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A comparison of two complete rations for their effect on intake, production and energy balance of dairy cows and first lactation heifers

William Morris Robbins

To the Graduate Council:

I am submitting herewith a thesis written by William Morris Robbins entitled "A comparison of two complete rations for their effect on intake, production and energy balance of dairy cows and first lactation heifers." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Science.

M. J. Montgomery, Major Professor

We have read this thesis and recommend its acceptance:

Eric W. Swanson, J. W. Holloway

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Accepted for the Council:

L. Evans Roth

Vice Chancellor
Graduate Studies and Research

A COMPARISON OF TWO COMPLETE RATIONS FOR THEIR EFFECT ON INTAKE, PRODUCTION AND ENERGY BALANCE OF DAIRY COWS AND FIRST LACTATION HEIFERS

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

William Morris Robbins

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ABSTRACT

During the winters of 1975-76 and 1976-77, 76 Holstein cows and first lactation heifers were subjected to an 18 week continuous feeding trial beginning the week of their calving. Two complete rations varying in forage:concentrate ratio were fed; Ration 1 - 37:62 on a dry matter basis plus 4.5 kgs of alfalfa hay and 2.7 kgs of concentrate fed in the milking parlor, and Ration 2 - 54:46 on a dry matter basis plus 2.25 kgs alfalfa hay and 2.7 kgs of concentrate in the parlor. Thus there were four treatment groups: a) first lactation heifers receiving Ration 1, b) second or more lactation cows receiving Ration 1, c) first lactation heifers receiving Ration 2, and d) second or more lactation cows receiving Ration 2.

Intake was considered both as complete ration dry matter, and with inclusion of alfalfa hay and parlor concentrate, total ration dry matter. Daily intake of complete ration dry matter was a) 9.75, b) 11.44, c) 9.54, and d) 12.32 kgs for the respective treatment groups showing a significant difference due to age ($P < .05$) but not to ration. Daily total ration dry matter consumption was a) 16.28, b) 17.97, c) 14.03, and d) 16.80 kgs, respectively with (b) significantly higher and (c) significantly lower ($P < .05$) than (a) or (d). Daily fat corrected milk production was a) 24.42, b) 29.63, c) 25.29, and d) 30.78 kgs respectively being significantly affected by age ($P < .05$) but not by ration.

Apparently the higher proportion of concentrate in Ration 1 allowed higher total consumption and a closer equilibration between energy intake and requirement although no increase in milk production was noticed.

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CHAPTER I

INTRODUCTION

If voluntary intake is the most important factor determining energy consumption by dairy cows (43), and if many present day cows are limited only by appetite from producing exceptionally large quantities of milk (60) then the desireability of increasing voluntary intake of energy early in lactation may be higher milk yields. Research has shown the importance of feed consumption in early lactation on milk production through the entire lactation (7).

At the peak of lactation, a high producing dairy cow's energy intake fails to meet the requirements of its production. A complete understanding of the regulatory mechanisms controlling intake would go far in allowing management practices designed to narrow the gap between intake and requirement. Or, if such a gap is somehow necessary to the physiology of lactation or to overall energy balance of the cow, then improved management practices would still be of interest if an increase in intake concomitantly increases production.

The emergence of an understanding that ration characteristics determine in a large way the rate of consumption of the ration has led to formulations designed to maximize intake. A feeding system which may allow increased intake is the complete ration because a high level of grain consumption is made possible. Numerous experiments have demonstrated the feasibility of complete rations as a system. Milk yields have been comparable when rations have been fed either complete or as separated components. And when proportional additions of concentrate result in increased energy intake by dairy cows, milk yield has generally risen.

The majority of feeding trials with complete rations reported have dealt with cows some weeks post-calving when the lactation curves were already declining. Any study of ration effect on the peak of lactation requires feeding during the first 6 to 8 weeks after calving.

Such a study also requires some method of evaluating progressive changes in the instantaneous relationship between intake and requirement. That is because the energy deficit which occurs is more a result of lack of synchrony between peak production and peak consumption than of a difference in absolute quantity. Development during the past 20 years of the Net Energy feeding standards seems ideal for studying this relationship because of the direct comparison between intake and requirement made possible by both being expressed in the same units.

This experiment was a comparison between two complete rations formulated to differ in proportion of concentrate to determine if energy desnity can affect amount of ration consumed in early lactation. Ration and milk yield were evaluated in terms of Net Energy for milk production to see if any increase in consumption affected energy balance at the peak of lactation and to see if a change in energy balance affected milk production.

CHAPTER II

REVIEW OF LITERATURE

Voluntary Intake

Factors which affect or control voluntary intake are numerous and they differ between non-ruminants and ruminants (2). In addition, a distinction exists between those factors regulating satiation day by day and those concerned with the long-term maintenance of energy balance (4). All are interrelated (3). For even though "errors" happen with consumption of individual meals, energy balance or a set rate of change in energy balance is apparent in the long run (4).

The notion that ruminants eat forage to the limits of rumen fill, and that consumption increases with increasing nutritive value until high energy density allows satiation within the limits of rumen fill has been well established (3, 4, 10, 44, 53). It would seem that the satiation signal might be fairly straight forward, simply tension on the rumen wall, when rumen fill is operative. However, to date any tension receptors have not been identified histologically (3). The physiological regulation of intake which allows satiation on a less than full rumen has been more difficult to explain.

Satiation. Any factor which acts in controlling the size of a meal must be undergoing some change during the course of the meal (3). Consequently, proposed mechanisms have been related to the rise in body temperature associated with eating (2, 3, 43), or to changes in rumen fluid composition and blood metabolites (3, 4, 43, 55). In a comprehensive review, Baile and Forbes (3) discounted the "thermostatic" mechanisms because temperature rises are more related to nonspecific activity than to feeding. Those researchers felt possible "chemostatic" mechanisms could be increased rumen fluid osmolarity, reduction in rumen pH, production of lactate, or, most probably, changes in ruminal volatile fatty acid (VFA) concentrations since ruminal infusions of acetate and propionate significantly reduce feed intake. Baile and Forbes (3) theorized acetate receptor sites would be on the lumen side of the rumen wall whereas propionate receptors would be on the walls of the ruminal veins.

Papas and Hatfield (55) have recently shown that infusions of VFA can seriously disturb the rumen acid-base balance. Consequently the reduction of intake resulting from infusions may be due to development of acidosis rather than a regulatory mechanism based on concentration of VFA.

Energy balance. Satiety means how an animal knows it is full, but a control of energy balance must establish the level of "full." Such a control could arise from response to a reference input signal (4) and alteration of the physiological and environmental circumstances of the animal. The end result would be change in the level of feed intake and maintenance of a constant energy balance (3). The ventromedial hypothalamus has been designated the source of the reference input signal (2, 3).

The source of the signal indicating alteration in physiological and environmental circumstances is less certain (3, 5, 21, 65). A "lipostatic" theory has been advanced (5) suggesting the release of some compound from fat depots in proportion to their size. Perhaps prostaglandin is such a compound (3). Baile and Forbes (3) saw a possible role for the flow of digesta through the intestine since this is a relative constant compared to rumen fill. Increased consumption by growing ruminants made possible by increased intestinal capacity is certainly one form of control of energy balance.

The relationship between increased gastrointestinal capacity and increased feed consumption has been observed with lactating cattle (10, 21, 65). Tulloch (65) found that rumen and intestinal volume were larger in a lactating cow than its dry twin. Hypertrophy of the alimentary tract was accompanied by decline in peritoneal fat. Restriction of alimentary capacity by excess peritoneal fat may have contributed to the significantly lower intake Yadava (69) noticed in over conditioned compared to less fat dairy cows. Part of the explanation for the decline in intake associated with late pregnancy may be rumen displacement by the enlarged uterus (21).

Whether alimentary hypertrophy is caused by the endocrine changes of lactogenesis (10) or made possible by more available space in the abdomen (21), the net result in the lactating dairy cow is a slow increase in appetite and achievement of maximum intake some weeks after the maximum nutritional requirement for milk production (65). Early in lactation, therefore, the cow is in negative energy balance (12) and uses the energy of its own body tissue to help meet requirements of its genetic milk producing potential (25, 38). A dairy cow cannot carry unlimited fat (47), and can mobilize only that which it has on reserve (38) which means that for most dairy cows, milk production is limited by their ability to consume energy (25). One approach to maximization of energy consumption has been through the use of complete rations (25).

Complete Rations

To increase the energy content of a ration the concentrate allowance is increased relative to the forage. If the concentrate is fed ad libitum with the inclusion of too little forage, milk fat depression occurs (59) with a consequent reduction in efficiency of conversion of energy to milk (67). Various physiological disorders have been associated with rations too low in fiber, including rumen parakeratosis, liver abscesses, bloat, and joint stiffness (29, 59). Therefore, to insure an adequate intake of forage when concentrates are fed ad libitum it is possible to blend the forage component directly with the concentrate, making a feedstuff commonly referred to as a complete ration (51, 59).

The complete ration concept lends itself well to mechanized feeding and induces cows to consume forage and concentrate in proportions that maximize milk production. Complete rations may enable the use of forages not ordinarily palatable enough, as dairy feeds (59). Kesler et al. (30) reported a satisfactory complete ration where the fiber source was ground up newsprint. Owen et al.

(54) fed lactating Holsteins complete rations with straw as the forage. Use of cottonseed hulls, corn cobs and shucks has been reported (24, 34). Rakes (59) envisioned the complete ration concept as spurring new research into making animal feeds from industrial by-products.

Complete rations may be formulated in a variety of physical forms: as pellets, or coarsely ground, or ensiled, as well as simply mixed together at the time of feeding (4, 28, 31, 35, 49, 57, 61, 68). Pelleted rations may be more expensive than the other forms if purchased from a mill (46, 59). On occasion, pelleting has been associated with milk fat depression (48, 61).

In theory, grinding the ration could do two things: a) increase dry matter intake by reducing rumen retention time (53), and b) depress milk fat production if level of rumen acetate declines (67). Leighton and Helm (31) noticed the later when feeding a complete ration of 30% ground alfalfa hay and 70% ground sorghum grain. McCoy et al. (35) fed ground alfalfa-bromegrass hay and ground shelled corn at the same 30:70 ratio and noticed neither a fat test depression nor increased intake over a ration containing long hay.

Ensiling offers the advantages of efficient storage and convenient handling for complete rations (33). Also, ensiled complete rations have more density than silage alone (32, 33), and may result in less fermentation loss of dry matter (32). Proper management may necessitate different forage:concentrate ratios for different groups of cows which means that ensiled complete rations may have to be altered before being fed (32, 33).

Use of corn silage as the forage ingredient of complete rations has been tested repeatedly (11, 12, 16, 23, 26, 46, 48, 62, 63). Reports on alfalfa haylage and grain sorghum silage are available (17, 52). Hooven et al. (28) found a trend toward decreased intake and fat corrected milk (FCM) during early lactation of 24 Holsteins with ensiled complete rations compared to rations of corn silage and concentrate fed separately. From day 121 onward the trend was not evident. Neither Montgomery (46) nor Marshall and Voight (33) found any difference in FCM yield or dry matter intake between corn silage complete rations mixed at feeding and the same ration ingredients fed separately. Both these experiments (33, 46) were conducted at a stage post-peak of lactation.

Because dairy cows are customarily fed complete rations in groups, whereas researchers often feed complete rations to individual cows, Coppock et al. (11) compared intake and production of 24 Guernseys to see if feeding practice could affect results. The complete ration fed was 60% corn silage and 40% pelleted concentrate. Though a slight increase was noted in consumption by group fed cows, it was not considered enough to invalidate extrapolation of experimental results with stanchion fed cows to group fed situations.

Within the references cited above of corn silage complete rations mixed at time of feeding (11, 12, 16, 23, 26, 46, 48, 62, 63), the range of dry matter intake percent of body weight was 2.31 to 3.78 which covered a wide range of milk yields and stages of lactation. Of these, the highest average daily milk yield was 30.9 kg, achieved with a dry matter intake of 3.85% of body weight (46).

Although the desired effect of increasing energy consumption in early lactation by high producing cows can be accomplished with complete rations (12), lower producers with access to the same ration may become over-fattened (59). Spahr and Harshbarger (63) acknowledged three ways of gaining some control over nutrient intake by individual cows. Those are: grouping cows according to production, and then changing the amount of ration allotment, or altering the nutrient composition of the ration fed to a group. A way of doing the latter is by changing the forage:concentrate ratio of the complete ration.

Forage:Concentrate Ratio

The general relationship of increased dry matter intake with increasing nutritive value (43) is indicated as complete ration proportion of concentrate is increased. Escano and Rusoff (17) fed complete rations of grain sorghum silage plus concentrate mixture at three different proportions, ranging from 71% silage to 43.8% silage on a dry matter basis. Addition of soybean oil meal kept all rations isonitrogenous. Kilograms of dry matter (DM) intake differed significantly between all three complete rations, the increase reflecting the increased proportions of concentrate. Estimated net energy intake and fat corrected milk production also increased significantly. Harner and Spahr (23) fed a forage of 90% corn silage plus 10% alfalfa haylage mixed with different proportions of concentrate to make three complete rations very similar in ratio to those of Escano and Rusoff (17). Dry matter intake, estimated net energy (ENE) intake and fat corrected milk production all increased with increasing concentrate for Harner and Spahr (23).

When unlimited by rumen fill, cattle can adjust their consumption so as to maintain constant digestible energy intakes (4). This was demonstrated by Cowsert and Montgomery (14) using isonitrogenous pelleted complete rations where the proportion of concentrate ranged from 0 to 67%. Compared to pelleted rations, rumen fill is apparently a more significant intake factor when corn silage is the complete ration forage. Coppock et al. (12) fed four forage:concentrate ratios to Holstein cows and only with the two highest concentrate proportions, 55 and 70%, did digestible energy intake seem not to change. Cows consuming the 70% concentrate ate more in the first third of lactation but less in the last two-thirds than cows on 55% concentrate so that total lactation intake was not very different. The highest concentrate proportion used by either Harner and Spahr (23) or Escano and Rusoff (17) was 56% which may explain the constantly rising intake of estimated net energy in those two experiments.

According to Putnam and Loosli (58) milk production should be expected to increase with increasing proportions of concentrate in the diet. Perhaps it would be more accurate to say production increases as dry matter intake increases, especially if rations like the 70% concentrate of Coppock et al. (12) are considered.

A series of experiments were conducted by Montgomery (46) to ascertain minimum concentrate levels in complete rations for different milk production rates. Corn silage was the forage used. With three groups of cows, producing initially 65 pounds of milk per day, intake per 100 pounds of body weight increased from 3.36 pounds DM at 40% concentrate dry matter to 3.55 pounds DM at 45% concentrate. However, when concentrate was increased to 55% dry matter, intake declined to 3.40 pounds. Using cows producing 70 to 75 pounds of milk per day, a comparison between a ration of 63% concentrate: 37% forage dry matter plus 10 pounds of additional hay per day to a ration of 45% concentrate: 55% forage plus 5 pounds additional hay was made. Dry matter intake and milk production were higher with higher concentrate, but the difference in intake could all be attributed to the 5 pound difference in hay consumption. Based on lactation persistency results, Montgomery (46) concluded a complete ration as fed forage:concentrate ratio of 1.5:1 plus 10 pounds hay per day was the optimum for milk yields of 75 pounds. Lower milk yields could best use 3:1 as fed ratios plus an additional 5 pounds of hay per day.

Experimental milk yields have not always increased with consumption rate. Enlow et al. (16) used a 2 x 2 factorial arrangement to compare complete rations of two different protein and two different energy levels. When considered across protein levels, the 60% concentrate ration ("High" energy) significantly increased dry matter intake over a 33% concentrate ration ("low" energy). Solids corrected milk yield was not significantly different at $P > .05$.

As with any ration when forage proportion becomes too low (58, 67), complete rations can depress milk fat percentage (59). A comparison of three forage:concentrate ratios in complete rations fed at different stages of lactation was made by Spahr and Harshbarger (63). The highest concentrate proportion used was approximately 60% of ration dry matter and both dry matter intake and milk production increased with increasing proportions of concentrate. However, milk fat percentage consistently showed a trend toward decline. Because at no time did milk fat percentage drop below "normal," these workers concluded milk fat production was not depressed. In fact, they suggested that use of complete rations may allow higher proportions of concentrate to be fed before milk fat depression becomes significant.

Coppock et al. (12) found a trend toward milk fat depression in their 70% concentrate complete ration compared to 55% concentrate or lower. Rakes (59) suggested 30% forage as the minimum to maintain normal milk fat secretion.

The concept has been considered that ruminants eat to satisfy their digestible energy requirements if unlimited by rumen fill (13). Theoretically, the optimum forage:concentrate ratio would permit high producing cows to meet their requirements and still prevent over-consumption by the low producers (12). In their search for the "optimum" dairy ration, Georgia workers (36) established the following characteristics: a) 65-68% digestible dry matter, b) 18-22% crude fiber, c) 12-14% crude protein, d) 0.7% calcium, and e) 0.5% phosphorous. They reported that in practice the majority of cows in a herd will match consumption with requirement well enough to permit use of a single ration. They suggested that cows with insufficient appetite or too great an appetite in relation to their need may have to be culled.

Coppock et al. (12), feeding four complete rations of different forage:concentrate ratios to 37 Holsteins found that although high concentrate rations allowed cows to meet energy requirements sooner, none of the rations allowed positive energy balance in the early weeks of lactation. Cows eating the higher concentrate ration (the 70% concentrate dry matter ration) reached energy equilibrium 8 weeks post partum. A trend toward increased weight gain was noticed with increasing proportions of concentrate but whether any cows became over-fattened was not reported. The cows in this study apparently did not match consumption to requirement with any precision, which supports the concept of different rations for differently producing groups.

Sims (62) fed a single complete ration throughout the lactation to 13 Holstein and 3 Brown Swiss cows. Including some additional alfalfa hay, the forage:concentrate ratio was approximately 50:50 on a dry matter basis. Mean body weight change was 693 kg, 3 days post calving to 639 kg at 12 weeks to 748 kg at 42 weeks of lactation. Over-fattening does not seem evident here. Average milk production for the 305 day lactations was 9,170 kg.

A consideration when comparing complete rations using corn silage to others of different forage composition is that the true concentrate proportion includes the corn grain of the silage (33). Most experimenters do not include this in their calculations.

If rations under comparison are not isonitrogenous, part of the increased consumption associated with increasing concentrate percentage may be due to increasing protein levels. The complete rations fed to Jerseys and Holsteins by Enlow et al. (16) resulted in significantly higher intake and milk yield when protein was 14% compared to 12% protein.

As ration proportions of concentrate become larger, consideration must be given to the possibility of changes in vitamin and mineral composition (22). Changing populations of rumen microflora may result in different rates of synthesis of B vitamins by dairy cattle. Also, those vitamins and minerals for which forage is the primary source may decrease in availability as forage percentages decrease, particularly vitamins A and D and calcium (22).

Net Energy System

The 1978 edition of NRC Nutrient Requirements for Dairy Cattle expresses both the energy value of feedstuffs and the energy requirements of dairy cattle in terms of Net Energy for milk production (NE_{milk}) (50). This expression is a mathematical approach to solving the "partition problem," the uncertainty of energy distribution between milk, maintenance, and body tissue gain in lactating animals (42). The expression assumes a) the efficiency of metabolizable energy use for tissue deposition is equal to the efficiency of metabolizable energy use for milk production (40), b) body tissue energy is used with an efficiency of 84% for milk production (38), and c) when adjusted for body tissue loss or gain, milk energy is secreted with essentially a constant "net efficiency" over a wide range of milk yields (42) (net efficiency defined as efficiency with which energy consumed in excess of maintenance needs is used for production).

Maintenance. High producing dairy cows in early lactation are losing weight and are thus, by definition, below maintenance even though consuming several times the energy needed to maintain a non-producing animal of the same size. The NE_{milk} system assumes the maintenance requirement is that proportion of the total net energy requirement for producing some quantity of milk which is not recovered as milk energy, adjusted for tissue gain or loss (42). According to Moe et al. (40), the maintenance requirement may be indirectly calculated by regression of total energy balance (metabolizable energy--total heat production) upon metabolizable energy intake. At zero metabolizable energy intake the value of total energy balance, which is necessarily a negative value, is equal to the maintenance requirement expressed in terms of production units, or units of NE_{milk}. In the 1978 NRC Nutrient Requirements for Dairy Cattle, the maintenance requirement is 80 kcal NE_{milk}/kg body weight $^{.75}$ (50).

There is by no means universal agreement as to the maintenance requirement of lactating cattle. Brody (8) used least squares analysis of the lactation records of 243 Missouri experiment station cows fitted to the equation $TDN = B(FCM) + C(W^{.73}) + D(\Delta W)$. The cost of maintenance in pounds of TDN was found to be 0.053 (Body weight $^{.73}$). This corresponds to 135 kcal ME/kg$^{.75}$/24 hours (18), a bit higher than the 116.7 kcal ME/kg$^{.75}$ of Moe et al. (40.

Demchenko (15) giving the Russian viewpoint, said, "In our opinion energy expenditure for maintenance estimated by formulas taking into account only the live weight of animals do not reflect all the energy costs of keeping their organism going." He did not believe dividing heat production into separate items was warranted.

Holter (27) reached a similar conclusion from experiments attempting to directly measure fasting metabolism of lactating cows. Cows in full lactation were abruptly fasted for 60 hours or until their respiration quotient equalled 70, and their fasting heat production measured. Another measurement was made on day 31 of the dry period. The first measurement was considered to be the fasting metabolism of the lactating cows, and it differed between high producers and low producers, being 118.5 kcal/kg$^{.75}$ and 103.7 kcal/kg$^{.75}$, respectively. The overall mean of 109 kcal/kg$^{.75}$ for lactating cows compared with a value of 100.3 kcal/kg$^{.75}$ for dry cows. This suggests a higher maintenance requirement for higher producing cows indicating that factors other than body weight affect the maintenance requirement of ruminants. If the apparent efficiency of energy use for maintenance is equal to that for milk production (40), then Holter's (27) value for maintenance requirement is 109 kcal NE_{milk}/kg$^{.75}$, a higher value than that of the 1978 NRC requirements (50).

Determination of the maintenance requirement is important to the NE_{milk} system because the calculated total NE_{milk} requirement equals the caloric content of the milk produced plus the NE_{milk}

required for maintenance (37). The actual intake of NE_{milk} is determined by the energy balance adjusted to zero tissue balance plus the maintenance requirement (40).

Determination of input and output NE for milk production values. Units of NE_{milk} intake can be determined, in general, by two different ways. In the first, a feedstuff is fed to cows of varying producing abilities and the resultant energy balance regressed on dry matter intakes. If the cows were fed at levels to minimize body weight change, energy balance is predominantly milk energy and the regression coefficient represents NE_{milk}. That is, it represents the change in milk energy produced resulting from a one unit change in dry matter intake.

The second way to calculate NE_{milk} values is to add an assumed maintenance requirement in NE_{milk} units to the total energy balance and divide into the dry matter intake. The theoretical effect of expressing feed energy in terms of NE_{milk} is that once the maintenance requirement is met, one unit of NE_{milk} intake results in one unit of NE_{milk} output.

Two output factors must be considered, milk energy and body tissue gain or loss. Milk energy is simply the gross energy of the milk produced whereas tissue gain or loss must be indirectly calculated by subtraction of heat production and milk energy from metabolizable energy intake. The sum of the two output factors is the energy balance (EB) (19).

Relationship of intake to requirement. The net energy intake represents only that portion of the gross energy consumed which is actually utilizable energy. In the lactating dairy cow energy may be utilized for three purposes, maintenance (including growth and gestation where appropriate), milk production, and body weight gain. It is not essential that a lactating cow gain body weight. Therefore, the NE_{milk} requirement is only for milk energy and maintenance energy. The above relationship can be expressed as formulas where:

$$EB = \text{Milk energy} \pm \text{Tissue energy} \quad (2\text{-}1)$$

$$NE_{milk}\ \text{requirement} = \text{Milk energy} + \text{Maintenance} \quad (2\text{-}2)$$

$$NE_{milk}\ \text{intake} = EB + \text{Maintenance} \quad (2\text{-}3)$$

$$NE_{milk}\ \text{intake} = \text{Milk energy} \pm \text{Tissue energy} + \text{Maintenance} \quad (2\text{-}4)$$

$$NE_{milk}\ \text{intake} \pm \text{Tissue energy} = \text{Milk energy} + \text{Maintenance} \quad (2\text{-}5)$$

From this it can be seen that NE_{milk} intake (2-5) is equal to NE_{milk} requirement (2-2) only when tissue gain or loss is zero. Figure 1 depicts this relationship graphically with idealized values. To the left of the point of intersection of requirement and intake some of the requirement is supplied by body tissue energy and the animal is losing weight. To the right of the point of intersection intake exceeds requirement and the animal gains body tissue. It would seem that a ration superior in providing energy earlier in lactation would result in a point of intersection of intake and requirement further to the left.

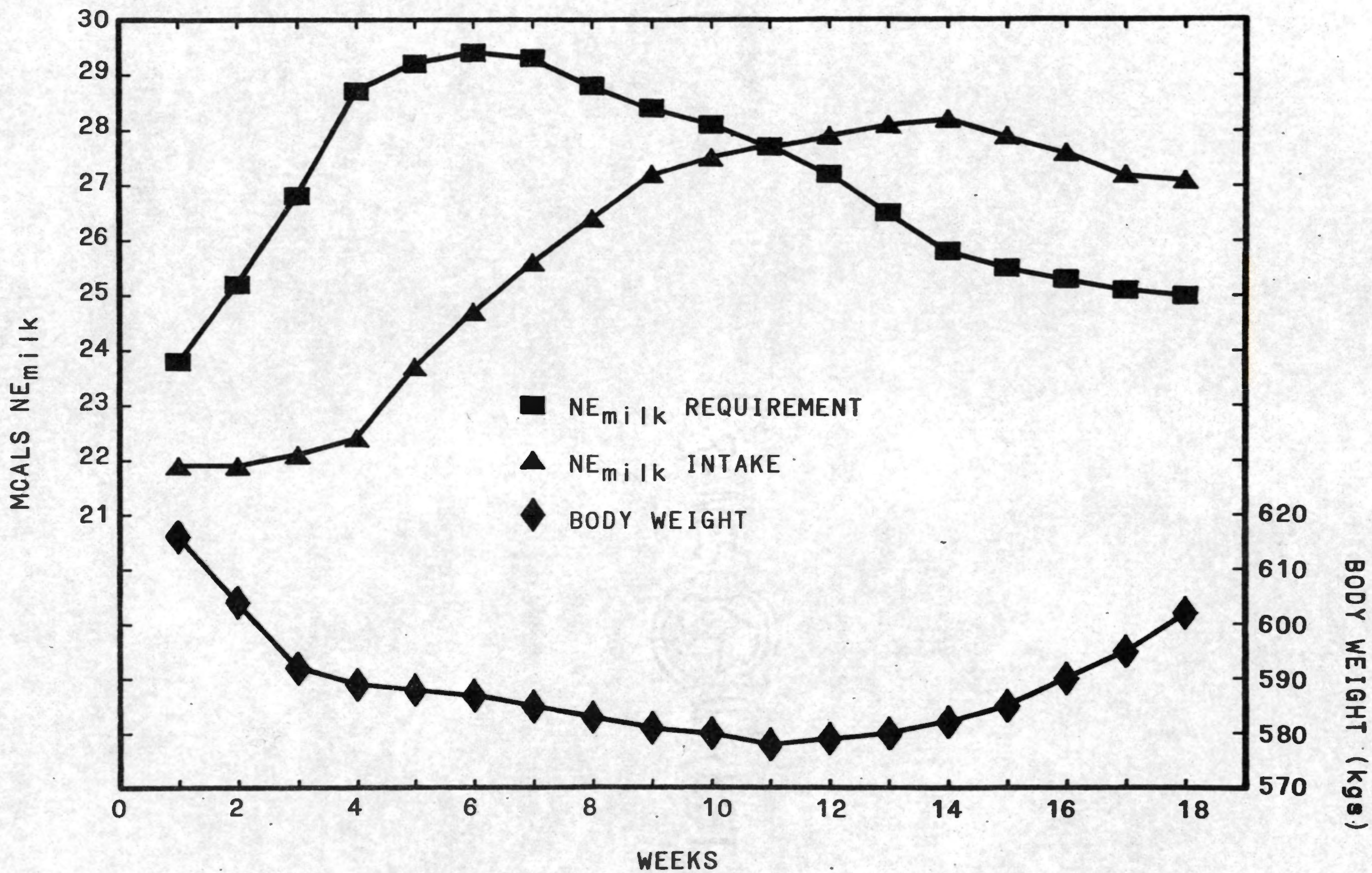

Figure 1. Theoretical relationship between NE_{milk} requirements, NE_{milk} intake, and body weight.

CHAPTER III

EXPERIMENTAL PROCEDURE

Objectives

This experiment was conducted to evaluate intake of two complete ration feeding systems early in lactation. Since the rations differed in forage:concentrate ratios an objective was to see if intake was affected by energy level and if milk production was affected by intake. Also, an objective was to determine if either of the rations was superior in providing more energy earlier in lactation. It was desired to evaluate the rations on the basis of resultant energy balance of the experimental animals in order to make conclusions as to the ability of the rations to provide the high level of nutrients required for the first 18 weeks of lactation.

Procedure

Holstein cows and first lactation heifers from the University of Tennessee herd at Knoxville were subjected to a continuous 18 week feeding trial during two winters, 1975-76 and 1976-77. Beginning the first day of the experimental period each year (which was October 15 in Year 1 and September 19 in Year 2) cows were alternately assigned to one of two ration groups as they calved. Any first lactation heifers that calved within the experimental period were, likewise, alternately assigned to the two ration groups until each group had been filled with a total of 20 cows or heifers. Thus, four treatment groups of unequal subclass numbers were created each year. They were: a) first lactation heifers fed Ration 1, b) second or more lactation cows fed Ration 1, c) first lactation heifers fed Ration 2, and d) second or more lactation cows fed Ration 2. Henceforth, treatment groups will be referred to as a) 1-1, b) 2-1, c) 1-2, and d) 2-2.

Each year the experimental period continued until all 40 cows had either been removed from the experiment or had completed 18 weeks of lactation. During Year 1, five cows did not complete 18 weeks of lactation; three on Ration 1 and two on Ration 2. One of those cows was considered to have had a normal lactation and was thus included in the data. During Year 2, two cows did not complete 18 weeks of lactation, representing both ration groups. One of those cows was included in the data. Since the treatment groups were not yet full at the time of its removal, the other cow was replaced by an additional group member. Thus there were data on 36 experimental animals during Year 1 and 40 during Year 2.

Prior to calving all animals had received the same dry cow ration, hay plus silage or greenchop ad libitum with some grain during the last month of gestation. At calving those to receive Ration 1 were switched to a complete ration intended to be 1.5 to 1 (as fed) corn silage and pelleted concentrate fed ad libitum plus 4.5 kilograms of alfalfa hay. Those to recieve Ration 2 were fed a complete ration intended to be 3 to 1 (as fed) corn silage and pelleted concentrate fed ad libitum plus 2.3 kilograms of alfalfa hay. In addition, all animals received 2.7 kilograms per day of a pelleted concentrate fed in the milking parlor.

Corn silage used was the same as that fed the entire herd, and was ensiled fresh each year. Silage dry matter was below 30% both trial years. The pelleted concentrate was a commercial 16% crude protein dairy mix and was the same whether fed as part of the complete ration or in the milking parlor. Alfalfa hay was purchased from sources in the mid-western states and was considered to be of good quality. Since the higher proportion of concentrate in Ration 1 would result in a higher crude protein percent, the rations were made isonitrogenous by the addition of soybean meal to Ration 2.

Samples of all feed components were taken once weekly and composited by month for laboratory analysis of dry matter, crude protein, acid detergent fiber, lignin, calcium, and phosphorous using standard AOAC procedures (1).

Factored across all treatment groups were cows receiving doses of iodine as part of an ongoing investigation into iodine tolerance by dairy cows. Doses were 5 mg/kg body weight (B.W.), 2.5 mg/kg B.W., and 1.25 mg/kg B.W., plus control cows receiving no iodine. The iodine cows constituted only a small minority of the experimental animals and are reported here only as a matter of record.

Complete rations were fed three times daily in quantities to insure 10% refusal. Each animal received its hay allotment before the afternoon feeding of complete ration. The milking parlor allowance of concentrate was fed in 1.35 kilogram increments at each milking. Water and trace mineralized salt were available free choice. All experimental animals were housed together in individual tie stalls and were allowed to exercise before and after milking, twice daily, for the duration of the experimental period.

The experimental period was divided into 7 day intervals not necessarily corresponding to calendar weeks. Lactation week 1 for each animal was the first full 7 day interval post-calving.

Milk yields were recorded daily and averaged by 7 day intervals. Milk fat percentages were obtained monthly from Dairy Herd Improvement Association records. Complete rations fed and refused were weighed daily and averaged by 7 day intervals. Body weights were measured at two week intervals throughout the experimental period. Data for each cow were organized into standardized lactation weeks so that comparisons between cows would not be confounded with stage of lactation.

Statistical analysis of the treatment means was by analysis of variance using the SAS-76 computer program of SAS Institute, Raleigh, North Carolina. Mean separation was by Duncan's multiple range test (64). Intake and milk output data from each treatment group were analyzed graphically by expression of energy values in terms of Net Energy for lactation as described by Moe et al. (40).

CHAPTER IV

RESULTS AND DISCUSSION

Rations

As mixed in the barn, the as fed forage:concentrate ratios of the complete rations differed from original intention for unknown reasons. Table 1 presents constituents and the forage:concentrate ratios. Calculation of actual complete ration ratios as fed was by simultaneous equations using the known values of silage, concentrate, and complete ration dry matters. Silage dry matter averaged less than 28% and that of the pelleted concentrate, 90% for both trial years.

Because hay and parlor concentrate were fed in fixed amounts whereas complete ration consumption varied with individual animals, forage:concentrate ratio of the total dry matter consumed by each animal was variable. A mean value of the total ratios for all 18 weeks of all cows on a ration would reflect some weeks when complete ration consumption was markedly below normal and consequent total ratios were not representative of normal. Therefore, total forage: concentrate ratios listed in Table 1 are values half way between the mean and the maximum value of all ratios per total ration.

Chemical analysis of the total rations composited by months of the experimental period is in Table 2. A fire in the drying oven destroyed all samples from trial year 2. The analysis listed in the table represents only the samples from trial year 1 but hopefully

Table 1. Actual Ration Constituents for Trial Years 1 and 2

Ration	Complete ration: As fed, Silage	Complete ration: As fed, Conc	Complete ration: Dry matter, Silage	Complete ration: Dry matter, Conc	SBM[a]	Per animal: Hay	Per animal: Conc	Total dry matter: Forage	Total dry matter: Conc
	(%)				(kgs)			(%)	
1	66.7	33.3	37.6	62.4	--	4.5	2.7	45	55
2	79.3	20.7	53.7	46.3	.86	2.25	2.7	52	48

[a]Pounds supplemented per 45.36 kgs of complete ration.

Table 2. Chemical Analysis of Complete Ration Dry Matter by Month, and Mean Crude Protein of Total Ration Dry Matter

	Complete ration						
	CP	ADF	Lignin	Ca	P	DM	Total ration CP
	(%)						
Ration 1							
Oct	16.58	22.00	3.90	1.12	.51	46.08	
Nov	14.43	20.26	2.94	.99	.56	46.35	
Dec	13.63	21.14	4.49	1.86	.64	48.28	
Jan	14.32	19.23	3.49	1.24	.69	49.21	
Feb	14.81	19.36	3.33	1.11	.37	46.53	
Mar	15.85	19.82	4.03	.83	.62	48.48	
Mean	14.94	20.30	3.70	1.19	.57	47.49	14.30
Ration 2							
Oct	16.75	24.38	3.70	.95	.63	41.79	
Nov	14.80	23.07	3.14	.79	.47	42.76	
Dec	11.62	26.36	5.08	1.34	.51	41.29	
Jan	14.28	23.71	3.98	.98	.58	42.57	
Feb	14.96	23.81	4.06	.74	.28	39.05	
Mar	15.86	22.47	3.99	.56	.48	43.42	
Mean	14.71	23.97	3.99	.89	.49	41.81	14.46

accurately reflects chemical composition for both years. Just as total ratio varied with the amount of complete ration consumed, so did the individual ration components. The listed crude protein percentage of the total rations represents a value half way between the mean and the maximum value of all crude protein percentages per total ration. The complete ration percentages of acid detergent fiber, lignin, calcium, and phosphorous were assumed close enough to total ration percentages to not warrant special calculations.

Increased fiber and lowered dry matter percentage reflect the greater proportion of corn silage in Ration 2 compared to Ration 1. The calcium and phosphorous provided by the total rations was sufficient according to standards of the National Research Council (50). By the same standards (50), protein consumption may have been deficient for the level of production achieved by the experimental animals.

Table 3 shows mean daily protein requirements for the treatment groups based on their average daily milk production through 18 weeks of lactation. Also shown is their estimated mean daily protein consumption calculated from total dry matter intake and percent crude protein of total dry matter. The table indicates that on the average no treatment groups consumed sufficient protein. Blaxter (6) has said that animals have the ability to overcome short periods of mild protein deficiency by mobilization of body tissue and thus experience no great reduction of protein secretion in milk. The dairy cows and first lactation heifers in this experiment were energy and protein deficient during part or all of the 18 week experimental period.

Table 3. Mean Daily Protein Requirement of Treatment Groups and Protein Supplied by Rations 1 and 2

	Treatment Groups			
	1-1	2-1	1-2	2-2
	(g)			
Protein requirement	2685	3097	2767	3299
Protein supplied	2314	2603	2002	2402

Intake

Treatment means of intake variables were first subjected to analysis of variance according to the model,

$$Y = \mu + \text{Ration} + \text{Age} + \text{Year} + \text{Interactions} + \text{Residual}. \quad (4\text{-}1)$$

In this way means of any factor across any other factor could be examined statistically.

Consumption of complete ration dry matter and total dry matter differed significantly between Years 1 and 2 ($P < .01$). Loss of the feed samples from Year 2 precludes any explanation of the difference on a chemical basis. The assumption that chemical composition was the same each year may be invalid. Since rainfall and other environmental conditions can affect silage quality from year to year with resultant differences in animal intake (45), the complete rations may have differed in palatability despite the best intentions of the researchers.

Significant differences ($P < .01$) because of age across ration and year were present in means of complete ration, total ration, and dry matter per hundredweight consumption. First lactation heifers were smaller in size with less rumen capacity and did not eat as much as older cows. Considering complete ration dry matter across age and year, there was no significant difference between amount of Ration 1 and Ration 2 consumed. If hay and parlor concentrate are considered, cows consumed significantly more ($P < .01$) total dry matter on Ration 1 than on Ration 2. The increase reflects the larger hay allowance of Ration 1, 4.5 kgs versus 2.25 kgs for Ration 2. When dry matter intake is expressed as a percentage of body weight the same significant difference between rations was evident suggesting that rate of consumption was affected by some factor other than size of the animal.

Other researchers using forage:concentrate ratios comparable to this experiment have observed increased dry matter intakes as concentrate proportion increased (17, 23, 26). The failure of Ration 2 animals to consume extra complete ration dry matter to compensate for their lower allotment of hay is in agreement with other published results. Rumen fill may have been a significant factor limiting intake of the experimental rations since they were apparently below the level of concentrate inclusion where energy intake was limited by physiological factors.

Table 4 presents treatment means of the intake variables by year and for both years combined. Also in Table 4 are treatment means of dairy cows by production groups. Cows averaging greater

Table 4. Treatment Means and Standard Errors of Daily Consumption of Complete Ration Dry Matter, Total Dry Matter, and Dry Matter Per Hundredweight[a]

	Treatment groups							
	1-1		2-1		1-2		2-2	
	$\overline{X}$	SE	$\overline{X}$	SE	$\overline{X}$	SE	$\overline{X}$	SE
	(kg)							
Complete ration DM								
Year 1	10.12	.22	12.72	.24	10.08	.19	13.74	.18
Year 2	9.43	.20	10.26	.19	8.93	.18	11.18	.20
Total cows	9.75^{d}	.15	11.44^{c}	.16	9.54^{d}	.14	12.32^{c}	.15
High producers	--	--	11.92	.21	--	--	12.47	.20
Low producers	9.75^{de}	.15	10.80^{cd}	.24	9.22^{e}	.14	12.14^{c}	.20
Total ration DM								
Year 1	16.65	.22	19.25	.24	14.57	.19	18.23	.18
Year 2	15.97	.20	16.79	.19	13.43	.18	15.68	.20
Total cows	16.28^{d}	.15	17.97^{c}	.16	14.03^{e}	.14	16.80^{d}	.23
High producers	--	--	18.45	.21	--	--	16.96	.23
Low producers	16.28^{c}	.15	17.33^{c}	.24	13.71^{d}	.14	16.63^{c}	.20
DM per CWT[b]								
Year 1	3.17	.04	3.02	.03	2.86	.04	2.94	.03
Year 2	2.86	.04	2.70	.03	2.39	.04	2.46	.03
Total cows	3.00^{c}	.03	2.86^{cd}	.02	2.64^{d}	.03	2.67^{d}	.02
High producers	--	--	2.90	.03	--	--	2.72	.04
Low producers	3.00^{c}	.03	2.80^{cd}	.04	2.60^{d}	.03	2.61^{d}	.03

[a]High producing first lactation heifers on Ration 2 are not included in the table.

[b]Dry matter per hundredweight.

[c,d,e]Means which do not bear the same superscript within a line differ ($P<.05$).

than 30 kgs of milk per day through 18 weeks were designated high producers and cows below 30 kgs were low producers. No first lactation heifers assigned to Ration 1 were in the high production category. Three of the Ration 2 first lactation heifers were high producers but their means are not included in the table. Any mean listed in a production category is the average of at least 10 animals (see Table 7 of Appendix).

Individual treatment group means of the intake variables were evaluated by analysis of variance according to the model,

$$Y = \mu + \text{Treatment group} + \text{Residual} \qquad (4\text{-}2)$$

so that the residual mean square would be appropriate for calculation of a pooled standard error. Where the model was significant, means were separated according to Duncan's multiple range test (64) and are so designated in the table.

Consumption of complete ration dry matter was influenced by age and thus size of the animals, being lowest for the two treatment groups containing first lactation heifers whether considered as total cows or by production group. Cows ate more of complete Ration 2 than they did of complete Ration 1 although the difference was not significant suggesting, perhaps, an attempt toward physiological regulation of intake.

The extra hay allotment of Ration 1 resulted in those animals consuming more total ration dry matter than Ration 2 animals. In fact, consumption by first lactation heifers receiving Ration 1 did not differ significantly from consumption by older cows on Ration 2. And when considered as dry matter per hundred weight, first lactation heifers on Ration 1 had the highest consumption rate of any treatment group. First lactation heifers on Ration 2 ate significantly less ($P < .05$) total ration dry matter than did any other treatment group. Perhaps this indicates that the smaller rumen capacity of the first lactation heifers was more significant in limiting intake of the higher forage ration than was the rumen capacity of the cows.

A question arises as to the effect of splitting the concentrates allotment between the complete ration and the milking parlor. Muller et al. (48) fed complete rations of corn silage plus concentrate where 0, 50 and 100% of the grain allotment was fed separately in the milking parlor. They observed no significant differences in dry matter intake or in fat corrected milk production. Therefore, although complete ration feeding systems do not usually include concentrate fed in the milking parlor, evidence suggests that no real differences resulted from doing so in this experiment. Perhaps feeding concentrate in the parlor would be one way to adjust individual forage:concentrate ratios according to production if complete rations are formulated at ensiling.

Milk Production

Curves of 4% fat corrected milk are shown in Figure 2. Persistency of lactation was greater for the first lactation heifers as the figure shows. Calculated from weeks 7 through 18, persistency was 99.4% and 99.3% per week for first lactation heifers on Rations 1 and 2 respectively. Values for older cows were 98.3% and 97.6% per week on the respective rations.

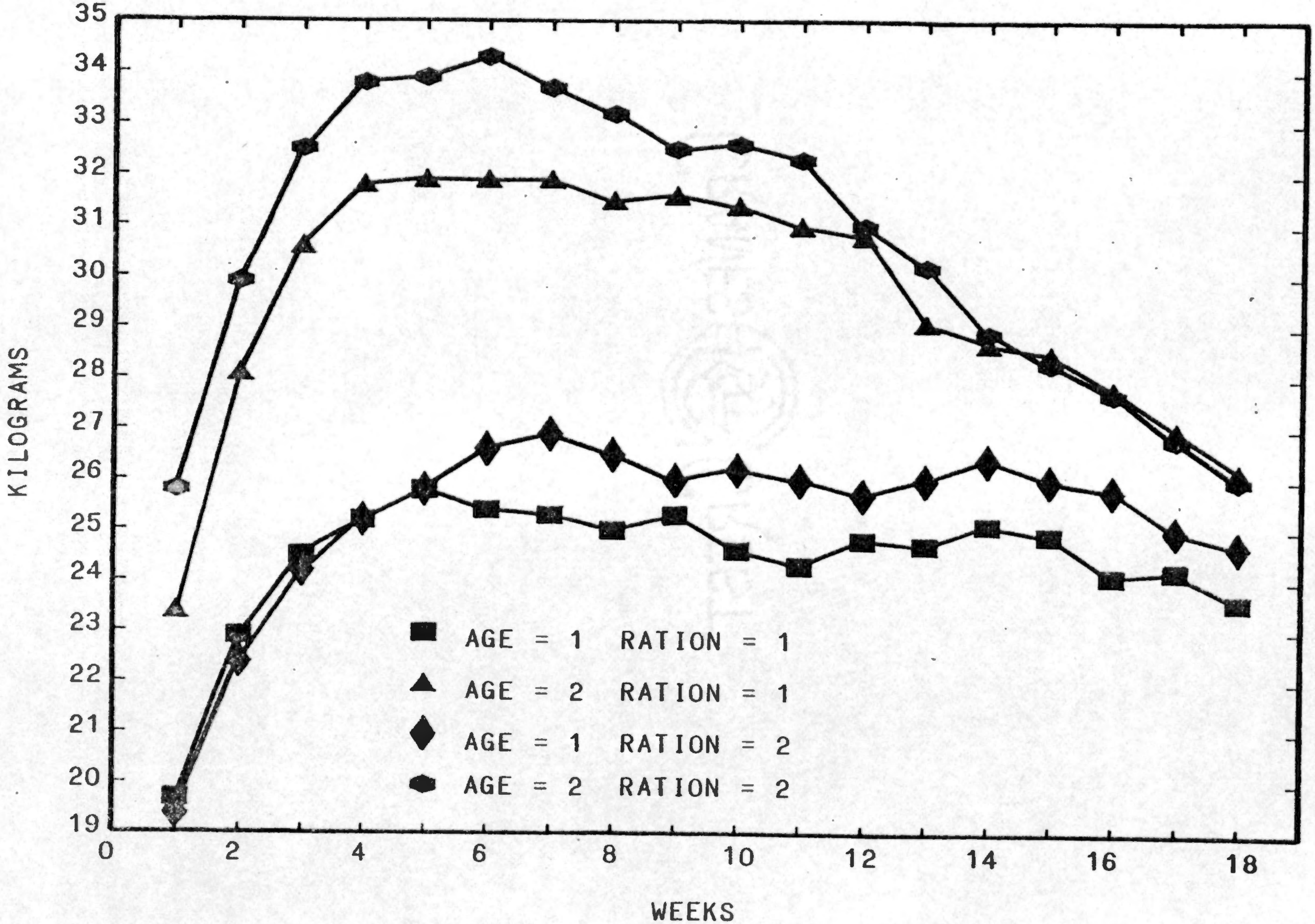

Figure 2. Production curves of 4% fat corrected milk, of all cows.

Treatment means of milk production by year, production groups and for total animals are in Table 5. Production variables were analyzed by the same models as the intake variables (4-1 and 4-2). Milk and fat corrected milk (FCM) production did not differ between trial years, however a trend toward lower milk fat percentage was evident in Year 2. Apparently the difference in feed consumption between trial years was not manifested as a difference in milk production. Means of all cows by ration across age and year showed no significant differences in either milk, butterfat, or fat corrected milk production. There were significant differences ($P < .01$) in milk and fat corrected milk production due to age when they were considered across ration and year. Milk and fat corrected milk showed an effect due to age when considered as individual treatment group means, the first lactation heifer treatment groups producing less than older cows. Age differences disappeared when animals were divided into production groups.

Figures 3 and 4 represent fat corrected milk production curves of animals by production group. The curves can be considered to show two different lactation periods: Period 1--the first 9 weeks, and Period 2--the last 9 weeks. Production means by period were analyzed using model 4-1. Means of fat corrected milk of high producing cows differed significantly between rations during Period 1 ($P < .05$). Ration 2 resulted in more milk production during Period 1 than did Ration 1 even though it was consumed in lesser quanitites. Ration differences were not significant during Period 2.

Table 5. Treatment Means and Standard Errors of Daily Production of Milk, Butterfat, and Fat Corrected Milk

	Treatment groups							
	1-1		2-1		1-2		2-2	
	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
	(kg)							
Milk production								
Year 1	25.25	.36	31.05	.40	25.69	.33	31.54	.40
Year 2	26.22	.26	31.87	.43	27.93	.41	32.50	.44
Total cows	25.91[b]	.22	31.48[a]	.29	26.75[b]	.27	32.07[a]	.30
High producers	--	--	34.62	.27	--	--	35.49	.34
Low producers	25.91[a]	.22	27.41[a]	.41	25.20[a]	.21	28.08[a]	.33
Fat production								
Year 1	3.65	.03	3.67	.02	3.75	.03	3.75	.02
Year 2	3.59	.04	3.57	.03	3.54	.05	3.72	.03
Total cows	3.62[a]	.03	3.62[a]	.02	3.65[a]	.03	3.73[a]	.02
High producers	--	--	3.58	.03	--	--	3.69	.03
Low producers	3.62[a]	.03	3.67[a]	.03	3.71[a]	.03	3.78[a]	.03
FCM production								
Year 1	24.21	.36	29.53	.39	24.68	.31	30.42	.42
Year 2	24.61	.30	29.72	.40	25.98	.43	31.06	.44
Total cows	24.43[b]	.23	29.63[a]	.28	25.29[b]	.26	30.78[a]	.31
High producers	--	--	32.42	.28	--	--	33.86	.37
Low producers	24.43[a]	.23	26.00[a]	.40	24.10[a]	.23	27.16[a]	.34

[a]Means which do not bear the same superscript within a line differ ($P < .05$).

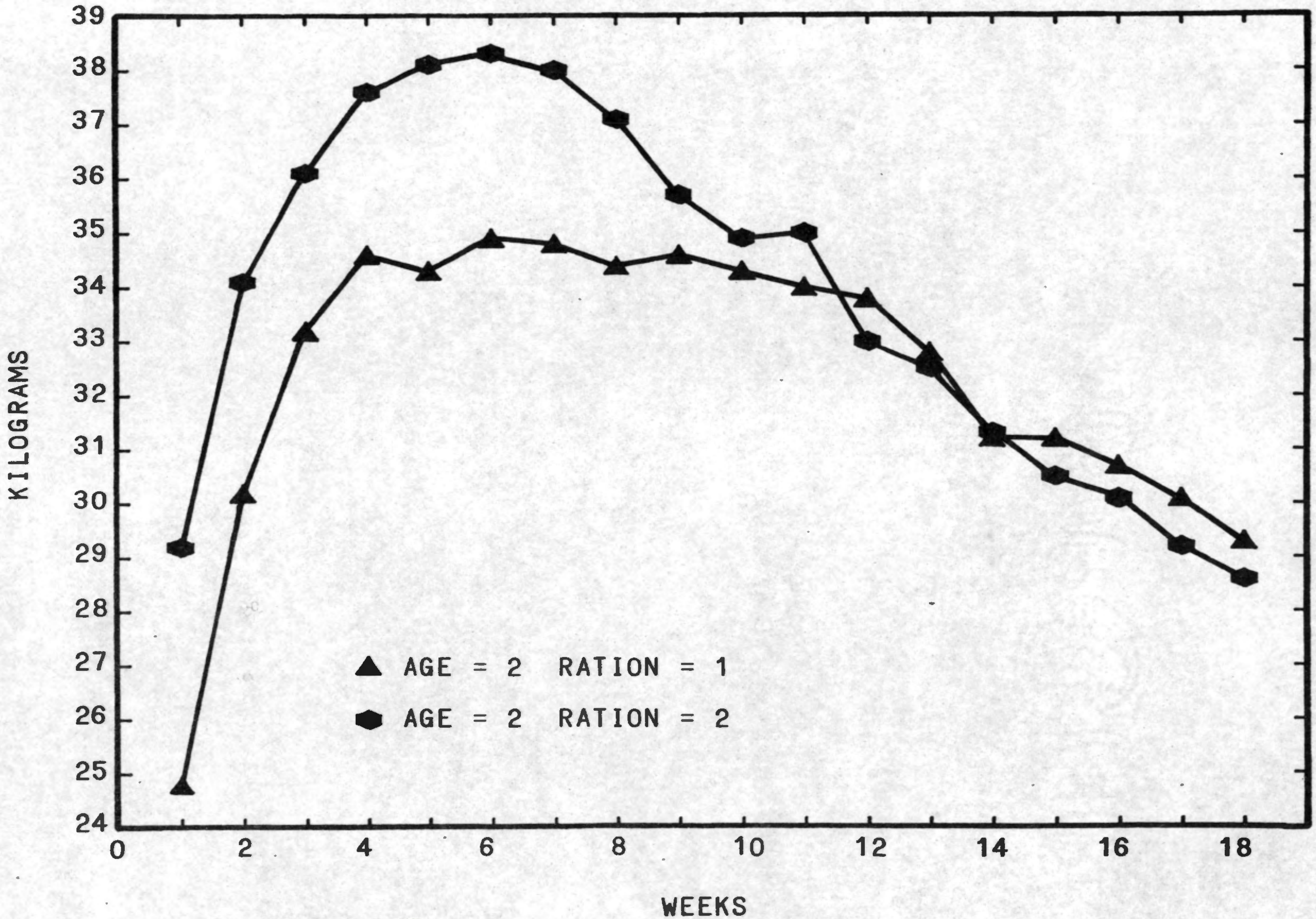

Figure 3. Production curves of 4% fat corrected milk of high producing cows.

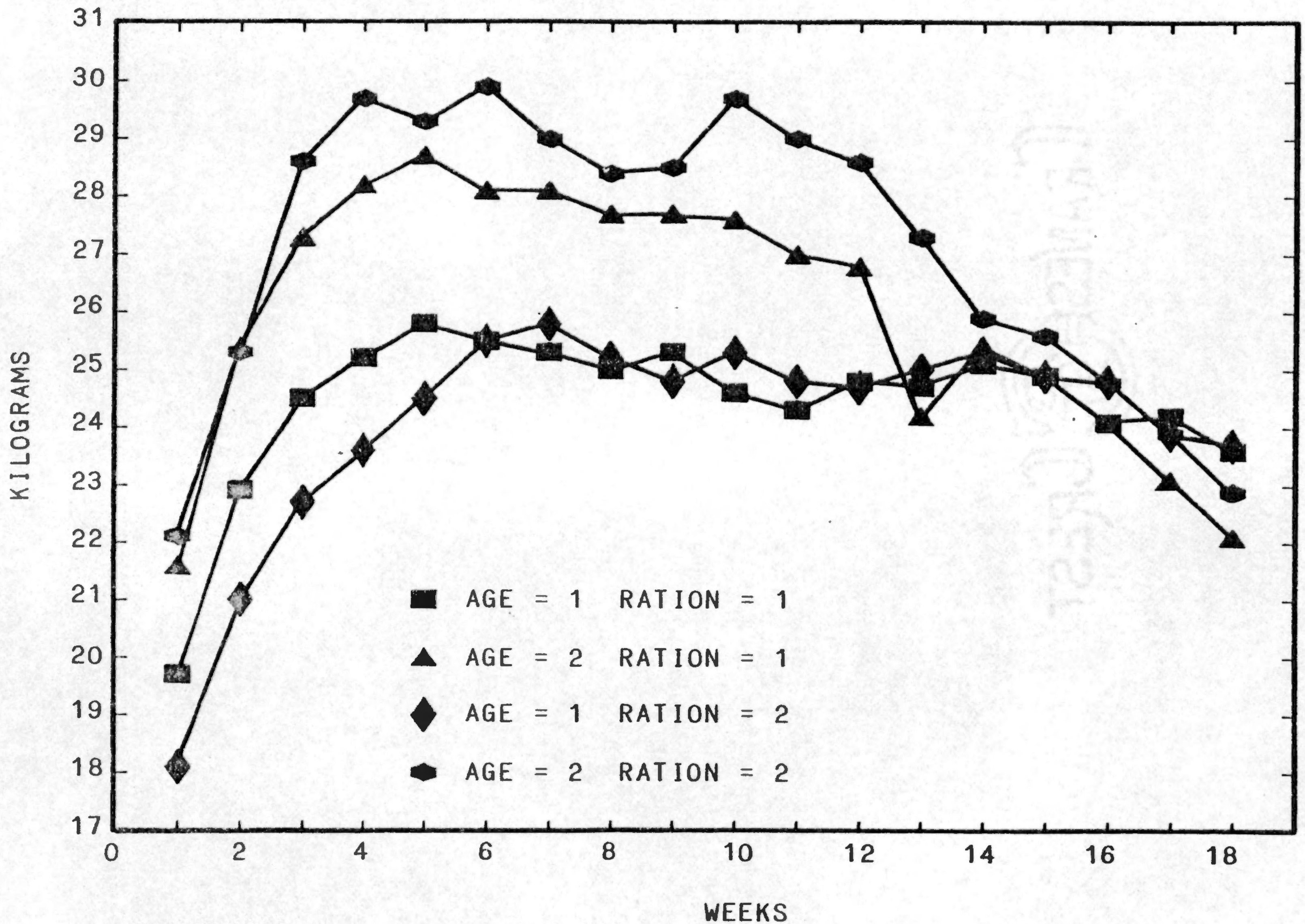

Figure 4. Production curves of 4% fat corrected milk of low producing cows.

Period means of low producing cows were not significantly affected by ration. Since the low producing group included both first lactation heifers and older cows, a significant age effect ($P < .01$) was present during Period 1. However, by Period 2 there was no production difference due to age, indicating further the greater persistency of the first lactation heifers.

Lack of an increase in milk production with the higher concentrate ration despite an increase in dry matter intake is contrary to the results of Montgomery (46), Escano and Rusoff (17), and Harner and Spahr (23). It is also contrary to the expectations of Putnam and Loosli (58) who predicted increased production with increasing proportions of concentrate. These results are in agreement with Enlow et al. (16) who found no significant difference in solids corrected milk production even though a 60% concentrate ration was consumed in greater quantity than a 33% concentrate ration. Since consideration of total dry matter consumption by individual treatment groups showed a difference in intake only for first lactation heifers receiving Ration 2, perhaps little difference in production should be expected. Because Ration 2 cows peaked higher in their production but demonstrated inferior persistency, a higher total production might have been achieved with Ration 1 had the experimental period been an entire lactation.

Even though not statistically different, average butterfat production was lower with Ration 1 than with Ration 2. This agrees with results of Spahr and Harshbarger (63) who showed a slight but nonsignificant decrease in butterfat test as proportion of concentrate increased up to 60% of ration dry matter.

Body Weight

Statistically, there were no significant differences in the means of body weight due to rations or to trial years. As would be expected, first lactation heifers weighed significantly less than older cows ($P < .01$) when considered across ration and year. Table 6 lists average body weights by year and by production group. Individual treatment group means showed a significant difference ($P < .05$) due to age for total cows and low producing cows. Also included in Table 6 are the average starting weights by production group and the average weights at the 18th week of lactation. The table shows that high producing cows were just able to regain their starting weights by 18 weeks. With the exception of first lactation heifers on Ration 2, all treatment groups of low producing animals weighed more than their starting weight at 18 weeks of lactation.

An 18 week experimental period is too short a time to conclude that a ration would or would not produce overweight cows. However, if the trends evident in Table 6 are consistent for an entire lactation, these results would support the findings of Coppock et al. (12) that cows do not regulate intake according to requirement with any precision. The results would also support the concept of different rations for differently producing groups (59). Since the rations fed were apparently still within the range of nutritive

Table 6. Means and Standard Errors of Body Weight

	Treatment groups 1-1 $\bar{X}$	1-1 SE	2-1 $\bar{X}$	2-1 SE	1-2 $\bar{X}$	1-2 SE	2-2 $\bar{X}$	2-2 SE
	(kg)							
Year 1	525	1.70	638	4.03	511	3.74	624	3.93
Year 2	561	3.92	624	3.84	567	5.09	639	4.48
Total cows	544^b	2.49	630^a	2.79	537^b	3.49	632^a	3.07
High producers	---	---	637	3.79	---	---	626	3.89
Starting weight	---	---	649	16.05	---	---	638	17.11
Wt at 18 weeks	---	---	647	18.13	---	---	638	15.48
Low producers	544^b	2.49	621^a	4.09	532^b	3.66	640^a	4.80
Starting weight	546	13.70	618	17.12	531	17.29	637	19.24
Wt at 18 weeks	563	9.31	645	16.22	554	17.78	671	23.48

[a,b]Means which do not bear the same superscript within a line differ ($P<.05$).

value where rumen fill was an important intake factor, regulation of intake may not have been possible, in which case the cows and first lactation heifers simply ate until they could hold no more. For high producing cows, that amount was insufficient to support milk production and large gains of body weight whereas for low producers it was sufficient.

Expression of Results as Net Energy

An objective of this experiment was to determine if either of the rations used was superior in providing more energy earlier in lactation. One approach to this objective would be through use of the Net Energy for milk production (NE_{milk}) system because both intake and output energy values can be expressed in the same units (40, 50).

Calculation of NE_{milk} intake by each animal was based on the amount of complete ration dry matter consumed, the forage:concentrate ratio of that dry matter, and individual NE_{milk} values for the ration constituents, listed in the 1978 edition of Nutrient Requirements for Dairy Cattle (50). Listed in Appendix Table 8 are NE_{milk} values of the ration constituents and formulas used to calculate NE_{milk} intake by ration.

Graphs of the intake:requirement relationships of the treatment groups by production group are presented in Figures 5 through 10.

Apparently neither of the rations allowed high producing cows to achieve energy balance within the 18 weeks of the experimental period. Yet body weight is on the increase by at most the 10th week. This may indicate that either the NE_{milk} requirements have been calculated too high or the NE_{milk} intake values are too low. The

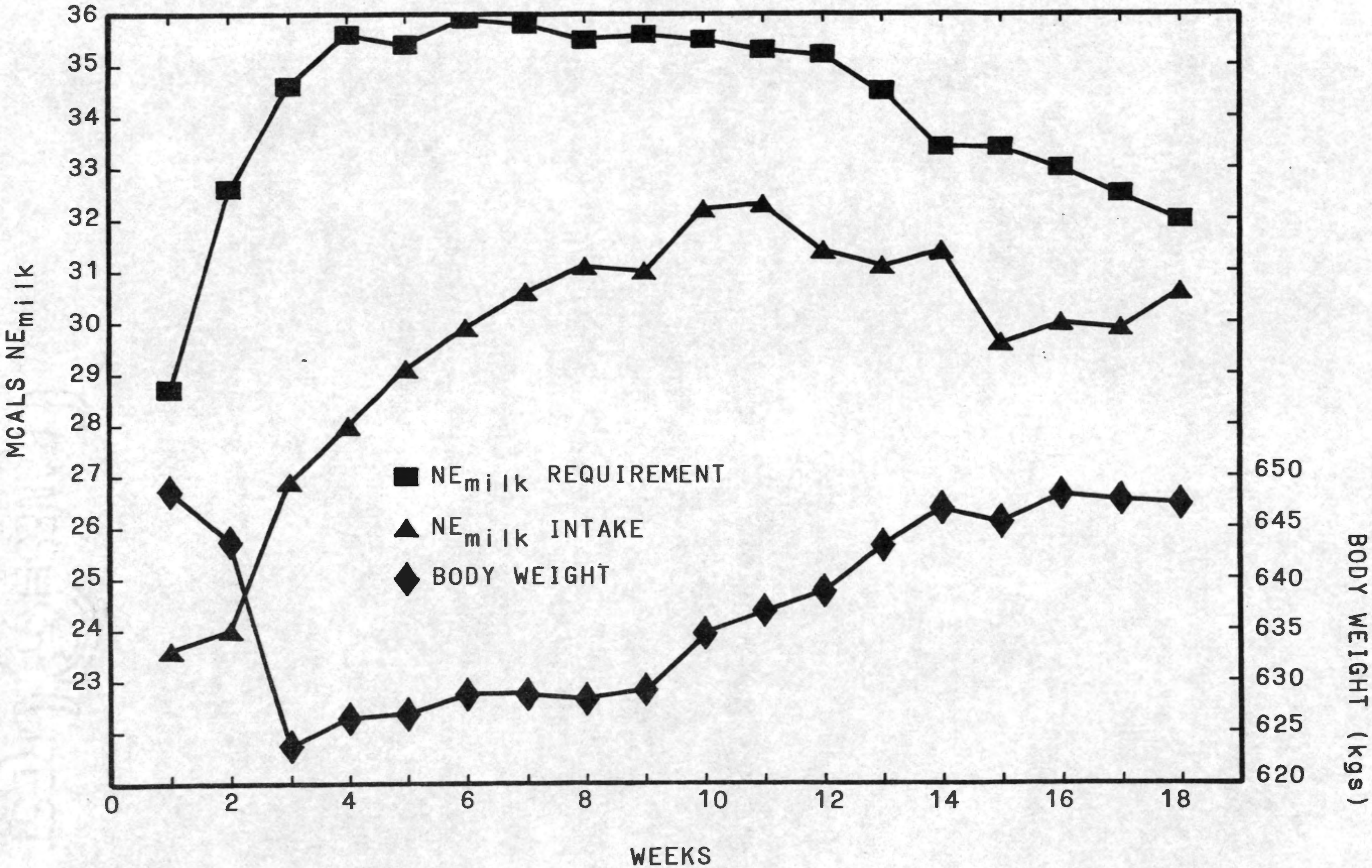

Figure 5. NE_{milk} intake:requirement relationship of high producing cows receiving ration 1.

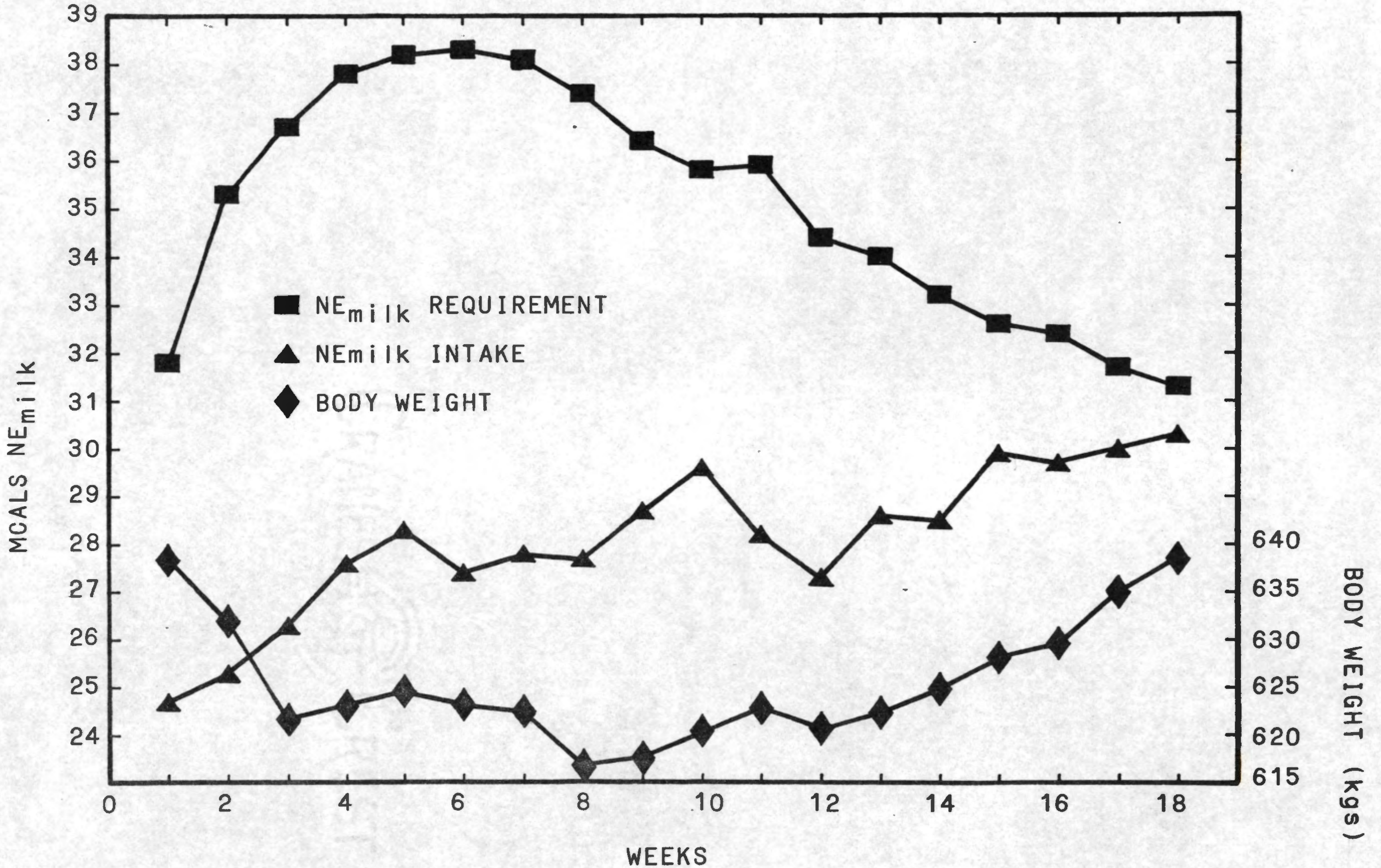

Figure 6. NE_{milk} intake:requirement relationships of high producing cows receiving ration 2.

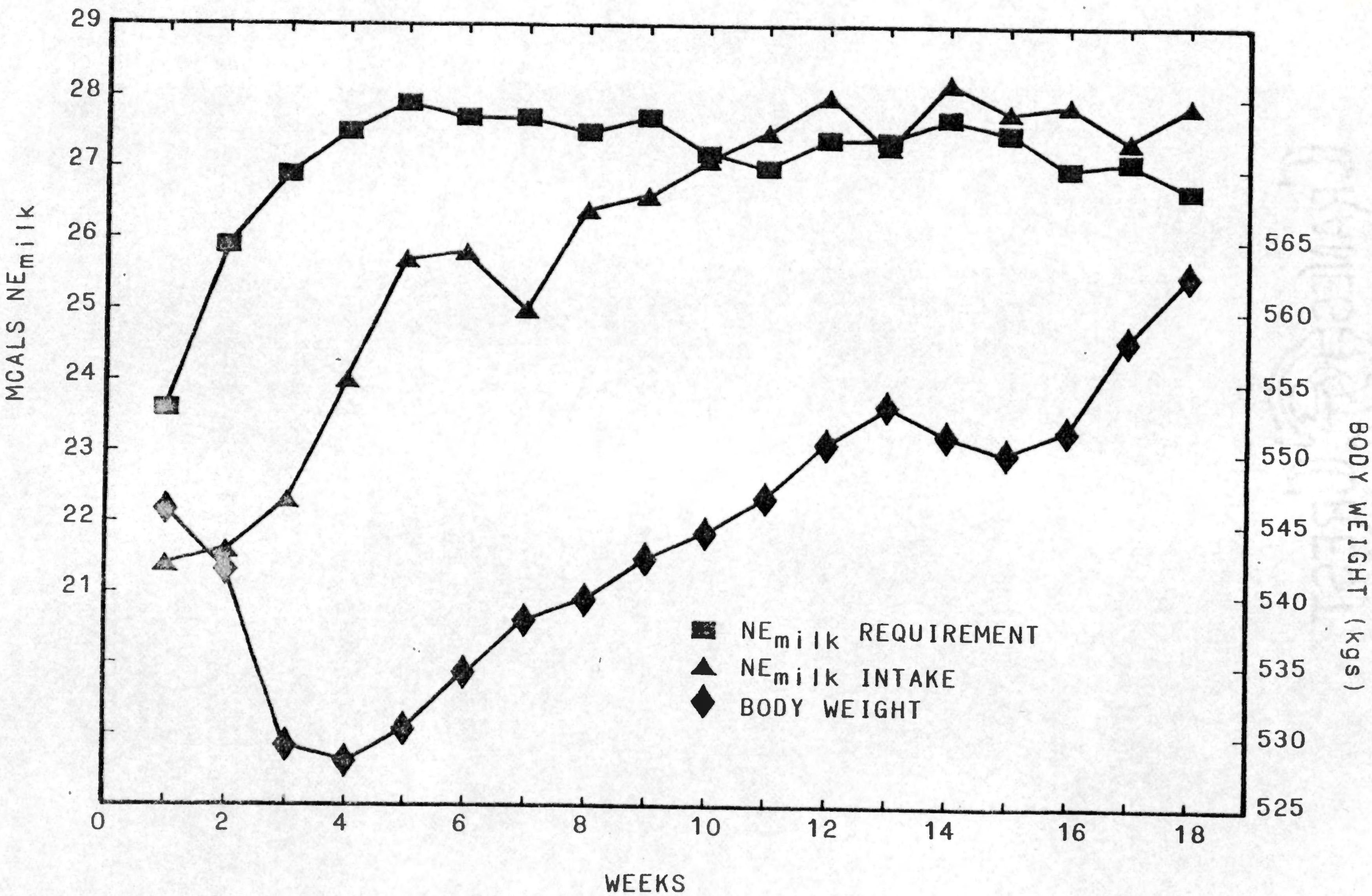

Figure 7. NE_{milk} intake:requirement relationships of low producing first lactation heifers receiving ration 1.

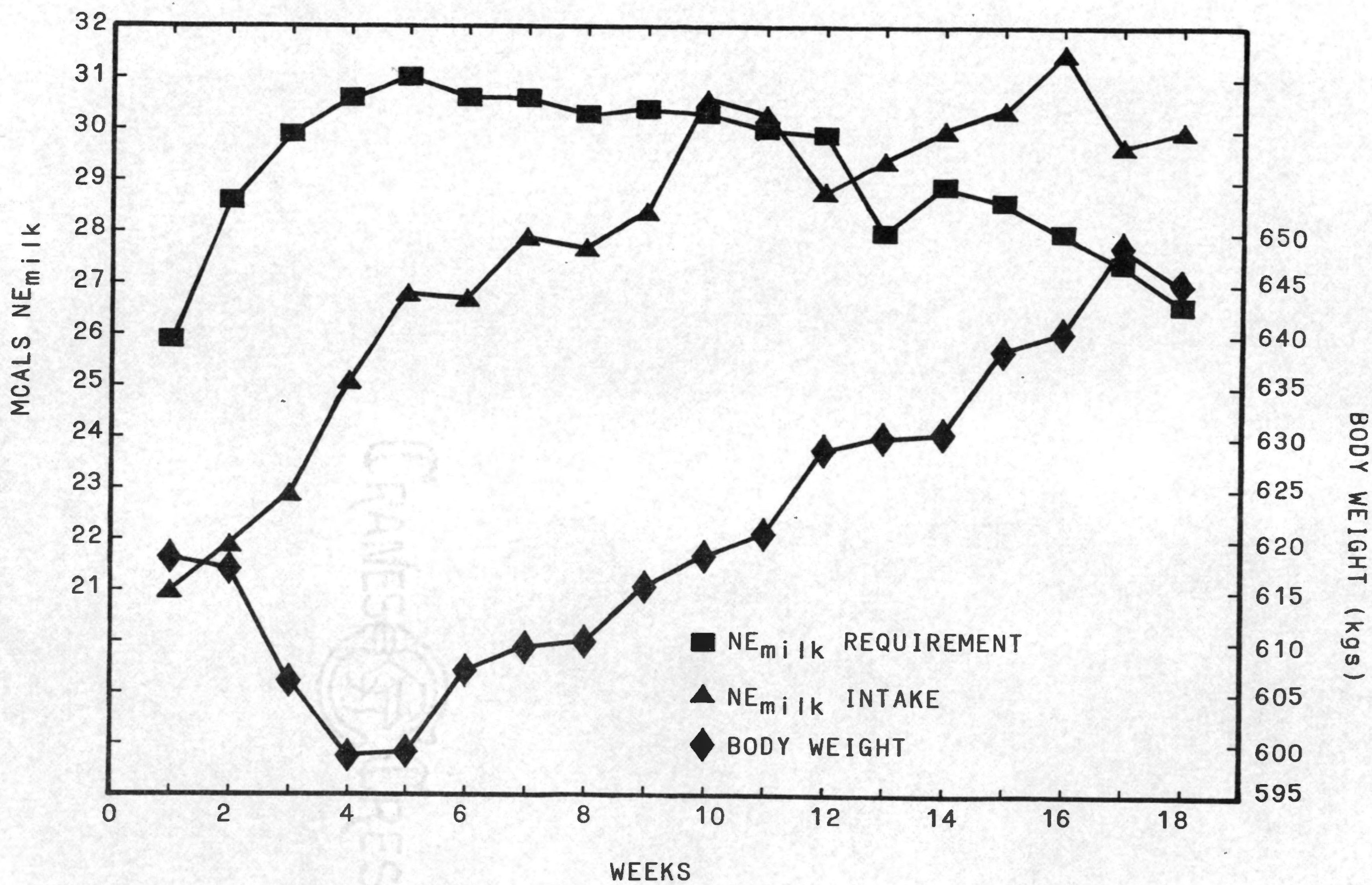

Figure 8. NE_{milk} intake:requirement relationship of low producing cows receiving ration 1.

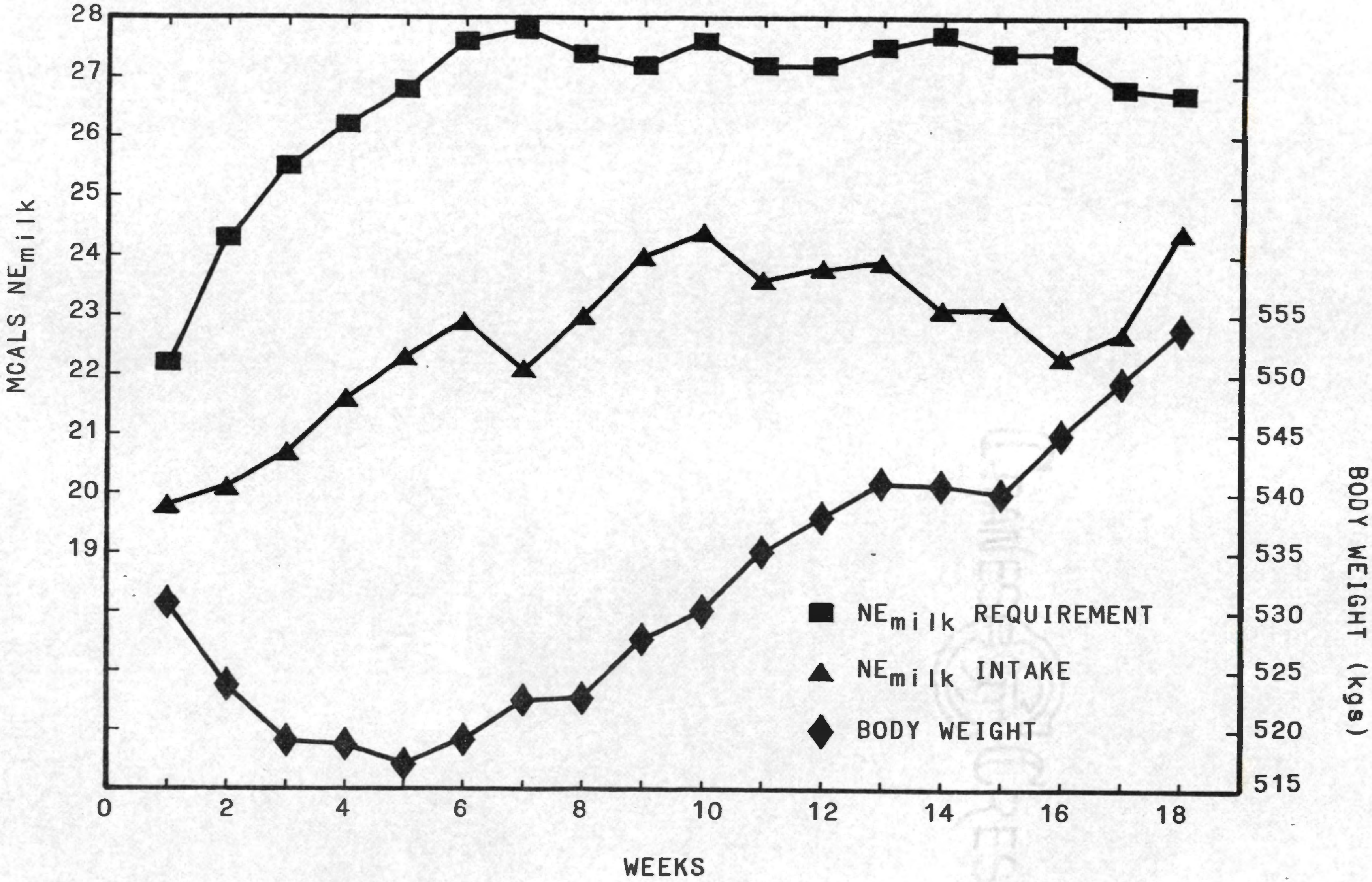

Figure 9. NE_{milk} intake:requirement relationship of low producing first lactation heifers receiving ration 2.

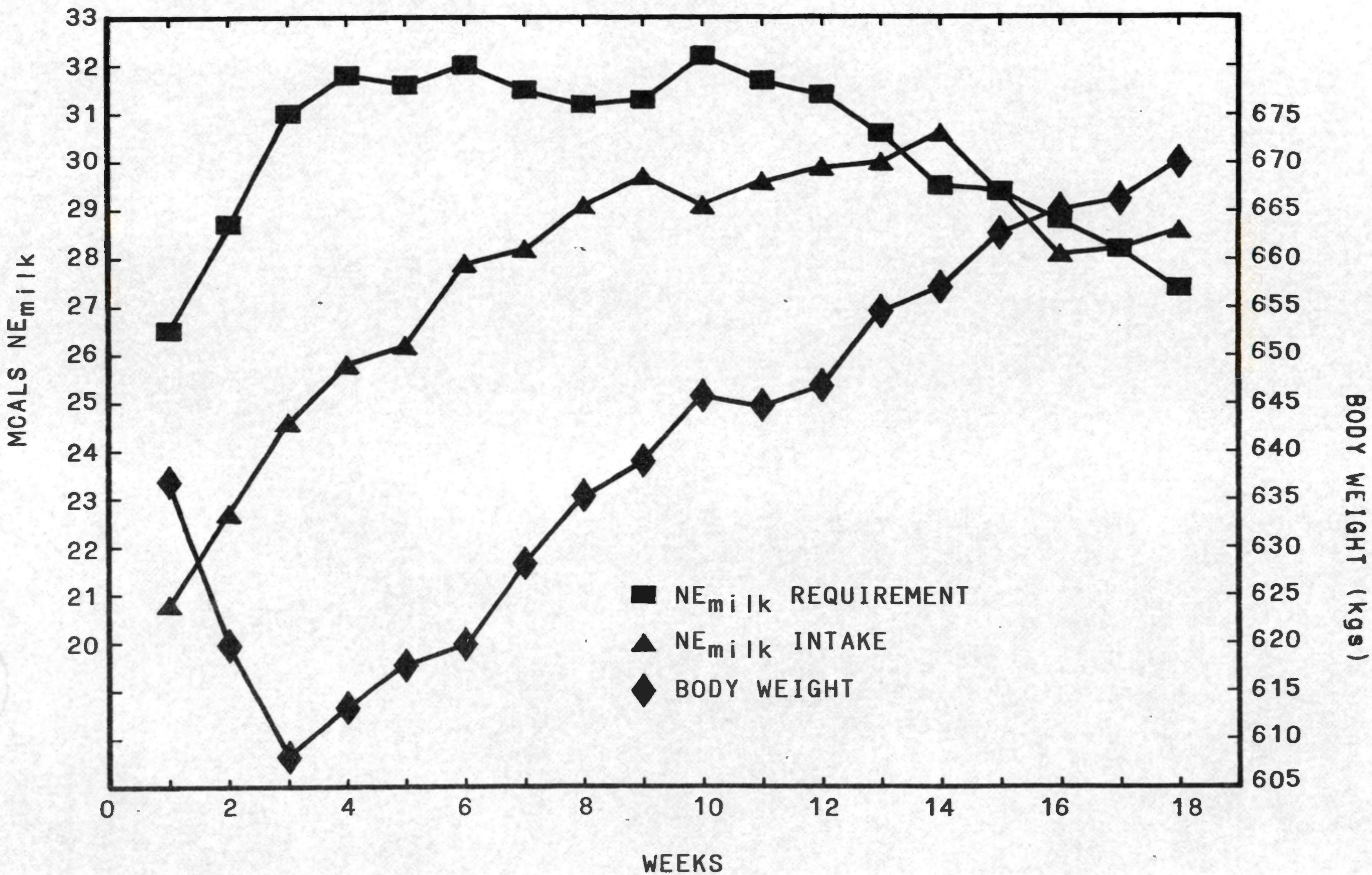

Figure 10. NE_{milk} intake:requirement relationship of low producing cows receiving ration 2.

amount of energy in a kilogram of fat corrected milk is not controversial within the range of butterfat yields by the high producing cows (66). The NRC (50) maintenance requirement of 80 kcals/ $kg^{.75}$ is debatable, however most counterproposals are for higher values.

Estimates of change in body composition based on change in body weight are not accurate (19, 38). Tissue loss which accompanies high milk production may be masked because of increased consumption of feed and water or the retention of water when fat is mobilized. The difference in weight from minimum to maximum on either ration was less than 30 kgs which could be, perhaps, attributed in part to factors other than body tissue change. If such is the case, the high producing cows may have been losing weight through the entirety of the experimental period as the intake: requirement relationship suggest although a trend toward achievement of energy balance is indicated.

Although not proven statistically, inspection of the graphs for high producing cows seem to indicate that Ration 1 was more successful at enabling higher energy consumption earlier in the lactation. The mean of milk production during the first 9 weeks of lactation is significantly higher ($P < .05$) for cows consuming Ration 2, however. This would support the observation of Flatt et al. (20) whose energy balance studies showed highest milk production early in lactation by the ration lowest of three others in proportion of concentrate. Those workers found the difference among rations was not due to intake level but to the fact that more body tissue was mobilized in conjunction with the high forage resulting in more total energy being available for milk production. In this experiment if Ration 1 came closer to enabling energy equilibrium by the high producing cows it was through a combination of allowing more energy intake and not allowing as much milk yield.

For low producing cows and first lactation heifers, the graphs show that energy balance was achieved within the 18 week experimental period, except for the first lactation heifers receiving Ration 2. Again, body weight curves do not agree with intake:requirement relationships. Weight gain during negative energy balance was less than 20 kg for Ration 1 but averaged over 40 kg for Ration 2. The points of intersection are at 10 weeks for Ration 1 and at 13.5 weeks for Ration 2 although energy balance was not achieved by first lactation heifers on Ration 2.

These energy balance results agree with those of Braund and Steel, as reported by Coppock et al. (12) who noted that first lactation heifers achieved energy equilibrium at 18 weeks and older cows at 13 weeks when fed a complete ration of corn silage plus concentrate. Perhaps Braund and Steel's ration more closely resembled Ration 2 of this experiment.

Coppock et al. (12) determined energy balance as the point where the digestible energy intake equalled the digestible energy requirement for production level of the cows used estimated from NRC tables. The results of those researchers were energy equilibrium at 5 weeks for first lactation heifers and 11 weeks for older cows when fed a complete ration of 45% forage and 55% concentrate, in partial agreement with this experiment.

From the graphs of intake:requirement relationships it seems that neither ration was entirely successful in meeting the energy requirements of high producing cows although energy intake may have been higher with Ration 1. Considering only low producing animals, Ration 1 may have been superior to Ration 2 because it resulted in the achievement of energy equilibrium three weeks earlier than did Ration 2.

CHAPTER V

CONCLUSIONS

The forage:concentrate ratios of the total rations used in this experiment did not differ widely from each other. Never-the-less, intake of the higher concentrate ration was greater. And apparently more energy was supplied earlier in the lactation with the higher concentrate ration. The fact that greater milk yield was not realized makes one wonder about the value of this extra energy supply. It also makes one curious about the effects of even wider forage:concentrate ratios on energy balance. To what extent can manipulation of diet increase intake or can intake be better enhanced by breeding cows with "reference input signals" more favorable to higher consumption?

Neither of the rations fed seem adequate for cows producing over 30 kgs of milk per day. For lower production levels, either of the rations seem sufficient within the 18 weeks of the experimental period. The higher concentrate ration made energy equilibrium possible earlier for the low producers receiving it. If such an effect improves milk production for a total lactation without excessive body weight gains, then Ration 1 would be superior to Ration 2 for cows producing less than 30 kgs of milk per day.

For first lactation heifers, which must make reasonably large amounts of milk or risk being culled, the higher concentrate ration is superior. Of the two, it was the only ration that allowed growth (positive energy balance) in addition to lactation within the 18 week experimental period.

LITERATURE CITED

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APPENDIX

Table 7. Animals Per Subcell for Trial Years 1 and 2 and Production Groups

	Treatment groups			
	1-1	2-1	1-2	2-2
Year 1	7	11	9	9
Year 2	8	12	8	12
Total	15	23	17	21
High producers	0	13	3	11
Low producers	15	10	14	10

Table 8. NE_{milk} Values of Ration Constituents and Formulas for Calculating NE_{milk} Intake

Constituent	Formula
Corn silage	= 1.47 Mcal/kg DM
Alfalfa hay	= 1.30 Mcal/kg DM
Pelleted concentrate	= -.12 + .0245 (78% TDN) = 1.79 Mcal/kg DM
Soybean meal	= 1.86 Mcal/kg DM
If ration = 1	
Concentrate NE_{milk}	= CRDM[a] x .4536 x .624 x 1.79
Corn silage	= CRDM x .4536 x .376 x 1.47
Alfalfa hay	= 9 x .4536 x 1.30
If ration = 2	
Concentrate NE_{milk}	= CRDM x .4536 x .463 x 1.79
Corn silage	= CRDM x .4536 x .537 x 1.47
Soybean meal	= (CRDM/.4024)/100 x 2 x .90 x .4536 x 1.86
Alfalfa hay	= 4.5 x .4536 x 1.30
All cows	
Parlor concentrate	= 5.4 x .4536 x 1.79
Total NE_{milk} intake	= Concentrate + Corn silage + Soybean Meal + Alfalfa hay + Parlor concentrate

[a]Complete ration dry matter.

Table 9. Daily Means of Intake and Production Variables of All Cows by Treatment Groups and Week

		Treatment groups			
		1-1	2-1	1-2	2-2
Week 1[a]	Milk (lbs)[b]	46.3	55.2	46.1	59.2
	Fat(%)[c]	3.6	3.6	3.5	3.8
	FCM(lbs)[d]	43.5	51.7	42.9	57.0
	CRDM(lbs)[e]	15.4	16.9	16.7	20.6
	TOTDM(lbs)[f]	29.8	31.3	26.6	30.5
	BW(lbs)[g]	1203	1401	1192	1406
Week 2	Milk	53.7	65.0	53.0	68.6
	Fat	3.6	3.6	3.5	3.8
	FCM	50.5	61.9	49.4	65.9
	CRDM	15.7	17.7	16.9	22.2
	TOTDM	30.1	32.1	26.8	32.1
	BW	1194	1393	1175	1380
Week 3	Milk	57.3	71.9	57.2	74.4
	Fat	3.6	3.6	3.5	3.8
	FCM	54.0	67.5	53.3	71.7
	CRDM	16.6	20.4	17.9	24.1
	TOTDM	31.0	34.8	27.8	34.0
	BW	1167	1358	1159	1356
Week 4	Milk	59.0	74.5	59.0	77.1
	Fat	3.6	3.6	3.6	3.8
	FCM	55.6	70.2	55.6	74.6
	CRDM	18.9	22.5	19.3	25.6
	TOTDM	33.3	36.9	29.2	35.5
	BW	1164	1355	1158	1363
Week 5	Milk	60.1	75.3	60.7	77.5
	Fat	3.6	3.6	3.6	3.8
	FCM	56.9	70.3	57.0	74.8
	CRDM	21.2	24.2	20.6	26.4
	TOTDM	35.6	38.6	30.5	36.6
	BW	1169	1355	1151	1370
Week 6	Milk	56.0	75.6	62.3	78.0
	Fat	3.6	3.6	3.6	3.8
	FCM	56.1	70.4	58.7	75.6
	CRDM	21.2	24.8	21.2	27.5
	TOTDM	35.6	39.2	31.1	37.4
	BW	1178	1365	1157	1370

Table 9 (continued)

		Treatment groups			
		1-1	2-1	1-2	2-2
Week 7	Milk	58.8	75.2	62.8	77.1
	Fat	3.6	3.6	3.7	3.7
	FCM	55.8	70.3	59.4	74.3
	CRDM	20.2	26.0	20.3	27.3
	TOTDM	34.6	40.4	30.2	37.2
	BW	1186	1368	1162	1378
Week 8	Milk	58.4	74.2	61.9	75.8
	Fat	3.6	3.6	3.6	3.8
	FCM	55.1	69.4	58.5	73.2
	CRDM	22.0	26.3	20.8	27.7
	TOTDM	36.4	40.7	30.7	37.6
	BW	1190	1368	1164	1378
Week 9	Milk	58.7	73.2	61.0	74.3
	Fat	3.7	3.7	3.6	3.7
	FCM	55.8	69.6	57.4	71.6
	CRDM	22.3	26.6	21.6	28.8
	TOTDM	36.7	41.0	31.5	38.7
	BW	1196	1374	1174	1383
Week 10	Milk	58.0	72.8	61.1	74.1
	Fat	3.6	3.7	3.6	3.8
	FCM	54.2	69.2	57.8	71.8
	CRDM	22.9	28.8	22.6	29.1
	TOTDM	37.3	43.2	32.5	39.0
	BW	1196	1374	1174	1393
Week 11	Milk	57.9	71.8	61.4	73.0
	Fat	3.5	3.7	3.6	3.8
	FCM	53.6	68.3	57.3	71.2
	CRDM	23.5	28.7	21.8	28.3
	TOTDM	37.9	43.1	31.7	38.2
	BW	1205	1388	1184	1395
Week 12	Milk	58.5	71.2	61.1	70.6
	Fat	3.6	3.7	3.5	3.8
	FCM	54.6	67.9	56.6	68.4
	CRDM	24.2	27.2	22.6	27.8
	TOTDM	38.6	41.6	32.5	27.7
	BW	1214	1399	1191	1394

Table 9 (continued)

		Treatment groups			
		1-1	2-1	1-2	2-2
Week 13	Milk	57.9	67.1	60.9	69.2
	Fat	3.6	3.7	3.7	3.8
	FCM	54.5	64.2	57.4	66.5
	CRDM	23.2	27.3	23.0	28.9
	TOTDM	37.6	41.7	32.9	38.8
	BW	1220	1406	1204	1404
Week 14	Milk	58.0	66.8	59.8	67.1
	Fat	3.7	3.7	3.8	3.7
	FCM	55.3	63.3	58.1	63.7
	CRDM	23.2	27.3	23.0	28.9
	TOTDM	37.6	41.7	32.9	38.8
	BW	1220	1406	1204	1404
Week 15	Milk	53.7	66.5	59.6	66.3
	Fat	3.7	3.6	3.8	3.6
	FCM	54.9	62.8	57.4	62.4
	CRDM	23.9	26.7	22.8	29.4
	TOTDM	38.3	41.1	32.7	30.4
	BW	1212	1416	1204	1419
Week 16	Milk	56.2	65.4	58.4	65.0
	Fat	3.6	3.6	3.9	3.6
	FCM	53.2	61.3	57.0	61.1
	CRDM	24.0	27.7	21.7	28.5
	TOTDM	38.4	42.1	31.6	38.4
	BW	1216	1421	1215	1423
Week 17	Milk	56.3	64.2	57.6	63.1
	Fat	3.6	3.5	3.7	3.6
	FCM	53.3	59.6	55.1	59.0
	CRDM	23.4	26.6	22.1	28.9
	TOTDM	37.8	41.0	32.0	38.8
	BW	1230	1429	1220	1431
Week 18	Milk	55.7	62.6	57.4	61.0
	Fat	3.6	3.5	3.7	3.6
	FCM	52.1	57.8	54.5	57.3
	CRDM	24.0	27.3	24.0	29.2
	TOTDM	38.4	41.7	33.9	39.1
	BW	1240	1425	1229	1440

Table 9 (continued)

[a]Indicated units are continuous throughout table.

[b]Milk production.

[c]Butterfat.

[d]Fat corrected milk production.

[e]Complete ration dry matter intake.

[f]Total dry matter intake.

[g]Body weight.

VITA

William Morris Robbins was born in Burlington County, New Jersey on June 29, 1950. The son of Dr. and Mrs. Morris A. Robbins, he spent a normal childhood. He graduated from high school at Riverside, New Jersey in 1968 and entered Bethany College in West Virginia the same year. At Bethany he was elected to their honor society--Bethany Kalon, as well as Beta Beta Beta biological honor society. He graduated in 1972 with a Bachelor of Science degree in Biology. He spent the next year apprenticed to a furniture workshop in southern West Virginia and continued furniture design and construction upon returning to New Jersey in 1973. He has exhibited in shows and galleries in West Virginia, Ohio, Pennsylvania, and New Jersey.

After returning to New Jersey, the author became involved in the dairy industry of his home county and worked on a succession of farming enterprizes which concluded only with his entrance into the Graduate School of the University of Tennessee in September 1976. He received the Master of Science degree with a major in Animal Science in June 1978.

The author is undecided whether to pursue furniture or farming, or both.