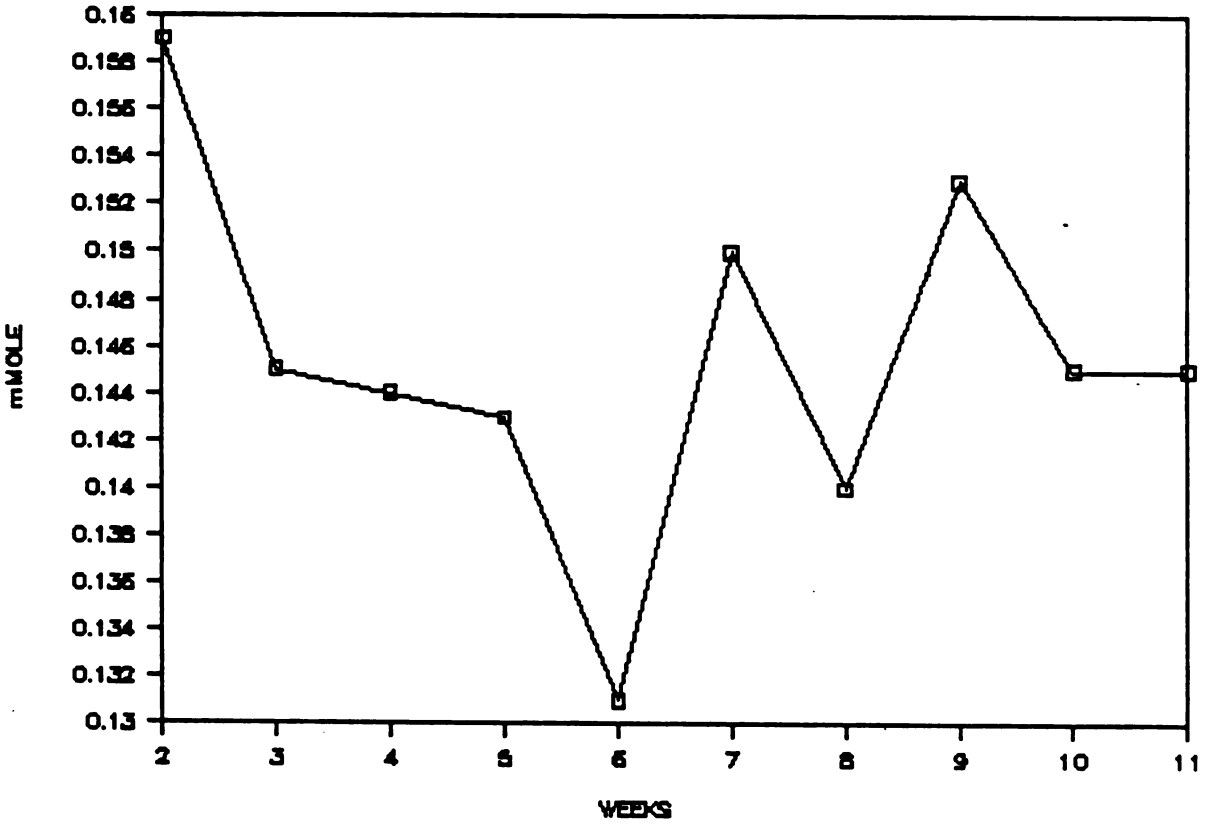

Figure 25. Mean weekly concentration of plama creatinine (mMoles) of experimental cows.

coefficients of the NEFA regression equations revealed a trend for the intercept and linear effects of lactation week to be different among rations ($P<.10$) while quadratic and cubic effects were non-significant ($P>.10$, Figure 26). First lactation cows had significantly lower NEFA levels ($P<.05$) but significantly higher plasma levels of glucose ($P<.01$) and insulin ($P<.05$) than did multiparous cows.

COMPARISON OF LACTATION WEEKS 8-11

As data from this experiment became available, it became increasingly clear that ration and body condition effects would be hard to measure in early lactation. It appeared as though the hormonal, neurological and metabolic effects of parturition were so great as to obscure the effect of ration or body condition. For this reason, a subset of data was prepared, consisting of only the last four lactation weeks of the experiment. Visual analysis of graphic data indicated that this period was relatively free from parturition effects.

Before examining this subset in more detail, it was of interest to compare the early weeks of lactation with the later weeks to see if there was a difference in the values of meaningful variables. The first three weeks of the experimental period (weeks 2-4) were chosen as the other comparison period because these weeks appeared to represent the maximal influence of the effect of parturition

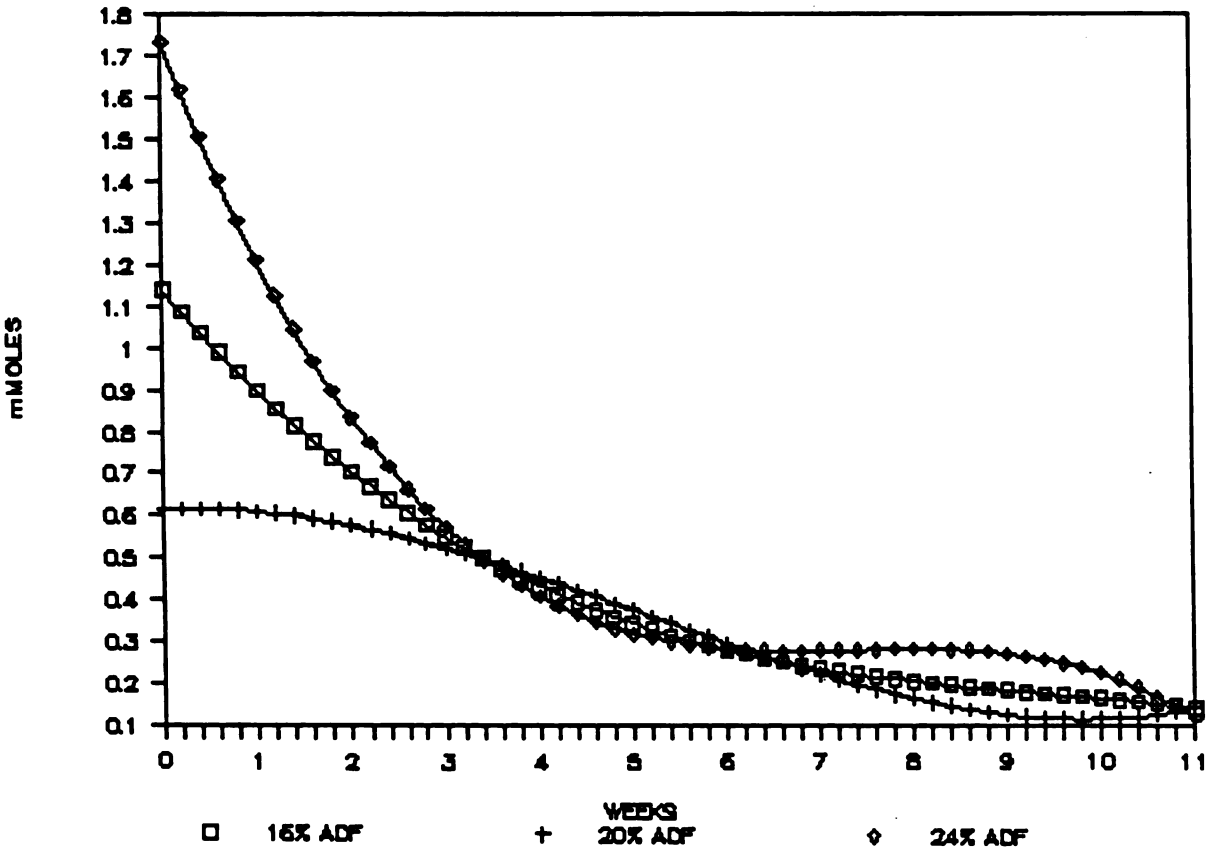

Figure 26. Regression plot of the effects of diet on plasma free fatty acid levels.

compared to those weeks that represented the maximal effects of dietary treatments (weeks 8-11). Because the prior selection of weeks to compare was made after initial study of the data, the probability of treatment effects have been conservatively estimated using the Bonferroni t statistic rather than the Students t for comparison of differences between treatment means.

There were significant differences for all variables between the early and late period except plasma creatinine and insulin, kg of milk protein/week and production of 4% FCM/100 kg of body weight (Table 12).

When only the last four lactation weeks of the experiment are considered, it becomes obvious that ration and body condition are having effects not seen earlier (Table 13). There is no significant effect due to lactation week during the last four weeks of the experiment. This indicates that the cows were in a more stable metabolic and productive state. There was also less of a spread in the ration fiber levels (16.9 %, 19.1 % and 21.7% ADF and 33.0 %, 34.1 % and 36.9% NDF for rations 1, 2 and 3 respectively). Body condition scores were also narrowed at this time (mean of 1.6 for thin cows and 1.82 for fat cows). Although feed intake and blood metabolites, with the exception of BHBA, were not significantly affected by ration during the final weeks of the experiment, several production variables were significantly different.

The mean weekly production of milk was the same for

Table 12. Probability of Significant F test and differences between means for experimental weeks 2-4 and weeks 8-11.

Variable		Significant F Period 1	Significant F Period 3	Mean	Mean	Probability of Period difference
Milk	Diet	0.17	0.05	239.7 ± 4.5	255.9 ± 1.8	.03
	Body Condition	0.60	0.30			
Milk Fat %	Diet	0.81	0.84	4.17 ± .07	3.35 ± .04	.01
	Body Condition	0.67	0.05			
Milk Protein %	Diet	0.31	0.55	3.28 ± .03	3.03 ± .01	.01
	Body Condition	0.71	0.50			
Milk Solids %	Diet	0.99	0.85	13.02 ± .16	12.10 ± .04	.01
	Body Condition	0.85	0.17			
4% FCM	Diet	0.22	0.10	249.3 ± 3.2	231.5 ± 2.3	.02
Yield	Body Condition	0.92	0.88			
4% FCM	Diet	0.07	0.05	43.2 ± .6	41.6 ± .4	.18
kg/BW	Body Condition	0.33	0.40			
Milk Fat	Diet	0.29	0.28	9.9 ± .1	8.7 ± .1	.01
Yield	Body Condition	0.87	0.52			
Milk Protein	Diet	0.28	0.02	7.8 ± .1	7.7 ± .1	.57
Yield	Body Condition	0.53	0.46			
Milk Solids	Diet	0.32	0.05	31.7 ± .6	31. ± .2	.01
Yield	Body Condition	0.66	0.72			
DMI	Diet	0.53	0.24	126.4 ± 1.4	156.6 ± 1.2	.01
	Body Condition	0.62	0.64			

Continued

Table 12. (Continued)

Variable		Significant F Period 1	Significant F Period 3	Mean	Mean	Probability of difference Period
Body Score	Diet	0.93	0.97	2.03 ± .01	1.70 ± .02	.01
	Body Condition	0.02	0.20			
Change BCS	Diet	0.37	0.69	-.05 ± .03	-.77 ± .02	.01
	Body Condition	0.81	0.20			
Change BW	Diet	0.89	0.76	-13.46 ± 1.84	-31.25 ± 1.29	.01
	Body Condition	0.05	0.05			
B-hydroxy-butyric	Diet	0.12	0.02	.641 ± .031	.489 ± .010	.01
	Body Condition	0.26	0.50			
Acetoacetic	Diet	0.34	0.81	.030 ± .004	.011 ± .001	.04
	Body Condition	0.16	0.19			
Glucose	Diet	0.21	0.14	.352 ± .003	.389 ± .004	.01
	Body Condition	0.23	0.51			
Triacyl-glycerol	Diet	0.28	0.31	.0058 ± .0003	.0077 ± .0004	.01
	Body Condition	0.36	0.35			
NEFA	Diet	0.64	0.22	.557 ± .03	.189 ± .016	.01
	Body Condition	0.74	0.25			
Creatinine	Diet	0.97	0.85	.149 ± .003	.146 ± .002	.34
	Body Condition	0.41	0.54			

Continued

Table 12. (Continued)

Variable		Significant F Period 1	Period 3	Mean	Mean	Probability of Period difference
Insulin	Diet	0.18	0.29	.299 ± .023	.331 ± .022	.30
	Body Condition	0.05	0.82			
NDF Intake	Diet	0.82	0.80	46.4 ± .54	53.9 ± .52	.01
	Body Condition	0.81	0.95			
ADF Intake	Diet	0.16	0.16	25.9 ± .28	29.75 ± .3	.01
	Body Condition	0.81	0.62			
Lignin Intake	Diet	0.02	0.02	4.61 ± .07	5.27 ± .06	.01
	Body Condition	0.45	0.14			
NDF Intake % BW	Diet	0.98	0.60	8.11 ± .09	9.75 ± .10	.01
	Body Condition	0.27	0.57			
ADF Intake % BW	Diet	0.23	0.19	4.52 ± .04	5.38 ± .06	.01
	Body Condition	0.33	0.91			
Energy Intake	Diet	0.16	0.06	210.8 ± 4.2	265.5 ± 2.2	.01
	Body Condition	0.58	0.66			
Energy Balance	Diet	0.97	0.20	-17.5 ± 1.26	30.65 ± 2.54	.01
	Body Condition	0.65	0.80			

Table 13. Effect of three ADF levels and two body conditions on selected contrasts of means for the final four experimental weeks.

Variable	Treatment	Selected Contrast	Means	Mean	SED	Units	P	Significant Interactions
Milk production	Body Condition	Thin v fat	260.30	250.90	11.9	kg		Ration by body condition (P<.10)
	Ration	Ration 1 v 3	269.00	232.40	14.0	kg	0.05	
		Ration 1 v 2	269.00	269.10	14.9	kg		
		Ration 2 v 3	269.10	232.40	14.9	kg		
		1st lactation v later	205.20	284.90	12.4	kg	0.01	
4% FCM production	Body Condition	Thin v fat	229.02	234.27	12.6	kg		Ration by body condition by fresh week (P<.01)
	Ration	Ration 1 v 3	240.67	209.61	14.9	kg		
		Ration 1 v 2	240.67	247.25	15.8	kg		
		Ration 2 v 3	247.25	209.61	15.8	kg		
		1st lactation v later	177.33	261.53	13.2	kg	0.01	
4FCM/100 kg body weight	Body Condition	Thin v fat	42.26	40.92	0.93	kg		
	Ration	Ration 1 v 3	44.04	37.81	1.10	kg	0.05	
		Ration 1 v 2	44.04	43.42	1.17	kg		
		Ration 2 v 3	43.42	37.81	1.17	kg		
		1st lactation v later	36.45	44.52	0.97	kg	0.01	
Milk fat %	Body Condition	Thin v fat	3.19	3.52	0.07	%		Ration by body condition by fresh week (P<.01)
	Ration	Ration 1 v 3	3.29	3.36	0.02	%		
		Ration 1 v 2	3.29	3.40	0.08	%		
		Ration 2 v 3	3.40	3.36	0.08	%		
		1st lactation v later	3.14	3.47	0.07	%	0.01	

Continued

Table 13. (continued)

Variable	Treatment	Selected Contrast	Means	Mean	SED	Units	P	Interactions
Milk protein %	Body Condition	Thin v fat	3.00	3.06	0.03	%		
	Ration	Ration 1 v 3	3.08	2.99	0.04	%		
		Ration 1 v 2	3.08	3.00	0.04	%		
		Ration 2 v 3	3.00	2.99	0.04	%		
		1st lactation v later	3.04	3.12	0.04	%		
Milk solids %	Body Condition	Thin v fat	11.94	12.29	0.11	%		Ration by body condition by fresh week (P<.01)
	Ration	Ration 1 v 3	12.19	12.02	0.13	%		
		Ration 1 v 2	12.19	12.09	0.14	%		
		Ration 2 v 3	12.09	12.02	0.14	%		
		1st lactation v later	11.81	12.13	0.12	%	0.01	
Milk fat production	Body Condition	Thin v fat	18.55	19.74	0.09	kg		Ration by body condition by fresh week (P<.05)
	Ration	Ration 1 v 3	19.46	17.43	0.11	kg		
		Ration 1 v 2	19.46	20.72	0.11	kg		
		Ration 2 v 3	20.72	17.43	0.11	kg		
		1st lactation v later	14.07	21.84	0.09	kg	0.01	
Milk protein production	Body Condition	Thin v fat	17.16	16.79	0.39	kg		
	Ration	Ration 1 v 3	18.25	15.18	0.46	kg	0.05	
		Ration 1 v 2	18.25	17.67	0.48	kg		
		Ration 2 v 3	17.67	15.18	0.48	kg		
		1st lactation v later	13.64	18.86	0.40	kg	0.01	
Milk solids production	Body Condition	Thin v fat	31.05	30.87	1.59	kg		
	Ration	Ration 1 v 3	32.78	27.85	1.88	kg		
		Ration 1 v 2	32.78	32.58	2.00	kg		
		Ration 2 v 3	32.58	27.85	2.00	kg		

Table 13. (continued)

Variable	Treatment	Selected Contrast	Means	Mean	SED	Units	P	Interactions
Body weight	Body Condition	Thin v fat	539.80	564.13	12.07	kg	0.05	Ration by body condition (P<.01)
	Ration	Ration 1 v 3	542.74	551.45	14.25	kg		
		Ration 1 v 2	542.74	561.11	15.11	kg		
		Ration 2 v 3	561.11	551.45	15.11	kg		
		1st lactation v later	486.61	384.42	12.57	kg	0.01	
Loss of body weight	Body Condition	Thin v fat	-19.70	-44.58	11.54	kg	0.05	
	Ration	Ration 1 v 3	-26.43	-35.51	13.62	kg		
		Ration 1 v 2	-26.43	-31.96	14.45	kg		
		Ration 2 v 3	-31.96	-35.51	14.45	kg		
		1st lactation v later	-21.70	-80.43	12.02	kg	0.05	
Body condition score	Body Condition	Thin v fat	1.60	1.82	0.10		0.05	
	Ration	Ration 1 v 3	1.72	1.77	0.11			
		Ration 1 v 2	1.72	1.60	0.12			
		Ration 2 v 3	1.60	1.77	0.12			
		1st lactation v later	1.85	1.63	0.10			
Loss of body condition score	Body Condition	Thin v fat	-0.66	-0.90	0.09			
	Ration	Ration 1 v 3	-0.92	-0.72	0.11			
		Ration 1 v 2	-0.92	-0.65	0.12			
		Ration 2 v 3	-0.65	-0.72	0.12			
		1st lactation v later	-0.90	-0.70	0.10			
Dry matter intake	Body Condition	Thin v fat	152.93	160.89	8.10	kg		
	Ration	Ration 1 v 3	164.27	148.03	9.57	kg		
		Ration 1 v 2	164.27	157.81	10.15	kg		
		Ration 2 v 3	157.81	148.03	10.15	kg		

Table 13. (continued)

Variable	Treatment	Selected Contrast	Means	Mean	SED	Units	P	Interactions
Plasma glucose	Body Condition	Thin v fat	0.39	0.39	0.561	mM/ml		Ration by body condition (P<.10)
	Ration	Ration 1 v 3	0.40	0.38	0.662	mM/ml		
		Ration 1 v 2	0.40	0.39	0.702	mM/ml		
		Ration 2 v 3	0.39	0.38	0.702	mM/ml		
		1st lactation v later	0.81	0.38	0.584	mM/ml		
Plasma Triacyl-glycerol	Body Condition	Thin v fat	0.0074	0.0080	0.0001	mM/ml		
	Ration	Ration 1 v 3	0.0070	0.0084	0.0004	mM/ml		
		Ration 1 v 2	0.0070	0.0078	0.0005	mM/ml		
		Ration 2 v 3	0.0078	0.0084	0.0005	mM/ml		
		1st lactation v later	7.5600	6.4100	0.0004	mM/ml	0.10	
Plasma non-esterified fatty acids	Body Condition	Thin v fat	0.17	0.21	0.015	mM/ml		
	Ration	Ration 1 v 3	0.16	0.23	0.018	mM/ml		
		Ration 1 v 2	0.16	0.18	0.019	mM/ml		
		Ration 2 v 3	0.18	0.23	0.019	mM/ml		
		1st lactation v later	0.19	0.19	0.016	mM/ml		
Plasma creatinine	Body Condition	Thin v fat	0.15	0.14	0.003	mM/ml		
	Ration	Ration 1 v 3	0.14	0.15	0.004	mM/ml		
		Ration 1 v 2	0.14	0.15	0.004	mM/ml		
		Ration 2 v 3	0.15	0.15	0.004	mM/ml		
		1st lactation v later	0.15	0.15	0.003	mM/ml		
Plasma insulin	Body Condition	Thin v fat	0.33	0.34	0.018	ng/ml		
	Ration	Ration 1 v 3	0.32	0.37	0.021	ng/ml		
		Ration 1 v 2	0.32	0.37	0.022	ng/ml		
		Ration 2 v 3	0.37	0.37	0.022	ng/ml		

Table 13. (continued)

Variable	Treatment	Selected Contrast	Means	Mean	SED	Units	P	Interactions
Plasma BHBA	Body Condition	Thin v fat	0.479	0.504	0.009			
		Ration 1 v 3	0.452	0.543	0.048		0.05	
	Ration	Ration 1 v 2	0.452	0.472	0.051			
		Ration 2 v 3	0.472	0.543	0.051			
		1st lactation v later	0.480	0.497	0.035			
Plasma Aceto-acetic acid	Body Condition	Thin v fat	0.012	0.009	0.002			
		Ration 1 v 3	0.012	0.011	0.001			
	Ration	Ration 1 v 2	0.012	0.010	0.001			
		Ration 2 v 3	0.010	0.011	0.001			
		1st lactation v later	0.013	0.01	0.009			
Ration NDF %	Body Condition	Thin v fat	35.10	34.27	0.34	%		
		Ration 1 v 3	33.05	36.88	0.40	%	0.01	
	Ration	Ration 1 v 2	33.05	34.10	0.42	%	0.01	
		Ration 2 v 3	34.10	36.88	0.42	%	0.01	
		1st lactation v later	34.99	34.56	0.35	%		
Ration ADF %	Body Condition	Thin v fat	19.27	19.25	0.16	%		
		Ration 1 v 3	16.95	21.68	0.19	%	0.01	
	Ration	Ration 1 v 2	16.95	19.13	0.20	%	0.01	
		Ration 2 v 3	19.13	21.68	0.20	%	0.01	
		1st lactation v later	19.58	19.08	0.16	%		
Ration lignin %	Body Condition	Thin v fat	3.36	3.52	0.04	%	0.10	
		Ration 1 v 3	2.92	4.02	0.05	%	0.01	
	Ration	Ration 1 v 2	2.92	3.34	0.05	%	0.01	
		Ration 2 v 3	3.34	4.02	0.05	%	0.01	
		1st lactation v later	3.55	3.37	0.04	%	0.10	

Table 13. (continued)

Variable	Treatment	Selected Contrast	Means	Mean	SED	Units	P	Interactions
Ration ash %	Body Condition	Thin v fat	6.57	6.92	0.09	%	0.05	
	Ration	Ration 1 v 3	6.24	7.19	0.10	%	0.01	
		Ration 1 v 2	6.24	6.78	0.11	%	0.01	
		Ration 2 v 3	6.78	7.19	0.11	%	0.01	
		1st lactation v later	6.98	6.60	0.09	%	0.05	
ORTS NDF %	Body Condition	Thin v fat	37.85	35.16	0.46	%	0.05	
	Ration	Ration 1 v 3	33.48	38.55	0.54	%	0.01	
		Ration 1 v 2	33.48	38.06	0.58	%	0.01	
		Ration 2 v 3	38.06	38.55	0.58	%		
		1st lactation v later	36.32	36.75	0.48	%		
ORTS ADF %	Body Condition	Thin v fat	20.75	20.26	0.21	%		
	Ration	Ration 1 v 3	17.64	23.49	0.25	%	0.01	
		Ration 1 v 2	17.64	20.41	0.26	%	0.01	
		Ration 2 v 3	20.41	23.49	0.26	%	0.01	
		1st lactation v later	20.66	20.46	0.22	%		
ORTS lignin %	Body Condition	Thin v fat	3.66	3.67	0.05	%		
	Ration	Ration 1 v 3	2.99	4.34	0.06	%	0.01	
		Ration 1 v 2	2.99	3.67	0.07	%	0.01	
		Ration 2 v 3	3.67	4.34	0.07	%	0.05	
		1st lactation v later	3.91	3.54	0.06	%		
ORTS ash %	Body Condition	Thin v fat	6.91	7.05	0.11	%		
	Ration	Ration 1 v 3	6.49	7.43	0.13	%	0.01	
		Ration 1 v 2	6.49	7.03	0.14	%	0.01	
		Ration 2 v 3	7.03	7.43	0.14	%	0.01	
		1st lactation v later	7.02	6.96	0.11	%		

Table 13. (continued)

Variable	Treatment	Selected Contrast	Means	Mean	SED	Units	P	Interactions
NDF consumed	Body Condition	Thin v fat	53.21	54.8	3.31	kg		Body condition by fresh week (P<.10)
	Ration	Ration 1 v 3	54.16	54.12	3.91	kg		
		Ration 1 v 2	54.16	53.45	4.14	kg		
		Ration 2 v 3	53.45	54.12	4.14	kg		
		1st lactation v later	43.25	59.89	3.44	kg	0.01	
ADF consumed	Body Condition	Thin v fat	29.06	30.55	1.72	kg		Body condition by fresh week (P<.01)
	Ration	Ration 1 v 3	27.59	31.67	2.03	kg		
		Ration 1 v 2	27.59	30.07	2.15	kg		
		Ration 2 v 3	30.07	31.67	2.15	kg		
		1st lactation v later	24.07	32.91	1.79	kg	0.01	
Lignin consumed	Body Condition	Thin v fat	5	5.59	0.30	kg		Body condition by fresh week (P<.01)
	Ration	Ration 1 v 3	4.75	5.86	0.35	kg	0.01	
		Ration 1 v 2	4.75	5.19	0.37	kg		
		Ration 2 v 3	5.19	5.86	0.37	kg	0.05	Ration by fresh week (P<.05)
		1st lactation v later	4.3	5.8	0.31	kg	0.01	
Ash consumed	Body Condition	Thin v fat	9.9	11.01	0.57	kg		Ration by fresh week (P<.10)
	Ration	Ration 1 v 3	10.11	10.57	0.67	kg		
		Ration 1 v 2	10.11	10.61	0.71	kg		
		Ration 2 v 3	10.61	10.57	0.71	kg		
		1st lactation v later	8.65	11.4	0.59	kg	0.01	
NDF consumed /100 kg body weight	Body Condition	Thin v fat	9.81	9.68	0.26	kg/100 kg		
	Ration	Ration 1 v 3	9.94	9.77	0.30	kg/100 kg		
		Ration 1 v 2	9.94	9.49	0.32	kg/100 kg		
		Ration 2 v 3	9.49	9.77	0.32	kg/100 kg		

Table 13. (continued)

Variable	Treatment	Selected Contrast	Means	Mean	SED	Units	P	Interactions
ADF consumed /100 kg body weight	Body Condition	Thin v fat	5.35	5.41	0.14	kg/100 kg		Body condition by fresh week (P<.05)
	Ration	Ration 1 v 3	5.07	5.72	0.16	kg/100 kg		
		Ration 1 v 2	5.07	5.35	0.17	kg/100 kg		
		Ration 2 v 3	5.35	5.72	0.17	kg/100 kg		
		1st lactation v later	4.95	5.62	0.14	kg/100 kg		
Lignin consumed /100 kg body weight	Body Condition	Thin v fat	0.92	0.99	0.02	kg/100 kg		Body condition by fresh week (P<.01)
	Ration	Ration 1 v 3	0.87	0.06	0.03	kg/100 kg		
		Ration 1 v 2	0.87	0.92	0.03	kg/100 kg		
		Ration 2 v 3	0.92	0.06	0.03	kg/100 kg		Ration by fresh week (P<.10)
		1st lactation v later	0.89	0.99	0.02	kg/100 kg		
Ash consumed /100 kg body weight	Body Condition	Thin v fat	1.83	1.95	0.04	kg/100 kg		
	Ration	Ration 1 v 3	1.86	1.9	0.05	kg/100 kg		
		Ration 1 v 2	1.86	1.89	0.05	kg/100 kg		
		Ration 2 v 3	1.89	1.9	0.05	kg/100 kg		
		1st lactation v later	1.78	1.94	0.04	kg/100 kg		
Difference in NDF between feed & ORTS	Body Condition	Thin v fat	-2.74	-0.89	0.38	%	0.05	Ration by body condition (P<.05)
	Ration	Ration 1 v 3	-0.44	-1.67	0.45	%	0.05	
		Ration 1 v 2	-0.44	-3.96	0.48	%	0.05	
		Ration 2 v 3	-3.96	-1.67	0.48	%	0.05	
		1st lactation v later	-1.33	-2.19	0.40	%	0.05	
Difference in ADF between feed & ORTS	Body Condition	Thin v fat	-1.48	-1.01	0.18	%		Body condition by fresh week (P<.10)
	Ration	Ration 1 v 3	-0.69	-1.82	0.21	%	0.01	
		Ration 1 v 2	-0.69	-1.28	0.23	%	0.05	
		Ration 2 v 3	-1.28	-1.82	0.23	%	0.05	

Table 13. (continued)

Variable	Treatment	Selected Contrast	Means	Mean	SED	Units	P	Interactions
Difference in lignin between feed & ORTS	Body Condition	Thin v fat	-0.3	-0.15	0.05	%		Body condition by fresh week (P<.01)
	Ration	Ration 1 v 3	-0.07	-0.32	0.06	%		
		Ration 1 v 2	-0.07	-0.33	0.07	%		
		Ration 2 v 3	-0.33	-0.32	0.07	%		
		1st lactation v later	-0.36	-0.22	0.06	%		
Difference in ash between feed & ORTS	Body Condition	Thin v fat	-0.34	-0.13	0.07	%		
	Ration	Ration 1 v 3	-0.25	-0.24	0.08	%		
		Ration 1 v 2	-0.25	-0.25	0.09	%		
		Ration 2 v 3	-0.25	-0.24	0.09	%		
		1st lactation v later	-0.41	-0.39	0.07	%		
Net energy value of feed	Body Condition	Thin v fat	1.69	1.69	0.003	MCal/kg		
	Ration	Ration 1 v 3	1.73	1.65	0.004	MCal/kg		
		Ration 1 v 2	1.73	1.7	0.004	MCal/kg		
		Ration 2 v 3	1.7	1.65	0.004	MCal/kg		
		1st lactation v later	1.69	1.7	0.003	MCal/kg		
Net energy balance	Body Condition	Thin v fat	27.17	34.72	5.51	MCal		
	Ration	Ration 1 v 3	44.41	25.44	6.50	MCal		
		Ration 1 v 2	44.41	19.98	6.89	MCal		
		Ration 2 v 3	19.98	25.44	6.89	MCal		
		1st lactation v later	21.56	36.07	5.73	MCal	0.05	
Net energy intake	Body Condition	Thin v fat	259.26	272.81	6.23	MCal		
	Ration	Ration 1 v 3	285.42	244.21	7.35	MCal	0.01	
		Ration 1 v 2	285.42	267.39	7.79	MCal	0.05	
		Ration 2 v 3	267.39	244.21	7.79	MCal	0.01	

rations 1 and 2 during this period. Both ration 1 and 2 resulted in significantly higher milk production than ration 3 ($P<.05$). There was no significant difference in milk composition among diets, although production of milk protein and total milk solids was significantly less for ration 3 than the other two rations ($P<.05$).

There was also a significant ration by body condition interaction effect on body weight ($P<.01$) and a trend for a significant ration by body condition interaction effect on milk production and plasma glucose ($P<.10$). The fat cows fed ration 2 weighed more and produced more milk than did thin cows fed the same ration. Thin cows produced more milk than fat cows on rations 1 and 3. Fat cows weighed more than thin cows fed ration 1 and 2 but not ration 3. Because all fat cows weighed more than thin cows at parturition, fat cows fed ration 3 must have lost greater amounts of weight by the last weeks of the experiment. Plasma glucose levels were higher for fat cows fed ration 1 than thin cows fed ration 1. For cows fed rations 2 and 3 plasma glucose was higher for thin cows.

During the last four experimental weeks, body condition had a significant effect on the milk fat percent (3.19 and 3.56 for thin and fat cows respectively, $P<.05$). This certainly indicates that fat body condition at calving has positive effects on milk production in the later weeks of lactation.

Dry matter intake, both in total or as a percent of body weight, was not significantly different among diets ($P>.10$) over the last 4 experimental weeks. However, DMI was linear with ration ADF during this period (164.3 kg/week, 157.8 kg/week and 148.0 kg/week for diets 1, 2 and 3 respectively). Dry matter intake was also linear with NDF content.

Milk production, however, was not linear with ration fiber level (269.0 kg/week, 269.1 kg/week and 232.2 kg/week for rations 1, 2 and 3 respectively). Efficiency of production (kg milk/kg DMI) was numerically, but not significantly, higher on ration 2 (1.71) than for ration 1 (1.64) or ration 3 (1.61). Consumption of NDF and ADF, either in total or per 100 kg of body weight was not different among dietary treatments or between body conditions ($P>.10$). Lignin intake, however, was different ($P<.01$) both on a total and percent of body weight basis among all rations. From strictly a statistical point of view, both NDF and ADF but not lignin could be considered as potential regulators of intake in the last four weeks of this experiment. Production of 4% FCM/100 kg of body weight tended ($P<.10$) to be lower for cows fed ration 3 than those fed ration 2. Production of 4% FCM was significantly higher for cows fed rations 1 and 2 compared to ration 3 ($P<.05$).

ENERGY BALANCE

Calculations of energy balance used in this study in absolute terms are of little value because energy content of the diets were estimated rather than determined by digestion trials. But the relative values do allow comparison of diets, given the assumption that energy requirements vary by body weight and milk production (NRC, 1988). Although heifers have an additional requirement for growth, this requirement has been deleted from the calculation. It was felt that this calculation should allow detection of the relative amounts and duration of negative energy balance among diets and between body conditions. This data is represented graphically in Figures 27 and 28. It is obvious that neither ration or body condition had a significant effect ($P>.10$) on the duration or length of negative energy balance. It is also apparent that in this study high milk production did not result in greater energy deficit; the cow simply reduced the amount of milk she produced to accommodate the amount of energy deficit that she could tolerate. This result further suggests that in early lactation hormonal control of feed intake is more important than dietary control, but dietary control is more important for milk production.

This finding of no difference in energy balance among diets or between body conditions is not supported by the current literature as previously reviewed. Most authors have found the degree of energy deficiency to be more

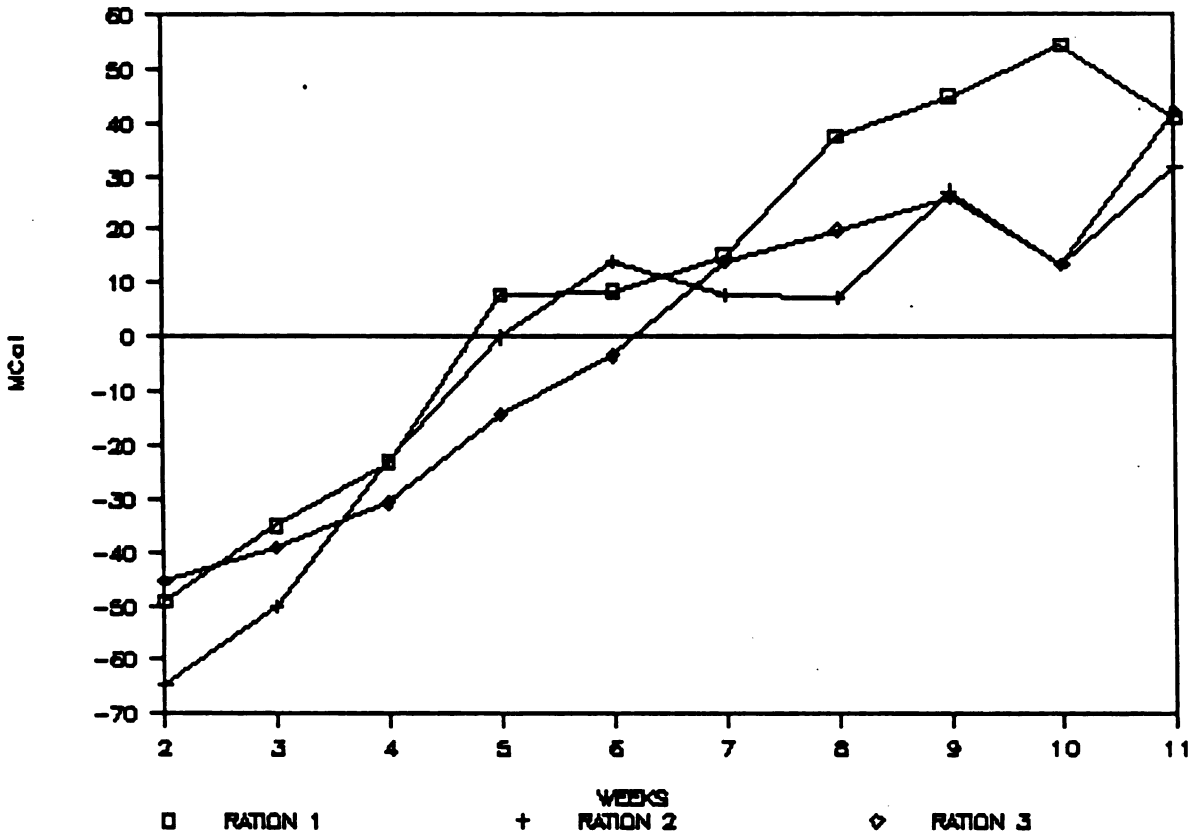

Figure 27. Mean weekly energy balance (MCal/week) of cows fed three levels of ADF.

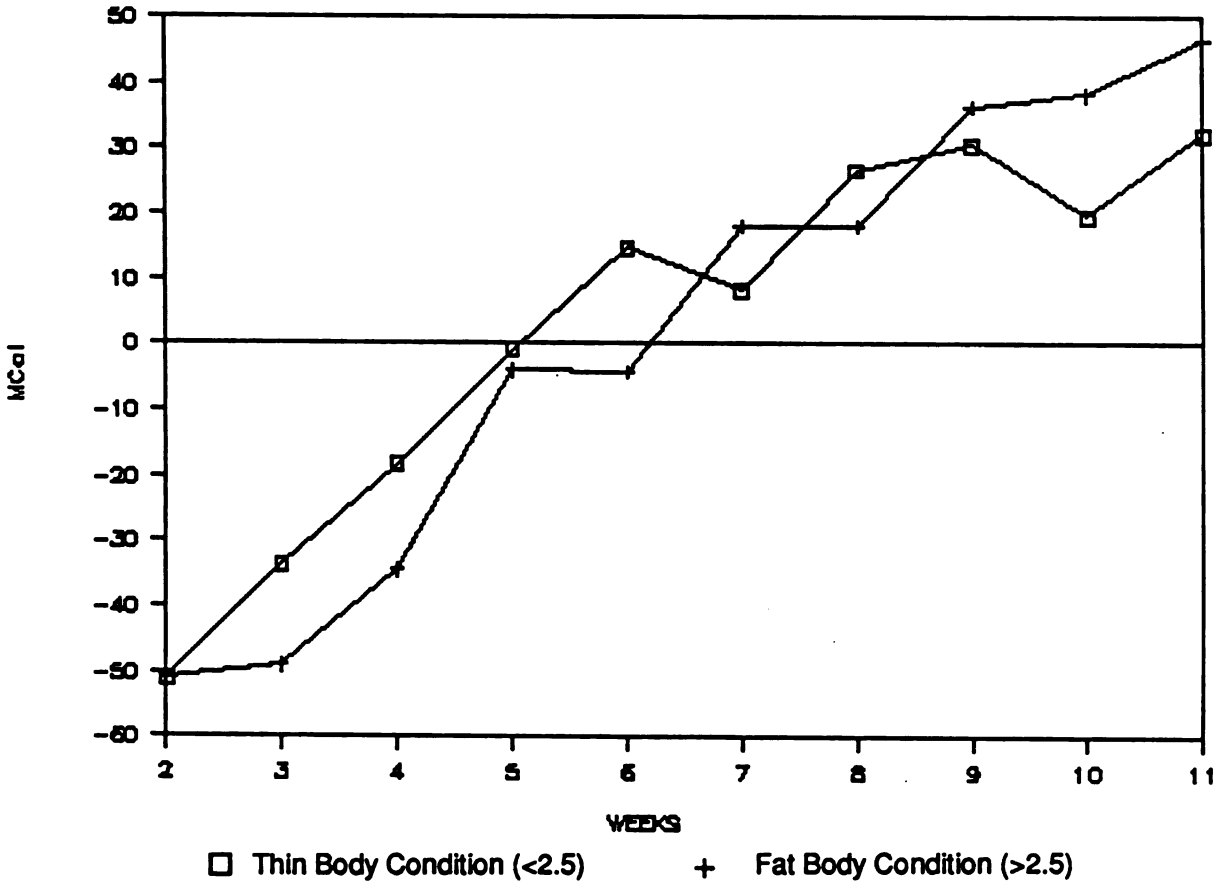

Figure 28. Mean weekly energy balance (MCal/week) of cows at two body conditions.

severe and longer lasting than in the present study. Since most of the conclusions about energy balance have been arrived at by calculations performed exactly as in this study, the differences between these other investigations and the current study is inexplicable.

DMI REGRESSION ANALYSIS

The regression model which best predicted intake consisted of the following terms:

DMI = Parity + Body weight + milk production + NEFA (R^2 =.73).

However the R^2 for NEFA was only .09, much less than the a priori selected minimum R^2 of .20.

The basic model was:

DMI= Parity + body weight + milk production (R^2 = .53)

Adding the quadratic or cubic effects for body weight or milk production improved the model only slightly. For any variable selected except these three, the R^2 never rose above the .09 reported for NEFA. Linear and quadratic terms were tried for all variables without effect.

The percent of variation that was explained by the basic model is presented in Table 14. Milk (R^2 = .48) explained 15 percent, parity explained 14.1 percent and body weight 9.6 percent. Parity plus milk explained the largest percent of variation at 17 percent.

Adding fiber terms, either linear, quadratic or cubic, to the basic model only improved the R^2 slightly. Lignin

Table 14. Correlation coefficients for explanation of dry matter intake variance by regression models.

Model	Variable	R^2
Milk + parity + body weight	milk	.48
	parity	.44
	body weight	.30
	parity + milk	.53
	body weight + milk	.48
	parity + body weight	.44
	parity + body weight + milk	.53
Milk + parity + body weight + NEFA	milk	.48
	parity	.44
	body weight	.29
	NEFA	.09
	milk + NEFA	.64
	parity + NEFA	.64
	body weight + NEFA	.55
	parity + milk	.53
	body weight + milk	.48
	parity + body weight	.44
	parity + milk + NEFA	.73
	body weight + milk + NEFA	.69
	parity + body weight + NEFA	.68
	parity + body weight + milk	.53
	parity + body weight + milk + NEFA	.73

was always improved the model more than ADF. ADF always improved the model more that NDF. However, none of these fiber fractions had an R^2 that was significant.

DISCUSSION

The first stated objective of this study remains unfulfilled. It is relatively easy to say that with the fiber levels and cows used in this study, ration fiber as measured by NDF, ADF or lignin had no statistically significant effect on intake. However, feed intake of cows fed ration 3 was numerically lower than cows fed the other 2 diets. It was postulated that if NDF were limiting intake, total dry matter intake would be depressed at different levels of ADF intake. Conversely, if ADF were limiting intake, it was believed that levels of NDF intake would be different. Total dry matter intake, however, was statistically the same on all ration levels of fiber ($P > .10$). This is probably due to the high degree of association of NDF with ADF on these diets.

The fact that the cows ate a constant amount of NDF and that the ratio of ingested NDF:ADF was significantly different among diets ($P < .01$) argues for the point that NDF can affect intake as first proposed by Mertens (1982). However, the fact that DMI/100 kg of body weight tended to be different between rations 1 and 3 by the very same probability ($P < .07$) that ADF/100 kg of body intake was different argues that ADF may be as effective a regulator

of DMI as NDF. Pearson correlations of NDF (R^2 -.09, P<.12) and ADF (R^2=-.15, P<.01) with DMI indicate that ADF is better correlated with DMI than NDF in this study (Appendix Tables 29 and 30). However, neither were correlated well enough to be considered a regulator of intake. Thus, the problem is unresolved.

It must also be recognized that the levels of NDF in the experimental rations were all higher than currently recommended for optimum production of 4% FCM for cows producing over 40 kg/day (Mertens, 1987; NRC 1989). Therefore, it may be that levels of NDF in the experimental diets were all high enough to depress feed intake on each of the experimental rations. Several observations argue against this hypothesis, however.

Comparison of actual DMI with predicted DMI from the 1988 NRC reveals that for stated amounts of milk and body weight, actual DMI was at or above predicted levels in spite of the fact that almost one third of the animals were primiparous cows who are known to have lower DMI per 100 Kg of body weight than older cows (DePeters et al, 1986).

Also the fact that each first lactation cow fed ration 1 suffered from laminitis is of great concern. Founder is considered to have its origin in ruminal lactic acidosis (Manson and Leaver, 1988), which is perceived to be prevented by high fiber diets.

Lastly, when using the regression analysis as a tool to explain variation in DMI on this data set, no fiber

fraction was correlated with DMI with an R^2 as high as .05 if milk production, parity and body weight were included in the model. Analysis of the cubic regression for ingested hemicellulose (i.e., the difference between ingested NDF and ingested ADF) revealed no differences in any of the slope parameters including the intercept among the experimental rations.

Ration NDF has failed to regulate feed intake of early lactation cows in a number of experiments (Broderick, 1985; DePeters et al., 1986; Sutton et al, 1988).

There are three possible explanations for the results obtained regarding the effects of fiber on intake found in this study: (1) ADF and NDF are so highly correlated on normal mixed forage:concentrate diets that even with grasses included, any differences between the effects of NDF and ADF on DMI are obscured; (2) the diets were high in NDF and the spread in NDF or ADF content among diets was not great enough to produce a detectable difference; (3) in early lactation the physiological and/or hormonal set point of the cow controls intake to a much larger degree than does fiber level.

A comparison of the feed intake between thin and fat dry cows (thin > fat, $P<.05$), indicates that feed intake was different based on energy demand. Fat cows were heavier and were gaining more weight ($P<.05$) and therefore had higher energy requirements. As proposed by Conrad

(1966) for animals at or near maintenance, DMI is regulated by the animal's need to extract total calories from the diet.

After parturition, it appears that the cows ate dry matter to the capacity of their digestive systems. It is possible that the trend for ration 3 to be consumed at lower levels may be more influenced by the difference between both the extent and rate of digestion between the forage and grain portion of the diets (Mertens, 1977) than by differences in NDF or ADF levels in the diet.

It also appears clear that body condition has a minimal effect on DMI or milk production during early lactation. These results were also unexpected, although in several studies, body condition has had no effect on DMI or milk production (Boisclair et al, 1986; Kunz et al, 1985). Comparison of these results with those of previous studies (Garnsworthy and Topps, 1987; Treacher et al, 1986; Seymour and Polan, 1986;) must be made with some caution. The cows in this study were not as widely divergent in body condition (thin = 2.26, fat = 3.24) as those in most other studies. Also, the design of their experiments required making cows intentionally thin or fat in the last trimester of lactation and during the dry period, thereby overriding the animal's metabolic set point (Kennedy, 1966) for the maintenance of body reserves. This may have predisposed those cows whose natural body condition is thin to ingest less dry matter after calving in order to reach their set

point of body fat (Baile and Della Ferra, 1974), or they may have deposited excessive amounts of fat in the liver with resulting decreases in dry matter intake (Morrow, 1976; Reid and Roberts, 1983).

There is some evidence, given the basic experimental design differences, that the results may not be as different as at first supposed. The regression plots of fat cows fed the highest fiber diet did trend toward having lower NDF intakes (Figure 17), i.e., these cows had a significant ration by body condition interaction. From similar plots of body weight for fat cows fed the low fiber ration, it can be seen that this group gained substantial weight (Figure 5). These results are the same as obtained by Topps and Garnsworthy (1986). The cows in the present study peaked in both milk production and dry matter intake before those in most other studies and overall produced more milk and consumed more dry matter during that time. The work of Nocek et al (1986) is perhaps most closely related to this study. The results these workers obtained were similar to those of the present study.

Changes in milk production, DMI, body weight, body condition and blood metabolites due to advancing lactation are well documented in other literature, and therefore will not be dealt with other than to say that those changes observed in the present study are similar to those previously reported.

The last stated objective of this study also was unfulfilled. Although significant effects on blood metabolites were observed due to ration and body condition, none of these was significantly correlated with either DMI or milk production so as to be a useful tool in predicting dry matter intake or milk production (Appendix Tables 29 and 30). This finding is supported by other researchers (Thye et al, 1970; Ducker et al, 1985). Also, even those variables with sufficient correlation to warrant inspection added no significant amount of accuracy to the DMI regression model. Nevertheless, some of the aspects of this blood profile work are useful in explaining some of the results of this study.

Ruminants are considered insulin insensitive (Brockman and Laarveld, 1985). Insulin has been shown to be responsible for general protein accretion (Horn et al, 1986) and lipolysis regulation (Bergman, 1968). Study of the present insulin data may help provide some insight into the role of insulin in the high-producing dairy cow.

First lactation cows had higher levels of plasma insulin and glucose, but lower levels of plasma NEFA than did older cows (Table 10). This further reinforces that there are large differences in the physiology of milking heifers, even though their milk production is markedly less than that of mature cows. The ratio of glucose:insulin or glucose:ketone levels were not different between first lactation and mature cows, however. Fat dry cows also had

higher levels of plasma insulin than thinner cows (mean = .269 vs .345 ng/ml). There was no significant difference between pre- and post parturient cows (P>.10). This is in contrast to other data (Ronge et al, 1988). An explanation for this result is difficult although the high amount of grain fed to the cows after calving in the present study may have resulted in a basal insulin concentration (Bergman et al, 1970). Also, the lack of a sufficient number of samples taken more than one week before calving may have biased the data. Blood insulin levels are known to decline one week preparturition (Rouge, et al.).

Fat dry cows were in a period of substantial weight and body condition gain compared to the thin dry cows (P<.05). Higher plasma insulin levels may be interpreted as the controlling mechanism for decreased lipolysis/increased lipogenesis as has been shown in other species (De Jonge, 1985). Since there is no demand for insulin by the pregnant uterus of cattle (Brockman, 1985), it may be assumed that the effects of insulin must be exerted in muscle and adipose tissue.

Observations on the blood metabolites of primiparous cows also support a role for insulin as a regulator of lipolysis. If the postulation of tissue insensitivity is accepted, then the higher insulin levels found in primiparous cows can be interpreted as an attempt to reduce

the high plasma glucose concentration. This is difficult to visualize, however, because with this scenario, fatty acid levels would have to be the same for both first and multilactational cows; the insensitivity to insulin should be general for adipose tissue. NEFA levels were significantly lower for the primiparous cows ($P<.05$). Therefore, lipolysis must have been inhibited to some extent, strongly suggesting that adipose tissue in milking cows is not insensitive to insulin. The plasma glucose concentration and higher insulin concentration indicate an increased supply of glucose from some source. There was no difference in the ratio of glucose:insulin, which is another indication that the tissues of the primiparous cows were not more insulin insensitive than tissues of the older cows. Therefore, the metabolism of younger cows must be in some respect different from older animals. This difference did not seem to be diet induced, but rather was reflective of the status of the animal. It can easily be postulated that this difference may well be due to the fact that the primiparous cows were still growing and required both more insulin and more glucose for tissue synthesis. However, because no idea of production and clearance times for glucose, NEFA or insulin are available from this study, a full explanation must await results from other investigators.

Blood ketone data is of similar interest. Cows fed ration 3 had significantly higher levels of BHBA ($P<.05$)

than did those fed ration 1. Although blood glucose was not different between these treatments, it was numerically higher for cows fed ration 1 than ration 3 (.364 vs .386 mM). Because of this, there was a significant difference in the ratio of glucose:BHBA in plasma (ration 1 > ration 3, $P<.01$). This is in agreement with the data of Gerloff et al (1986) who showed an inverse relationship between blood glucose and BHBA levels for cows with some degree of hepatic lipidosis. Early lactation cows are thought to undergo some degree of fat infiltration in the liver in early lactation (Morrow, 1981; Watson and Williams, 1988) with resultant increases in ketogenesis. Somewhat surprisingly, there were no differences in the plasma levels of NEFA between these rations ($P>.10$).

This difference in the glucose:BHBA ratio between diets 1 and 3 indicates that a shift in either production or clearance of BHBA must have occurred for the cows fed these rations. Concurrently, one could postulate a difference in the metabolic fate of NEFA. A hint as to what this mechanism might be is provided by comparison of the fat and thin cows. Cows that were fat had lower ratios of BHBA:ACAC ($P<.05$). It should be recalled that fat cows lost more body condition and therefore should have had higher rates of ketogenesis. This result would indicate an increased clearance of BHBA from the blood for extra hepatic use or a reduction of fatty acid metabolism.

Heifer blocks also had higher (P<.01) glucose:BHBA ratios. In this instance the level of BHBA was not different between cows and heifers although the level fatty acids was lower for the first lactation cows. The rise in ratio was entirely due to glucose levels. Still it is important that BHBA levels were the same even though NEFA levels were lower. This may point to the fact that ketones are far more important as metabolic fuels in the ruminant than was previously thought. These findings demonstrate the need for further research into how the animal regulates the production and utilization of energy producing substrate under different dietary regimes.

CONCLUSIONS

Several observations made in this study are at variance with those of other workers. These have been discussed where pertinent. It will be incumbent upon future studies to justify these variances with the facts.

It is important to recognize that in the present study both dietary ADF levels and body conditions were within a narrow range. Fiber levels varied over time and significantly among blocks. Although NDF levels in the rations were high, daily NDF consumption as a percent of body weight was also high (approximately 1.3%).

From this study within the conditions cited above as well as those imposed by early lactation and relatively high milk production, the following conclusions can be

made:

1. Ration fiber levels had no statistically significant effect on dry matter intake.

2. Body condition had no measurable effect on intake. After peak milk production, body condition had a significant and positive effect on milk fat test.

3. Cows in higher body condition lost more body condition than cows with lower body scores.

4. No blood metabolite measured explained a significant portion of the variation in dry matter intake.

5. Fat dry cows had higher blood insulin values than thin dry cows. Primiparous post parturition cows had higher blood insulin values with higher glucose levels and lower NEFA levels than multiparous cows.

6. Fat post partum cows had lower ratios of BHBA:ACAC than thin cows. Higher levels of BHBA were associated with lower levels of plasma glucose.

7. Net energy balance was not different among treatment groups. Neither diet nor body condition changed the amount or duration of negative energy balance.

APPENDIX TABLES

Appendix Table 1. Mean weekly milk production (kg/week) of cows fed three levels of ADF and at two body conditions.

Ration	Obs.	Week of Lactation 2	3	4	5	6	7	8	9	10	11	SE
1	10	216.9	264.1	280.8	285.9	287.2	280.7	280.8	274.0	265.0	257.8	± 22.8
2	8	224.6	260.3	268.9	269.9	279.5	276.4	280.2	275.6	262.0	258.5	± 25.8
3	10	200.0	215.8	233.5	240.5	240.7	240.4	237.9	242.0	235.8	213.7	± 22.8
Body Condition												
T	15	211.0	250.3	261.6	264.8	269.8	266.7	266.5	268.3	257.3	249.0	± 18.6
H	13	215.5	240.5	259.3	265.4	266.7	263.3	262.8	256.9	249.5	234.5	± 20.0
Overall Mean												
	28	213.1	245.8	260.5	265.1	268.4	265.1	264.8	263.0	253.7	242.3	± 8.14

Appendix Table 2. Mean weekly milk fat percent of cows fed three levels of ADF and at two body conditions.

Ration	Obs.	Week of Lactation 2	3	4	5	6	7	8	9	10	11	SE
1	10	4.38	4.16	4.01	3.63	3.61	3.50	3.18	3.14	3.38	3.44	± 0.45
2	8	4.57	4.00	3.93	3.48	3.18	3.41	3.56	3.23	3.38	3.44	± 0.50
3	10	4.41	4.38	3.84	3.48	3.54	3.34	3.34	3.35	3.38	3.40	± 0.45
Body Condition												
T	15	4.46	4.03	3.74	3.42	3.18	3.34	3.13	3.12	3.31	3.20	± 0.37
H	13	4.40	4.38	4.15	3.67	3.79	3.50	3.59	3.37	3.46	3.69	± 0.40
Overall Mean												
	28	4.43	4.19	3.93	3.53	3.46	3.41	3.34	3.24	3.38	3.43	± 0.27

Appendix Table 3. Mean weekly milk protein percent of cows fed three levels of ADF and at two body conditions.

Ration	Obs.	Week of Lactation 2	3	4	5	6	7	8	9	10	11	SE
1	10	3.46	3.19	3.05	3.06	3.07	3.05	3.03	3.04	3.13	3.12	± 0.18
2	8	3.41	3.19	3.00	3.03	3.00	2.96	3.02	2.99	2.96	3.01	± 0.20
3	10	3.53	3.32	3.36	3.04	3.03	3.00	3.02	2.99	3.00	2.96	± 0.18
Body Condition												
T	15	3.47	3.26	3.08	3.01	3.00	3.03	3.01	2.97	3.00	3.01	± 0.15
H	13	3.49	3.22	3.23	3.09	3.08	2.98	3.04	3.06	3.07	3.06	± 0.60
Overall Mean												
	28	3.48	3.24	3.15	3.05	3.04	3.01	3.02	3.01	3.04	3.03	± 0.11

Appendix Table 4. Mean weekly total milk solids per cent of cows fed three levels of ADF and at two body conditions.

Ration	Obs.	Week of Lactation 2	3	4	5	6	7	8	9	10	11	SE
1	10	13.18	12.89	12.69	12.36	12.54	12.51	12.14	12.03	12.31	12.26	± 0.18
2	8	12.94	12.69	14.04	12.20	11.91	12.16	12.24	11.91	11.98	12.23	± 0.22
3	10	13.29	13.10	12.49	12.17	12.32	12.06	12.07	12.06	12.02	11.93	± 0.18
Body Condition												
T	15	13.15	12.78	13.18	12.13	11.97	12.25	11.99	11.83	11.95	11.97	± 0.12
H	13	13.18	13.04	12.80	12.38	12.64	12.24	12.32	12.21	12.30	12.33	± 0.14
Overall Mean												
	28	13.16	12.90	13.00	12.25	12.28	12.25	12.15	12.01	12.11	12.14	± 0.06

APPENDIX TABLE 5. Mean weekly production (kg/week) of 4% fat corrected milk of cows fed three levels of ADF and at two body conditions.

Ration	Obs.	Week of Lactation 2	3	4	5	6	7	8	9	10	11	SE
1	10	231.0	276.6	284.2	271.8	270.0	262.7	246.2	238.5	240.1	237.8	± 36.76
2	8	243.9	262.3	268.2	251.7	247.1	254.2	266.5	244.2	240.5	237.8	± 41.10
3	10	215.8	230.6	229.4	220.4	226.4	214.9	214.5	216.0	213.7	194.3	± 36.76
Body Condition												
T	15	229.0	253.1	252.4	242.5	237.0	241.8	232.4	232.1	232.3	219.4	± 30.01
H	13	226.5	259.6	268.9	253.7	260.4	244.8	250.3	232.1	229.0	225.6	± 32.24
Overall Mean												
	28	227.9	256.1	260.0	247.7	247.9	243.2	240.7	232.1	230.8	222.2	± 21.97

Appendix Table 6. Mean weekly body weight (kg) of cows fed three levels of ADF and at two body conditions.

Ration	Obs.	Week of Lactation 2	3	4	5	6	7	8	9	10	11	SE
1	10	571.1	555.7	548.7	539.8	548.1	543.7	542.3	540.3	543.1	545.3	± 20.5
2	8	593.1	576.3	567.5	561.2	554.6	555.5	560.8	560.3	559.9	563.5	± 25.7
3	10	587.0	571.5	559.2	551.7	552.6	554.1	560.1	549.2	548.0	548.4	± 20.5
Body Condition												
T	15	560.8	551.1	548.0	536.2	539.7	536.9	542.7	538.2	539.4	539.0	± 13.7
H	13	608.7	585.9	569.3	566.2	565.4	566.8	565.4	566.8	566.9	561.9	± 15.8
Overall Mean												
	28	583.0	567.2	557.8	550.1	551.6	550.8	553.9	549.2	549.6	551.6	± 7.3

Appendix Table 7. Mean change in body weight (kg) from second week of lactation for cows fed three levels ADF and at two body conditions.

Ration	Obs.	Week of Lactation 2	3	4	5	6	7	8	9	10	11		SE
1	10	0.0	-15.0	-21.1	-29.2	-21.1	-25.2	-25.5	-29.5	-25.9	-24.9	±	0.21
2	8	0.0	-16.8	-25.5	-31.9	-38.5	-37.5	-32.3	-32.8	-33.2	-29.6	±	0.24
3	10	0.0	-15.5	-27.7	-35.3	-34.3	-32.8	-26.9	-37.7	-38.9	-38.5	±	0.21
Body Condition													
T	15	0.0	- 9.4	-12.0	-23.1	-19.9	-22.4	-15.9	-21.7	-20.0	-21.2	±	0.17
H	13	0.0	-22.8	-39.5	-42.5	-43.4	-41.9	-41.8	-46.8	-47.2	-42.5	±	0.19
Overall Mean													
	28	0.0	15.6	24.7	32.1	30.8	31.5	27.9	33.4	32.6	31.1	±	0.13

Appendix Table 8. Mean weekly production of 4% fat corrected milk as a percent of body weight (kg/100kg body weight) for cows fed three levels ADF and at two body conditions.

Ration	Obs.	Week of Lactation 2	3	4	5	6	7	8	9	10	11	SE
1	10	5.71	7.03	7.36	7.15	7.00	6.80	6.45	6.27	6.28	6.17	± 0.867
2	8	5.60	6.43	6.64	6.32	6.29	6.45	6.63	6.16	6.03	5.98	± 0.970
3	10	5.12	5.63	5.77	5.64	5.79	5.53	5.43	5.60	5.54	5.03	± 0.867
Body Condition												
T	15	5.67	6.49	6.55	6.42	6.26	6.39	6.11	6.14	6.10	5.79	± 0.709
H	13	5.22	6.20	6.63	6.32	6.48	6.07	6.18	5.83	5.76	5.61	± 0.760
Overall Mean												
	28	5.46	6.36	6.59	6.38	6.37	6.24	6.14	6.00	5.94	5.71	± 0.518

Appendix Table 9. Mean weekly body condition score for cows fed three levels of ADF and at two body conditions.

Ration	Obs.	Week of Lactation 2	3	4	5	6	7	8	9	10	11	SE
1	10	2.23	2.01	1.89	1.76	1.80	1.75	1.69	1.74	1.62	1.83	± 0.515
2	8	2.15	1.85	1.64	1.56	1.56	1.66	1.54	1.61	1.59	1.65	± 0.576
3	10	2.28	2.18	1.92	1.80	1.81	1.80	1.75	1.74	1.84	1.75	± 0.515
Body Condition												
T	15	1.97	1.81	1.67	1.52	1.57	1.59	1.54	1.62	1.60	1.63	± 0.177
H	13	2.50	2.26	2.01	1.95	1.93	1.92	1.82	1.79	1.79	1.89	± 0.204
Overall Mean												
	28	2.22	2.02	1.83	1.72	1.74	1.74	1.67	1.70	1.69	1.75	± 0.095

Appendix Table 10. Mean weekly change in body condition score from week of calving for cows fed three levels ADF and at two body conditions.

Ration	Obs.	Week of Lactation 2	3	4	5	6	7	8	9	10	11	SE
1	10	-0.41	-0.63	-0.75	-0.88	-0.84	-0.89	-0.95	-0.90	- .02	-0.81	± 0.471
2	8	-0.10	-0.40	-0.61	-0.69	-0.69	-0.59	-0.71	-0.64	-0.66	-0.60	± 0.526
3	10	-0.18	-0.33	-0.57	-0.81	-0.72	-0.74	-0.77	-0.69	-0.70	-0.74	± 0.471
Body Condition												
T	15	-0.27	-0.45	-0.59	-0.74	-0.69	-0.67	-0.72	-0.63	-0.66	-0.63	± 0.384
H	13	-0.20	-0.47	-0.72	-0.87	-0.82	-0.85	-0.93	-0.88	-0.97	-0.83	± 0.413
Overall Mean												
	28	-0.24	-0.46	-0.65	-0.80	-0.75	-0.75	-0.82	-0.75	-0.80	-0.72	± 0.281

Appendix Table 11. Mean weekly NDF concentration (%) of rations for cows fed three levels of ADF and at two body conditions.

Ration	Obs.	Week of Lactation 2	3	4	5	6	7	8	9	10	11	SE
1	10	33.98	33.65	34.49	33.24	33.63	32.53	34.03	33.97	32.04	32.14	± 0.55
2	8	37.97	36.79	38.64	38.00	37.19	36.53	35.12	34.40	33.40	33.46	± 0.62
3	10	39.89	37.86	39.54	39.13	39.16	38.84	37.83	36.13	36.63	36.92	± 0.55
Body Condition												
T	15	37.31	35.74	37.14	36.85	37.56	35.76	36.52	35.17	34.38	34.34	± 0.45
H	13	37.14	36.41	37.87	36.54	35.54	36.11	34.75	34.51	33.72	34.08	± 0.49
Overall Mean												
	28	37.23	36.05	37.48	36.71	36.62	35.93	35.70	34.86	34.07	34.22	± 0.33

Appendix Table 12. Mean weekly ADF concentration (%) of rations for cows fed three levels of ADF and at two body conditions.

Ration	Obs.	Week of Lactation 2	3	4	5	6	7	8	9	10	11	SE
1	10	17.70	17.32	17.68	17.87	17.89	17.35	17.22	17.06	16.97	16.53	± 0.94
2	8	20.69	21.10	21.70	21.18	20.95	20.31	19.40	19.26	18.83	19.04	± 1.12
3	10	23.79	22.68	23.65	23.72	23.74	23.42	22.30	21.43	21.60	21.38	± 0.94
Body Condition												
T	15	20.60	20.21	20.88	21.48	21.14	20.50	20.11	19.19	19.02	18.77	± 0.60
H	13	20.88	20.44	21.05	20.25	20.52	20.21	19.13	19.32	19.32	19.22	± 0.83
Overall Mean												
	28	20.73	20.32	20.96	20.91	20.85	20.36	19.66	19.25	19.16	18.98	± 0.56

APPENDIX TABLE 13. Mean weekly lignin content (%) of rations for cows fed three levels of ADF and at two body conditions.

Ration	Obs.	Week of Lactation 2	3	4	5	6	7	8	9	10	11	SE
1	10	3.08	2.91	2.94	3.16	3.13	3.05	2.95	2.99	2.99	2.74	± 0.14
2	8	3.69	3.68	3.86	3.75	3.70	3.48	3.32	3.25	3.33	3.46	± 0.16
3	10	4.50	4.15	4.43	4.45	4.51	4.28	4.28	3.95	4.04	3.82	± 0.14
Body Condition												
T	15	3.72	3.64	3.81	4.01	3.74	3.71	3.60	3.33	3.26	3.25	± 0.12
H	13	3.81	3.50	3.66	3.54	3.84	3.50	3.44	3.50	3.70	3.43	± 0.13
Overall Mean												
	28	3.76	3.57	3.74	3.79	3.79	3.61	3.53	3.41	3.46	3.33	± 0.09

Appendix Table 14. Mean weekly ash content (%) of rations for cows fed three levels of ADF and at two body conditions.

Ration	Obs.	Week of Lactation 2	3	4	5	6	7	8	9	10	11	SE
1	10	6.02	6.16	6.31	6.36	6.30	6.22	6.07	5.97	6.41	6.50	± 0.29
2	8	7.01	6.95	6.70	6.67	6.60	6.44	6.68	6.55	6.72	7.16	± 0.33
3	10	7.31	7.37	7.73	7.47	7.40	7.21	7.30	7.29	7.12	7.05	± 0.29
Body Condition												
T	15	6.79	7.01	6.92	6.92	6.78	6.70	6.61	6.46	6.50	6.71	± 0.24
H	13	6.73	6.61	6.93	6.75	6.78	6.56	6.76	6.79	7.04	7.09	± 0.26
Overall Mean												
	28	6.77	6.82	6.93	6.84	6.78	6.64	6.68	6.61	6.75	6.88	± 0.17

Appendix Table 15. Mean weekly dry matter intake (kg/week) of cows fed three levels of ADF and at two body conditions.

Ration	Obs.	Week of Lactation 2	3	4	5	6	7	8	9	10	11	SE
1	10	111.5	135.4	145.9	158.8	158.4	158.0	163.4	163.7	169.7	160.3	± 12.21
2	8	114.7	126.2	146.1	151.5	157.3	155.6	159.3	160.9	150.3	160.7	± 15.3
3	10	112.2	120.8	126.4	131.9	142.1	147.2	148.3	150.9	142.3	150.6	± 12.2
Body Condition												
T	15	112.0	129.5	139.3	146.2	152.7	149.8	155.9	156.1	149.2	150.5	± 8.1
H	13	113.5	125.3	138.6	148.5	151.7	157.7	157.8	160.9	160.4	164.5	± 9.4
Overall Mean												
	28	112.7	127.6	139.0	147.1	152.3	153.5	156.8	158.3	154.4	157.0	± 4.4

Appendix Table 16. Average daily dry matter intake as a percent of body weight (kg/100 kg body weight) for cows fed three levels of ADF and at two body conditions.

Ration	Obs.	Week of Lactation 2	3	4	5	6	7	8	9	10	11	SE
1	10	2.80	3.47	3.77	4.17	4.11	4.14	4.29	4.30	4.44	4.17	± 0.43
2	8	2.80	3.17	3.70	3.86	4.07	4.01	4.06	4.10	3.80	4.07	± 0.48
3	10	2.69	2.99	3.20	3.39	3.64	3.79	3.76	3.90	3.67	3.91	± 0.43
Body Condition												
T	15	2.84	3.34	3.63	3.87	4.04	4.00	4.10	4.13	3.93	3.99	± 0.35
H	13	2.66	3.04	3.46	3.73	3.83	3.97	3.96	4.07	4.04	4.13	± 0.38
Overall Mean												
	28	2.76	3.21	3.54	3.80	3.94	3.99	4.03	4.10	3.99	4.06	± 0.26

Appendix Table 17. Mean weekly consumption of NDF (kg) for cows fed three levels of ADF and at two body conditions.

Ration	Obs.	Week of Lactation 2	3	4	5	6	7	8	9	10	11	SE
1	10	40.09	45.37	50.60	52.94	53.22	51.47	55.50	55.30	55.89	51.50	± 7.22
2	8	43.13	46.32	56.30	58.05	58.54	57.19	56.03	55.21	49.35	53.24	± 8.07
3	10	44.54	45.45	50.10	51.10	55.78	57.33	55.08	54.18	51.77	55.45	± 7.22
Body Condition												
T	15	41.17	46.00	51.55	53.40	57.47	53.69	56.58	54.67	50.52	51.06	± 5.90
H	13	41.97	45.29	52.63	54.15	53.57	56.93	54.25	55.10	54.80	56.12	± 6.33
Overall Mean												
	28	41.54	45.67	52.05	53.75	55.65	55.20	55.50	54.87	52.42	53.41	± 4.31

Appendix Table 18. Mean weekly consumption of ADF (kg) for cows fed three levels of ADF and at two body conditions.

Ration	Obs.	Week of Lactation 2	3	4	5	6	7	8	9	10	11	SE
1	10	19.50	23.54	26.10	28.94	28.46	27.50	28.06	27.63	28.44	26.22	± 3.99
2	8	23.35	26.32	31.47	31.97	32.93	31.70	30.82	30.91	28.01	30.53	± 4.46
3	10	26.47	27.17	29.75	30.87	33.87	34.54	32.55	32.05	30.27	31.81	± 3.99
Body Condition												
T	15	22.62	25.90	28.80	31.11	32.29	30.84	31.15	29.65	27.79	27.65	± 3.25
H	13	23.63	25.31	29.10	29.78	30.96	31.65	29.64	30.73	30.33	31.51	± 3.50
Overall Mean												
	28	23.09	25.63	28.94	30.50	31.67	31.21	30.45	30.15	28.97	29.45	± 2.38

Appendix Table 19. Mean weekly consumption of lignin (kg) for cows fed three levels of ADF and at two body conditions.

Ration	Obs.	Week of Lactation 2	3	4	5	6	7	8	9	10	11	SE
1	10	3.45	4.00	4.35	5.15	5.02	4.87	4.84	4.86	4.99	4.30	± 0.70
2	8	4.13	4.54	5.59	5.59	5.81	5.35	5.17	51.00	4.94	5.55	± 0.79
3	10	4.99	4.94	5.57	5.82	6.47	6.35	6.26	5.86	5.66	5.66	± 0.70
Body Condition												
T	15	4.09	4.67	5.25	5.82	5.70	5.60	5.53	5.07	4.66	4.72	± 0.58
H	13	4.32	4.28	5.02	5.16	5.85	5.47	5.33	5.54	5.86	5.63	± 0.85
Overall Mean												
	28	4.20	4.49	5.14	5.51	5.76	5.54	5.44	5.29	5.22	5.14	± 0.39

Appendix Table 20. Mean weekly consumption of ash (kg) for cows fed three levels of ADF and at two body conditions.

Ration	Obs.	Week of Lactation 2	3	4	5	6	7	8	9	10	11		SE
1	10	6.70	8.37	9.20	10.10	9.89	9.69	9.90	9.73	10.63	10.19	±	1.28
2	8	8.02	8.69	9.70	10.00	10.31	9.95	10.55	10.40	9.97	11.51	±	1.44
3	10	8.26	8.88	9.65	9.78	10.48	10.56	10.79	10.99	9.95	10.54	±	1.28
Body Condition													
T	15	7.63	9.05	9.52	10.02	10.25	9.95	10.18	9.88	9.53	10.02	±	1.05
H	13	7.64	8.20	9.48	9.89	10.18	10.22	10.66	10.94	10.97	11.47	±	1.13
Overall Mean													
	28	7.64	8.65	9.50	9.96	10.22	10.08	10.40	10.37	1.11	10.69	±	0.77

Appendix Table 21. Mean weekly plasma concentration of glucose mMoles for cows fed three levels of ADF and at two body conditions.

Ration	Obs.	Week of Lactation 2	3	4	5	6	7	8	9	10	11	SE
1	10	0.353	0.382	0.377	0.380	0.390	0.387	0.395	0.405	0.410	0.377	± 0.023
2	8	0.352	0.359	0.359	0.378	0.387	0.386	0.391	0.400	0.387	0.387	± 0.026
3	10	0.346	0.316	0.347	0.362	0.371	0.377	0.369	0.375	0.393	0.386	± 0.023
Body Condition												
T	15	0.343	0.343	0.351	0.382	0.378	0.384	0.384	0.394	0.393	0.383	± 0.019
H	13	0.359	0.362	0.373	0.365	0.388	0.382	0.385	0.391	0.403	0.384	± 0.020
Overall Mean												
	28	0.350	0.352	0.361	0.373	0.383	0.383	0.384	0.393	0.397	0.383	± 0.014

Appendix Table 22. Mean weekly plasma insulin concentration (ng/ml) for cows fed three levels of ADF and at two body conditions.

Ration	Obs.	Week of Lactation 2	3	4	5	6	7	8	9	10	11	SE
1	10	0.439	0.238	0.282	0.330	0.271	0.234	0.292	0.311	0.366	0.310	± 0.026
2	8	0.203	0.225	0.271	0.282	0.368	0.304	0.368	0.268	0.238	0.292	± 0.033
3	10	0.376	0.292	0.327	0.293	0.238	0.618	0.289	0.397	0.414	0.393	± 0.026
Body Condition												
T	15	0.441	0.245	0.335	0.329	0.325	0.326	0.299	0.279	0.395	0.327	± 0.018
H	13	0.242	0.264	0.249	0.274	0.250	0.467	0.328	0.388	0.290	0.343	± 0.020
Overall Mean												
	28	0.349	0.254	0.295	0.303	0.289	0.391	0.313	0.330	0.346	0.335	± 0.009

Appendix Table 23. Mean weekly plasma concentration of NEFA mMoles for cows fed three levels of ADF and at two body conditions.

Ration	Obs.	Week of Lactation 2	3	4	5	6	7	8	9	10	11	SE
1	10	0.737	0.496	0.436	0.323	0.300	0.298	0.200	0.133	0.140	0.163	± 0.100
2	8	0.581	0.521	0.408	0.501	0.233	0.218	0.180	0.175	0.171	0.180	± 0.111
3	10	0.878	0.475	0.448	0.327	0.262	0.378	0.280	0.186	0.303	0.149	± 0.100
Body Condition												
T	15	0.829	0.427	0.363	0.397	0.285	0.303	0.173	0.174	0.152	0.175	± 0.081
H	13	0.643	0.574	0.514	0.350	0.249	0.304	0.280	0.152	0.271	0.148	± 0.087
Overall Mean												
	28	0.743	0.496	0.433	0.375	0.268	0.304	0.223	0.164	0.207	0.163	± 0.060

Appendix Table 24. Mean weekly whole blood concentration of β-Hydroxy butyric acid mMole for cows fed three levels of ADF and at two body conditions.

Ration	Obs.	Week of Lactation 2	3	4	5	6	7	8	9	10	11	SE
1	10	0.612	0.584	0.505	0.577	0.481	0.465	0.431	0.472	0.491	0.415	± 0.117
2	8	0.591	0.575	0.550	0.538	0.448	0.483	0.476	0.462	0.472	0.479	± 0.130
3	10	0.792	0.862	0.648	0.607	0.680	0.600	0.587	0.513	0.503	0.571	± 0.117
Body Condition												
T	15	0.754	0.690	0.612	0.606	0.527	0.542	0.486	0.468	0.488	0.475	± 0.095
H	13	0.574	0.670	0.519	0.542	0.559	0.492	0.515	0.503	0.493	0.504	± 0.102
Overall Mean												
	28	0.670	0.681	0.569	0.576	0.542	0.518	0.499	0.484	0.490	0.489	± 0.070

Appendix Table 25. Mean weekly whole blood concentration of acetoacetic acid mMoles for cows fed three levels of ADF and at two body conditions.

Ration	Obs.	Week of Lactation 2	3	4	5	6	7	8	9	10	11	SE
1	10	0.028	0.020	0.008	0.018	0.014	0.021	0.004	0.008	0.013	0.022	± 0.016
2	8	0.025	0.023	0.017	0.023	0.017	0.010	0.008	0.009	0.017	0.008	± 0.018
3	10	0.034	0.054	0.042	0.021	0.030	0.011	0.018	0.008	0.008	0.012	± 0.016
Body Condition												
T	15	0.043	0.042	0.032	0.023	0.023	0.021	0.011	0.008	0.014	0.019	± 0.013
H	13	0.013	0.023	0.011	0.018	0.018	0.006	0.009	0.009	0.010	0.009	± 0.014
Overall Mean												
	28	0.029	0.033	0.022	0.021	0.020	0.014	0.010	0.008	0.012	0.014	± 0.101

Appendix Table 26. Mean weekly plasma triacylglycerol concentration (mMoles of trioleien) for cows fed three levels of ADF and at two body conditions.

Ration	Obs.	Week of Lactation 2	3	4	5	6	7	8	9	10	11	SE
1	10	0.0043	0.0045	0.0061	0.0061	0.0093	0.0068	0.0063	0.0075	0.0061	0.0079	± 0.0016
2	8	0.0074	0.0050	0.0056	0.0062	0.0107	0.0107	0.0098	0.0080	0.0070	0.0065	± 0.0018
3	10	0.0055	0.0073	0.0066	0.0082	0.0095	0.0100	0.0091	0.0073	0.0082	0.0090	± 0.0016
Body Condition												
T	15	0.0046	0.0056	0.0063	0.0078	0.0079	0.0094	0.0083	0.0080	0.0065	0.0070	± 0.0013
H	13	0.0068	0.0058	0.0059	0.0058	0.0118	0.0087	0.0083	0.0071	0.0078	0.0089	± 0.0014
Overall Mean												
	28	0.0056	0.0057	0.0061	0.0069	0.0098	0.0091	0.0083	0.0076	0.0071	0.0079	± 0.0009

Appendix Table 27. Mean weekly concentration of plasma creatinine mMoles of cows fed three levels of ADF and at two body conditions.

Ration	Obs.	Week of Lactation 2	3	4	5	6	7	8	9	10	11	SE
1	10	0.147	0.142	0.158	0.126	0.137	0.144	0.134	0.157	0.140	0.142	± 0.016
2	8	0.167	0.141	0.133	0.161	0.122	0.155	0.151	0.147	0.143	0.149	± 0.017
3	10	0.165	0.151	0.138	0.147	0.135	0.152	0.137	0.154	0.152	0.145	± 0.016
Body Condition												
T	15	0.156	0.141	0.144	0.136	0.132	0.155	0.141	0.149	0.150	0.152	± 0.013
H	13	0.164	0.150	0.143	0.152	0.131	0.143	0.139	0.157	0.139	0.137	± 0.014
Overall Mean												
	28	0.159	0.145	0.144	0.143	0.131	0.150	0.140	0.153	0.145	0.145	± 0.009

Appendix Table 28. Mean weekly calculated energy balance of cows fed three levels of ADF and at two body conditions.

Ration	Obs.	Week of Lactation 2	3	4	5	6	7	8	9	10	11	SE
1	10	-49.2	-35.0	-23.2	7.8	8.5	15.2	37.6	44.9	54.4	40.8	± 9.8
2	8	-64.7	-50.3	-22.8	0.0	14.1	7.8	7.3	27.1	13.5	31.9	± 12.3
3	10	-45.3	-39.2	-30.8	-14.3	-3.4	14.1	19.9	26.1	13.6	42.0	± 9.8
Body Condition												
T	15	51.1	-33.7	-18.4	-0.9	14.6	8.1	26.6	30.4	19.5	32.0	± 6.6
H	13	-50.9	-49.1	-34.4	-4.0	-4.3	18.0	18.0	36.2	38.2	46.5	± 7.6
Overall Mean												
	28	-51.0	-40.9	-25.8	-2.3	5.8	12.7	22.6	33.1	28.2	38.7	± 3.5

Appendix Table 29. Pearson correlation coefficients for selected variables with dry matter intake.

Variable	R^2	P
Milk production	.62	.0001
Body weight	.48	.0001
Change in body weight	-.12	.0444
Body condition score	-.08	.1993
Change in body condition score	-.02	.7409
4% FCM production	.54	.0001
4% FCM/100 kg body weight	.46	.0001
Milk fat %	.03	.5917
Mik protein %	-.02	.0001
Blood BHBA concentration	-.23	.0001
Blood ACAC concentration	-.14	.0155
Ketone ratio	-.09	.1154
Plasma glucose	.04	.4590
Plasma insulin	-.01	.8543
Plasma NEFA	-.34	.0001
Plasma triacylglycerol	.04	.5345
Plasma creatinine	-.03	.6399
Ration NDF content	-.09	.1180
Ration ADF content	-.15	.0100
Ration lignin content	-.21	.0005
Energy balance	.53	.0001

Appendix Table 30. Pearson correlation coefficients for selected variables with milk production.

Variable	R^2	P
Dry matter intake	.62	.0001
Body weight	.62	.0001
Change in body weight	.33	.0001
Body condition score	-.11	.0693
Change in body condition score	.10	.1043
4% FCM production	.89	.0001
4% FCM/100 kg body weight	.84	.0001
Milk fat %	.09	.1212
Mik protein %	-.29	.0001
Blood BHBA concentration	-.12	.0432
Blood ACAC concentration	.01	.9900
Ketone ratio	.02	.6936
Plasma glucose	-.14	.0181
Plasma insulin	-.13	.0352
Plasma NEFA	-.06	.3127
Plasma triacylglycerol	-.03	.6548
Plasma creatinine	-.03	.6231
Ration NDF content	.01	.9594
Ration ADF content	-.14	.0188
Ration lignin content	-.25	.0001
Energy balance	-.21	.0005

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