EFFECT OF ENERGY AND PROTEIN LEVELS ON MILK PRODUCTION DURING LATE LACTATION

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ABSTRACT

EFFECT OF ENERGY AND PROTEIN LEVELS ON MILK PRODUCTION DURING LATE LACTATION

By

Vern Emery Erickson

Two experiments were conducted to determine the effects of varying the protein and energy intake of dairy cows during late lactation in the Andrews University Dairy herd.

In Experiment I, 5 pounds of hay and ad libitum corn silage were fed to both the control and experimental groups (24 cows per group). To the control group, 9.0 pounds of high moisture corn (HMC) and one pound of 55 percent protein concentrate (containing NPN) were mixed into the corn silage at feeding time, and 0.7 pound of soybean meal (SBM) was fed in the parlor. The experimental group received only corn silage and hay. Average dry matter intake and milk production values for the control group were 29.9 and 29.9 pounds per day and for the experimental group were 26.5 and 22.9 pounds per day, respectively for a 30-day period.

Data from Experiment I indicate that feeding corn silage ad libitum and 5.0 pounds of average quality alfalfa hay was not sufficient to maintain normal production of cows producing 30 pounds of milk daily. The calculated intake of both energy and protein exceeded National Research Council (NRC, 1966) requirements by 10 to 13 percent in the control group, whereas energy was equal but protein intake was approximately 25 percent less than NRC in the experimental group fed no concentrates or protein supplement. At the end of the fourth week the experimental group produced 9.4 pounds less milk per cow daily than controls. This resulted in a loss of 30 cents per cow daily in gross income minus feed cost.

In Experiment II removal of 14.0 pounds of high moisture shelled corn from the ration of cows producing 35 to 37 pounds of milk daily and fed corn silage ad libitum, 5.0 pounds of alfalfa, and 0.5 pound of supplemental protein resulted in no significant difference in milk production, milk fat production, or body weight over an eight-week period. Calculated intake of energy was 33 percent higher and protein 9 percent lower than NRC requirements in the control group, whereas energy intake was equal to NRC but protein intake 21 percent less than NRC requirements in the experimental group. All cows followed a normal lactation curve downward and gained weight in this experiment. Removing the corn from the ration increased income above feed cost 21 cents per cow daily.

From the results of these experiments it appears that feeding 10 to 20 percent less protein than the NRC standards during late lactation had no effect on performance; but feeding 25 percent less protein than the requirement significantly affected milk production. A ration containing 11 percent crude protein on a dry matter basis was adequate to maintain normal milk production whereas 10 percent crude protein was too low under the conditions of this experiment. Energy intake equivalent to the 1966 NRC allowances for total digestible nutrients (TDN) maintained milk production of cows in late lactation as well as a ration containing 33 percent more TDN, from shelled corn, when adequate protein was fed under the practical farm conditions of this experiment.

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INTRODUCTION

Dairy farm management methods have been subjected to dramatic changes in recent years in order to reduce costs and maintain or improve profits.

The adoption of bulk methods for handling of feeds and management of cattle requires careful attention to the effects of such changes on the health and performance of cattle and the efficiency of utilization of feed resources. Thus, the management system must be sufficiently flexible to allow providing a reasonably well-balanced diet for all of the cattle in keeping with their productive requirements.

Among the most significant changes on Michigan farms have been the trends toward larger herds and the feeding and management of cattle in one or more groups. Increased use of corn silage, or hay-crop silage, as the major source of forage has commonly accompanied expanding herd size. The advantages offered by a silage feeding system for mechanical handling during harvesting, storing, and feeding of forages produced on the farm have helped to reduce the cost of dairy production compared to dry hay.

Methods of handling and feeding grain have also changed substantially. On many of the larger dairy farms, corn is stored in silos as high moisture (25-32% moisture) shelled corn or ground ear corn in order to expedite the harvesting process, reduce field and storage losses, and eliminate the cost of heat-drying and further processing.

The traditional practice of hand-feeding of concentrates to lactating cows according to their individual production requirements was largely lost with the advent of the milking parlor. While the use of milking parlors increases labor efficiency in the milking process, individual feeding is more difficult to accomplish and incompatible with milking efficiency when high producing cows are allowed enough time in the milking parlor to eat the amount of concentrates required.

The combination of circumstances resulting from bulk handling of feeds and group handling of cattle has prompted some dairymen to feed a blended mixture of forages and concentrates to the milking herd thereby eliminating the practice of individual feeding. Sub-grouping of the herd according to different levels of milk production, stage of lactation, or age of the cattle is commonly practiced in an attempt to feed concentrates according to requirements and approximate the practice of individual feeding.

The Andrews University dairy herd at Berrien Springs, Michigan, was recently expanded to include 240 milk cows plus young stock. Feeding and management conditions were similar to those typically found on modern mid-west dairy farms of similar size. The feeding program consisted of corn silage and high moisture shelled corn processed in conventional silos, baled hay limited to five pounds per cow daily, and sufficient protein supplement, minerals, and vitamins to balance the ration.

Prior to these experiments the herd had been plagued with health problems at calving time typical of the so-called "fat-cow syndrome." The incidence of milk fever, ketosis, metritis, and mastitis was too frequent and resulted in poor milk production. This condition largely subsided after the dry cows were separated from the milking herd and groups were fed concentrates according to milk production.

In view of the tendency for cows in late lactation to fatten excessively when fed a ration of corn silage ad libitum and concentrates according to a thumb-rule, such as one pound of concentrates per three pounds of milk, the research reported herein was conducted to determine the effects on milk production and body weight when supplemental energy as high moisture corn or both energy and protein supplement were eliminated from the ration of cows in late lactation.

Other research pertaining to these topics is also discussed in the review of literature.

REVIEW OF LITERATURE

The nutrients provided dairy cattle are major factors in determining the level of milk production, health condition, and profit from a dairy enterprise.

Nutrient requirements for dairy cattle have been studied by numerous investigators over the years. The most recent estimates of the nutrient requirements for dairy cattle were published in 1966 by the National Academy of Sciences, National Research Council (NRC) in publication 1349, Nutrient Requirements of Dairy Cattle (135).

Nutrient Requirements:

The National Research Council (135) states that for a 1,210 pound cow 8.4 pounds of total digestible nutrients (TDN) are required for maintenance of a lactating cow. Morrison's (131) requirements for a 1200 pound lactating cow are 9.3 for TDN or 7.4 therms (or megacalories) of net energy.

Requirements for energy according to Rebhan (145) differ for animals differing in body condition. The animal that is the fattest requires the most energy per unit of weight for maintenance. A maintenance ration is the amount of feed required to support an animal which is doing no work and yielding no product.

Rebhan referred to Haecker's (70) report that showed that the cost of producing a pound of butter increased when a cow carried an average of 80 pounds more flesh one year than the previous year. Also maintenance requirements change with more exposed body surface area.

The requirements for energy or total digestible nutrients vary widely depending upon the animal's activity, the climatic condition, and the quality and the quantity of feed fed. The variance among cows of similar size and breed in maintenance requirements under controlled activity is as much as 8 to 10 percent (177).

The maintenance value given in the NRC tables provides minimal energy to cover usual activity of cows fed in confinement. Cows grazing may require from 25 to 100 percent more energy for maintenance than for those confined (100, 148, 180).

Reid (149) set the amount at 40 percent more total digestible nutrients for cows grazing than cows in confinement. He found that a 1000 pound cow required 11.3 pounds of TDN per day to support maintenance, including expense of grazing. The same cow when confined in the barn would utilize only 7.9 pounds of TDN. Reid continues by saying that the selection of grazing by cows will increase the quality of the diet 10 to 25 percent more in total digestible nutrients than that harvested as a soiling crop. Thus, for the same amount of dry matter consumed, cows will eat two to five pounds more total digestible nutrients. However, when 75 percent of the forage available is consumed by grazing, the advantage for selection would be less.

In addition to feeding a properly balanced ration appetite, appearance, and health of cattle should be observed to insure optimum performance.

Energy is expressed in megacalories (or therms) which is the amount of heat required to raise the temperature of 1,000 kilograms of water one degree centigrade.

In analyzing a feed for its useful purposes of maintenance, milk production, and reproduction, each feed will supply a different quantity of metabolizable and net energy. To find net energy one must take gross energy and subtract the energy loss in the feces, urine, combustible gases and heat increment. That which is left is used for milk production, fattening, reproduction, growth, and maintenance (131). Net energy values should be considered as averages because of effects of varying levels of intake, animal species, and combination of feeds fed on the resulting net energy value.

Due mainly to fiber content, feeds vary widely in net energy. Morrison (131) believed that net energy values are a better measure of the value of the feed than using total digestible nutrients values.

Some studies (30, 117) have questioned the superiority of the net energy systems over the total digestible nutrient system. Other reports (158, 129) indicate that the estimated net energy system is a more accurate system for evaluating feeds for productive purposes.

Kone (107) states that the TDN system of feed evaluation is subject to several sources of error. It over evaluates forages, its analytical methods are empirical, and its energy value assignments to components are questionable. However, TDN values are still used because of ease of determination. Net energy values are difficult to obtain.

Moore (129) compared estimated net energy values of Morrison, Forbes, and the productive energy values of Fraps. He then plotted them graphically against the TDN values. He found that net energy value of feeds decreased at a faster rate than the TDN values. He concluded that the energy value of a unit of TDN in concentrates is greater than that of the same unit in roughages. Morrison (132) agreed by saying that "There is no question but what net energy values are theoretically more accurate than total digestible nutrients for comparing the values of roughages or low grade concentrates with values of grain and other high grade concentrates for productive purposes."

Armstrong (5) and Becker (15) state that net energy values of feeds vary greatly depending upon whether they are utilized for maintenance or growth and probably also for milk production.

Loosli et al (117) replaced part of the TDN from hay with an equal amount of TDN from concentrates and concluded that the TDN system overestimated the value of forages when compared to concentrates.

In making conversions the National Research Council (NRC) (37) assumed that 1.0 kg of TDN had 4,400 kilocalaries of digestible energy and 3,740 kcal of metabolizable energy.

Net energy values should be used more than they are especially for corn silage. The value of the grain contained in corn silage is more accurately estimated with net energy values than with TDN.

In calculating the nutritional requirements of dairy cattle, the size of the animal, stage of gestation, and quantity and quality of milk produced is usually taken into account in order to estimate the requirements accurately.

Nutritional requirements for maintenance of lactating cows vary widely depending on their size, breed, type of housing, and their ability to utilize nutrients. These factors can vary from one animal to another as much as 8 to 10 percent (134). Grazing cattle may require as much as 25 to 100 percent more energy for maintenance than those in confinement (148, 157).

Reproduction requirements vary among the different breeds as much as 60 to 100 percent. The weight changes according to the combined weight of the fetus, fluids, and fetal membranes. This can increase a cow's weight up to 121 pounds more at time of parturition (15).

Fat is a highly concentrated energy product. As the percent of fat in the milk increases, more nutrients are required to maintain the energy balance of the animal.

In a paper recently presented at the American Dairy Science Association, the National Research Council (134) recommended a standard value for a given fat test regardless of the level of production. Thus they concluded that recent studies at the USDA and Norway did not support the need for substantially higher intakes of protein, energy, and minerals per unit of milk for high milk yields.

Protein is required to maintain all body functions. The values given in tables for the needs of protein are sufficient to support the animal if adequate energy and other required nutrients are supplied. A ration with a very wide protein-to-energy ratio, where protein meets minimum requirements, depresses efficiency of ration utilization, growth rates, and milk yields (134).

A deficiency of protein depresses milk yields and may lower milk-protein content (155). Morrison (131) recommends 1.52 pounds of crude protein for maintenance of a 1200 pound cow and .045 pound of protein per pound of milk testing 3.5 percent fat. The protein requirements vary with body weight, milk production level, percent fat, and reproductive status of the animal.

Minerals known to be required by dairy cattle are calcium, phosphorus, magnesium, potassium, sodium, chloride, sulfur, iodine, iron, copper, cobalt, manganese, zinc, and selenium. These elements are needed for maintenance and growth of body tissue, production of milk, fat metabolism, and reproduction. They maintain osmotic pressures, acid-base equilibria and the irritability of muscles and nerves, and are required for the function of several enzyme systems (134).

In prevention of milk fever maintenance of proper ratio of calcium to phosphorus is important when feeding pregnant dry cows a calcium to phosphorus ratio of 2.3:1 will reduce the incidence of milk fever according to one report (64).

Effects of Energy on Milk Production

Several researchers (11, 55, 32, 38, 46, 47, 45, 59, 130) increased the amount of concentrate in the ration and milk production increased.

Irvin et al (101) specifically state that increased milk production was due to increasing the net energy intake by increasing the amount of concentrates fed.

Jumah et al (105) used nine Holstein cows producing an average of 19,171 pounds of milk. They found a high correlation (r = 0.82) between the energy allowance and milk production. In an earlier experiment Jensen et al (102), using cows which produced 11,000 pounds of milk per year, found that 0.5 pound of TDN was required per pound of fat-corrected milk (FCM).

The National Research Council in 1966 (134) stated that energy requirements for high levels of milk production were greater than previously recognized. They increased the standard required for milk production ten percent for average levels and 25 percent for higher milk production levels. This conclusion was based on observations that digestibility of the ration declines as intake is increased four to five times maintenance levels. Since the need for higher energy intake per pound of milk at high levels of milk production was not supported by metabolism studies at Beltsville and in Norway, the NRC has returned to the earlier standards for the 1971 revision (118).

Hooven and Plowman (85) experimented with two groups of 19 cows. One group was fed ad libitum grain, hay, and silage while the other group was fed 110 percent of Morrison's upper standard. They found no difference in FCM, solids-not-fat, and persistency of production. However, cows fed the ad libitum ration consumed more estimated net energy and gained more body weight but produced only 1.51 pounds of milk per therm of net energy compared to 1.79 pounds of milk per therm for cows fed the controlled ration.

Elliot and Loosli (59) fed diets where the level of estimated net energy intake above maintenance was held constant. Production of FCM was not different on diets where 40, 60, or 80 percent of the estimated net energy came from concentrates.

Hoogendoorn and Grieve (84) reported results of three levels of roughages containing 1.65, 3.30, and 5.50 pounds per 100 kg of body weight, each was supplemented with concentrates providing 90, 100, and 120 percent National Research Council requirements (134) for digestible energy. Twenty-seven cows were used throughout one complete lactation. When cows were offered 90 percent of the National Research Council requirements a significant decrease in milk production was obtained in the 16th week. Maximum milk production could be obtained by providing 90 percent energy requirement during peak production and 100 percent during decline of production.

The 1971 NRC tables (118) list the amount of energy required for milk production for various levels of milk fat. For each .05 percent of increase in fat test above 3.0

percent, the extra energy required is from .03 to .05 megacalories of net energy per pound of milk.

Early research with lactating dairy cows by Huffman and Duncan (93, 94, 95, 96, 97) fed an all-roughage ration following parturition showed that milk production declined steadily as body fat was depleted to a point that milk production and body fat would be maintained by the amount of roughage consumed. Supplying concentrates at this time gave the cows the capability to increase milk production. It was thought that energy alone was ineffective in increasing milk production because feeding of purified starch or sugar instead of corn grain did not increase milk production. Burroughs et al (40) showed that starch lowered the digestibility of the ration.

Huffman (99) in later work reported that early cut hay and corn silage, containing ears, gave favorable results over mature hay plus corn stalks and leaves less the ears.

Beach (14) found that digestible nutrients from corn were more valuable for maintenance and for milk production than digestible nutrients from roughages. Moore et al (129), Sarrinen et al (158), and Irvin et al (101) concluded that the increase of milk production when fed concentrates was because the cows had an increased intake of net energy.

Putnam and Loosli (144) fed rations in which either

80, 60, or 40 percent of the dry matter content came from forages and the balance from concentrates. They found a slight difference in the amount of milk produced per pound of TDN fed. The range was from 2.10 pounds of FCM milk to 1.93 pounds of FCM per pound of TDN for the 80 and 40 percent roughage rations, respectively.

Mather et al (120) reported that feeding grain at one pound of grain to 3 pounds of milk depressed forage intakes but increased milk production. They found no evidence of diminishing returns in the high potential cows and little for the low-producing cows.

Huffman (92), in reviewing the literature, reported increased milk yields of cows fed high levels of concentrates over those fed low levels of concentrates. Ninety-five percent of the cows responded by increased milk production from increased grain feeding. Approximately 40 percent of these cows showed a profitable response.

Brown et al (36) reported that feeding grain at the rate of one pound of grain per 2.5 pounds of milk and grain ad libitum provided more milk than one pound of grain per 3.5 pounds of milk. The protein, fat, solids not fat content of the milk were not significantly effected by the different feeding regimes. Economically the cows which received grain ad libitum and one pound of grain per 2.5 pounds of milk returned approximately $35 more over feed cost during the 280-day trial than the cows which received grain at the rate of one pound of grain per 3.5 pounds of milk.

A review by Reid (146) indicated that cows produced 70 to 80 percent as much on all roughage diets as when concentrates were supplemented at a level of one pound of grain to 6 pounds of milk. The extra 20 to 30 percent increase in milk production could be extra net profit.

Wing (185) in Florida, using three different rations, and the Morrison standards, concluded that liberal forage systems supplemented with concentrates can support maximum milk yields. This work agrees with work done by Huffman (92) that no increase of milk production was noted over ad libitum feed versus one pound of grain per 2.5 pounds of milk.

Several workers (58, 11, 32, 38, 46, 47, 45, 130, 59) have substantiated Huffman's review that high level grain feeding has resulted in increased milk yield. If the cows have the potential, they will respond to the greater energy intake. Ronning (93) agreed with this and added that there were no definite health problems encountered from 10 to 100 percent concentrate feeding. One animal had a case of laminitis but it was not positively diagnosed.

Hoglund (82) suggested a method for high level grain feeding by starting to feed grain two weeks before calving and increasing the grain during lactation until maximum production is obtained, keeping in perspective the law of diminishing returns.

Kesler and Spahr (106) reported observations made on 41 cows fed to their maximum consumption, but with a controlled percent of concentrates in the diet. They concluded that most of the cows reached their maximum intake of productive energy when concentrates made up 50 to 60 percent of the ration (14 to 16 percent fiber). Unlimited grain feeding did not always increase production and may have been detrimental to the cow.

Schmidt and Schultz (159) divided 63 cows into 3 groups which received no grain, 6 pounds of grain, and 15 pounds of grain during the 8-week dry period. Each group was fed 2 pounds of corn silage per 100 pounds of body weight plus ad libitum good quality hay. After calving all cows received grain according to production. No statistical differences in milk, butterfat, or 4 percent fat corrected milk production were obtained.

Burt (39) cited Bonnier's (29) experiments where monozygous twins were reared on different planes of nutrition 65 to 70 and 120 to 135 percent of the recommended levels. The animals on the higher rate produced 634 to 570 pounds more milk in the first two lactations respectively than the animals on the low plan of nutrition. This was due to the fact that the poorer fed animals grew during the first two lactations. Burt also cited Hansen (72) in which heifers were fed at two nutritional planes. The group fed adequately matured faster and produced more milk than the under fed group.

Burt (39) reported that Woodward (187) using 10 cows obtained no differences in milk production or live weight gain when grain was fed at 12 pounds or 4 pounds per day for two months before parturition. A second experiment (188) was done with fat and thin cows. The fat cows consumed an average of 1,016 pounds of grain more than the thin cows. Most of the grain was fed during late lactation and the dry period but two hundred pounds of this grain was fed after calving. The additional grain before parturition produced an extra 100 pounds of milk in late lactation and 483 pounds more after parturition in the first 90 days. There was no difference in milk production after 100 days from parturition in which time the fat cows lost 24 pounds and the thin cows gained 16 pounds in body weight, the later being 34 pounds lighter.

Burt (38) suggested that very low levels of feeding will have adverse effects on production and health during the next lactation. He also added that high levels of feed before calving will have adverse effects upon mammary gland development.

Greenhalgh and Gardner (66) cited Boutflour (30) that heavy grain feeding 6 weeks before calving (steaming up) increased to 75 percent of the estimated grain requirement for early lactation, built up the cow's reserves and accustomed her to a heavy grain ration resulting in higher milk production in the subsequent lactation. Blaxter (27) reported that feeding 6 pounds of concentrates 6 weeks before calving resulted in significantly greater milk yields over a control ration of bulky feeds. In a third group the net energy of the bulky feed matched the energy in the grain and no increase in milk yield was obtained.

Greenhalgh and Gardner (66) fed more grain for 6 weeks before parturition than was required for maintenance. No increase in milk production was observed. These results are different than those reported by Fountaine (65), Blaxter (27), Lees (114), and Boutflour (30). Greenhalgh and Gardner explained that this difference was because the control cows in the other experiments actually lost weight or did not keep up with the fetus increase in weight, meaning they were being under fed. Greenhalgh and Gardner (66) also reported no increase in udder edema due to grain feeding while dry.

Swanson and Hinton (169) fed paired cows equal amounts of extra concentrates either in late lactation or during the dry period. Those cows fed grain during the dry period produced 302 pounds of milk more than those cows fed grain during late lactation. Only 307 pounds of grain were used to produce that increase. These results agree with Reid (146) who stated that cows should be fed in such a way that most of the necessary increase in body weight should be made during the dry period.

Hemken (74) stated that a high producing cow can utilize body fat for half of her energy needs during the early phase of lactation, and failure to consume enough nutrients, especially energy, limited milk production for many dairy cows.

Grain should be fed in such a way as to challenge the cow by increasing the energy intake during the early part of the lactation period. The preponderance of evidence indicates that cattle fed energy according to published requirement standards produce milk at or near their inherited potential. Under farm conditions adjustments in concentrate feeding rates may be necessary to compensate for variations in the energy value of forages and other conditions.

Effects of Energy on Body Weight

The amount of energy in a ration can directly affect body condition. Reid (147) cited an experiment by Bines et al (25) where three different rations were fed: 1) oat straw, 2) rye grass fed ad libitum, and 3) 3 kg of rye grass with ad libitum concentrates. By feeding one of these different rations he could change the condition of a lactating cow from fat to thin and vice versa. Essentially he was varying the energy an animal received. These data agree with other workers who concluded that high level grain feeding increases milk production and body condition of lactating cows (11, 32, 38, 45, 46, 47, 59, 129).

Hoglund (82) pointed out that high level grain feeding is not well defined. Hillman (79) stated that farmers in Michigan have been continuing the high level of grain feeding after peak production resulting in cows becoming too fat at the end of lactation. The consequences were the development of many health problems.

Hemken (74) stated that limitation of milk production often is the result of an animal's inability to consume enough energy. So when an animal is in peak production she is using body fat as well as consumed nutrients. He referred to studies at Beltsville, Maryland, that indicated a high producing cow can utilize body fat for half of her energy needs during early lactation. If the ration is not sufficient in the supply of energy for milk production, fat stores are rapidly expended. When the excess body fat is utilized, milk production will be reduced.

Moe et al (126) indicate that tissue energy used for milk production during early lactation depends upon feed intake, body condition, and genetic potential. Moe's work indicates that milk may be produced from body tissue reserves with an efficiency of 82 to 84 percent.

Besides the effect energy has on body condition, age also affects body weight changes. Miller et al (125) reported in a study of 1004 lactations of 477 cows in the Beltsville herd that first calf heifers gained the most, 84 kg during lactation. Mature cows gained only 34 kg. Cows in second and later lactations lost weight from the first to the second month in lactation while first lactation animals gained weight. The difference was due to mobilization of fat reserve by the older cows and this increased milk production.

After body fat has been mobilized for milk production, sufficient energy must be fed after peak production to re-establish the animal to the desired body condition (126).

Kesler, Spahr (105), and Jorgensen (103) reported that feeding a diet too high in energy (concentrates) may force the animal into a fattening type of metabolism which may be antagonistic to a metabolism desirable for milk production. The reason for this apparent shift in energy utilization is not clear.

Effects of Obesity on the Health

Cattle that receive more energy than required tend to become excessively fat and are prone to a higher incidence of health problems.

Ketosis or hyperketonemia refers to ketone body accumulation in the blood. Bergman (23) in his review stated that ketosis may occur in all mammalion species and can be brought forth by many factors such as starvation, low carbohydrate and high fat diets, cold exposure, anesthesia, impaired liver function, hypoglycemia, and endocrine disorders such as diabetes or growth hormone as well as other endocrine excesses (54, 179). The digestive tract, liver, and mammary gland seem to be the major sites of ketone body production in ruminants (23).

Some high moisture silages increase the amount of butyrate (1, 162) produced which is then metabolized into ketone bodies. During ketosis, hepatic ketogenesis accounts for most of the ketone bodies, particularly if the animal is starving. The major sources of these ketone bodies are from the free fatty acids which are mobilized from fat in body stores (23).

Depriving ruminants of food induces fat mobilization, hepatic ketogenesis, and ketosis (109). This has been observed in sheep as well as in cattle (150).

Spontaneous ketosis and hypoglycemia, a disease called acetonemia, is usually found in cows that give high milk yields and that are in excellent nutritional condition, often too fat, and often in herds which are adequately fed (164, 165). Spontaneous ketosis develops initially in cows whose feed consumption is equal to or greater than the majority of cows. The cow which develops ketosis is usually the one which is well fed, healthy, and a highly productive cow but may consume less feed than required for the high level of production (109).

Schultz (163) concludes that management of the feed is the only way to control ketosis. One should provide feeds containing adequate nutrients according to feeding standards. The feeds should be offered at the optimum level of the cow's ability to consume the feed without going "off feed." The management practices which maximize intake in early lactation and minimize prolonged mobilization of body fat should be utilized. Schultz suggests that during the latter part of the dry period grain should be fed at the rate of one percent of body weight at calving. Then grain should increase by one pound per day, limiting the grain to 2 percent of body weight and at the same time supplying at least one third of total dry matter intake as forage (163).

Since there is no cure for ketosis, Schultz recommends the following: 1) Avoid having excessive fattness at calving, 2) Increase concentrate feeding slowly during the later part of the dry period and rapidly after calving, using care so the animal doesn't go off feed, 3) Feed good quality forage, 4) Do not make abrupt changes in the ration especially to low quality materials, 5) Feed recommended levels of protein, minerals, and vitamins, 6) Avoid hay crop silage high in butyric acids, 7) Maximize intake by providing comfort, exercise, and stress-free areas, 8) In problem herds, test milk weekly for ketones, 9) If possible select strong cows with good appetites.

The observation by Koropov et al (108) who reported higher ketones when cows were fed a concentrate type ration would appear to contradict these recommendations. The conditions under which Koropov's experiments were conducted were not defined and may account for the discrepancy.

No work has been reported on how obesity effects mastitis and milk fever. Personal observation has been that fat cows have more problems at time of calving which often leave the animal in a weakened condition.

Emery et al (60) used 98 heifers and 50 cows in which half of them received grain 21 days prepartum, while the others received no grain. Each treated heifer received 220 kg of grain which resulted in 54 extra kg of milk during the 45-day milking period. The treated cows each received 295 kg of grain, which resulted in an increase of 36 kg of milk. Feeding grain during late pregnancy to cows in good condition was not economical. An increase in edema was noted in the heifers. Metritis, retained placenta, and indigestion were noted but were not significantly different between the groups. Milk fever and mastitis were significantly greater in the group fed extra grain. Similar increases in various diseases have been previously noted in studies by Emery (61) and Robertson (152).

Reid (146) concluded that if cows are thin and in poor body condition after a lactation, they should be fed in such a way that the necessary increase in body weight would be made during the dry period.

The physical form of roughages fed may be important to the health of cattle. Tyrrell et al reported a high incidence of health problems and mortality among cows fed only corn silage and liberal concentrates compared to cows fed hay, silage, and a similar amount of concentrates over a three-year period. Whether the effects were due to differences in the energy concentrations of the two rations, differences in physical form of the forages, or discrepancies in other nutrients was not clear. The possibility exists that the texture and acidity of the total diet influence rumen fermentation and rate of passage of feed nutrients. Therefore nutrient substrate and utilization should be considered as possible contributors to health problems in cattle.

The higher incidence of health problems commonly found in herds fed excessive amounts of energy may be due to obesity, or obesity may only be a symptom of other inbalances in the ration. The evidence indicates that cattle fed balanced rations in relation to their nutrient requirements, particularly during the dry period, are less prone to ketosis, metritis, and mastitis than when fed excessively.

Milk Fat Test Depression

Balch et al (12) reported that diets low in hay and high in concentrates given to lactating dairy cows were important in determining the extent of milk fat depression. They found a greater depression with steamed flaked maize than with maize meal or oats and barley due to the effect of heating the starch on the flora of the reticulo-rumen.

Jorgensen and Schultz (103) fed four different kinds of concentrates to determine the effect of each on milk percentage. Ranking them according to the most drastic effect on milk fat was: 1) pelleted corn, 2) ground corn, 3) herd mix, and 4) corn and cob meal. These are ranked according to the fiber content. A mixture of eight pounds of hay plus twenty-eight pounds of grain would contain about eight percent fiber when using either pelleted or ground corn but up to 12 percent fiber when using corn and cob meal.

Kesler (106) and Balch et al (12) suggested that fiber levels below 13 to 14 percent of dietary proportions of above 50 to 60 percent concentrate in the ration may be detrimental to the lactating cow.

Brown et al (37) found no significant difference in milk fat percentage within summer and winter lactation trials for cows fed milo and barley at concentrate to roughage ratios of 40 to 60 and 60 to 40. Their data indicated that a higher ratio of concentrates would reduce milk fat content.

Miller et al (124) found a reduction in milk fat percentage of cows fed corn silage that was chopped a second time through a re-cutting machine compared to the original normal cut. They concluded that a chopper knife setting of .39 to .51 inch is necessary to avoid fat depression in cows consuming corn silage as the sole roughage when feeding concentrates to meet the milk production needs of high producing cows.

Thomas et al (172) reported that addition of 0.70 percent of sodium bicarbonate plus 0.35 percent of magnesium oxide (MgO) or twice or three times that level added to the grain increased fat production in cows fed a high grain ration. The effects were the same when large quantities of sodium bicarbonate and MgO were administered into the rumen via a fistula or mixed with the grain. High levels of these minerals fed to cows on a normal ration did not change milk fat secretion since milk production was reduced and milk fat percentage increased but grain consumption was reduced.

In other work, Thomas (171) administered 272 or 363 grams per day of sodium bicarbonate and 136 or 181 grams per day of MgO. Fed alone or separate, MgO and sodium bicarbonate increased fat test and rumen pH but decreased molar proportion of valerate and propionate in the rumen of cows on a low-roughage high-concentrate ration. Daily milk and fat production was increased by addition of sodium bicarbonate, but addition of MgO caused a slight decrease.

Hillman (79) stated that feeding mineral supplements to increase test has not routinely increased the fat test on farms where the test has already decreased. Maintaining a normal fat test or raising a low fat test can be accomplished by feeding a balanced ration of good quality forage and concentrates.

The evidence indicates that the percent of milk fat can be depressed by feeding excessive amounts of concentrate in relation to forage, by feeding a ration too low in fiber content, and by finely chopping, grinding, or pelleting of the ration. The fat test depression may be returned to normal by correcting these conditions. Cattle fed milk fat depressing rations frequently become excessively fat and are susceptible to health problems.

Energy Effects on Reproduction

Several workers have demonstrated the importance of adequate nutrient levels for fertility in calves and heifers (3, 149, 168). Tuff (173) found that normal estrous cycles did not take place when mature cows were under-fed.

Zimmerman et al (190), McGillivray et al (123), and Rigor et al (151) reported that additions of a high-energy source to a basal ration for a short period of time enhanced ovulation rate in the gilt. In working with ewes, Howland et al (86) reported that the nutritional level of the diet is important for normal reproductive performance.

Wiltbank et al (183) reported that onset of post-partum estrus was delayed when TDN intake was limited to one-half of the recommended allowance by the National Research Council in 1958 (134) and that the interval from first breeding to conception was longer when the TDN allowance was reduced.

Wiltbank (183, 184) indicated that a low level of energy before calving delayed the onset of estrus following parturition and decreased conception rate for the following parturition. In contrast cows fed adequately after parturition had a high conception rate.

Dunn (57) fed 8.7 MCal (low) and 17.3 MCal (high) of calculated digestible energy per head daily to 240 two-year old heifers 60 days before their first parturition. At calving time prepartum energy groups were subdivided into three groups fed 14.2, 27.3, or 48.2 MCal of digestible energy daily postpartum. The results indicated that the level of energy intake can alter reproductive performance. Percent pregnant at 120 days after calving was directly related to post-calving energy level. Eighty-seven percent of the cows fed the high energy level after calving were pregnant as compared to seventy-two percent of those on the moderate level and sixty-four percent of those fed the low energy level. The onset of estrus was delayed in the cows which received the low level of energy before calving. In this group thirty percent of the Hereford cows and nine percent of the Angus cows failed to show estrus.

Reproductive performance was further studied by Hollon and Branton (83) when 1172 pregnancies from 2057 services were analyzed for the effect of early post partum weight changes. Of the animals gaining weight during the month of service, 1477 services resulted in 907 pregnancies or 61 percent conceived and required 1.63 services per cow. Among those animals losing weight, 580 services resulted in 237 pregnancies or 41 percent conceived and 2.45 services were required per cow. For animals which gained during the 30 to 90 day post partum period, 814 first services resulted in 519 pregnancies or a 64 percent conception rate. Those cows losing weight had 358 first services resulted in 165 pregnancies or a 46 percent conception rate. Body weight changes during the 30 to 90 day post partum period had no significant effect on conception rate of later services. Adequate energy levels must be maintained to expect high reproductive efficiency.

Moe et al (125) using 50 cows for 3 complete lactations reported that liberal grain feeding increased the interval between first and second calving by 26 to 46 days over moderate levels of grain feeding. Services per conception increased from 1.53 to 1.78 services per cow as a result of liberal amounts of grain feeding.

An optimum level of feeding grain apparently depends on many factors such as the condition of the cow post and prepartum, the rate at which the animal will mobilize her body reserves after parturition, and the animal's potential for consuming high levels of energy. For high productive efficiency an animal must be in good nutritional health.

Nutrient Value of Corn Silage

Energy

An all-silage forage program is becoming increasingly popular stated Hemken and Vanersall (75) because of areas where hay curing is difficult and field curing losses are high, silage offers a method of circumventing this problem. Silage feeding is easier to automate and in most areas offers more potential of maximizing production of energy per acre.

Some early reports on use of corn silage seemed to conflict with recent research. Waugh (181) reported that cows performed better when fed one-half pound of hay per 100 pounds of body weight with corn silage than when corn silage was fed as the only roughage. The dry matter in the corn silage was from 19.8 to 25.0 percent. The low dry matter in the corn silage could have been the reason for that poor result. Pratt (143) also reported in 1930 that heavy corn silage feeding resulted in slightly greater dry matter consumption and in slightly greater milk production. The group fed less silage produced more milk and also lost more weight.

Coppock (51) cited an Iowa Study (141) in which 22 heifers were paired at birth and fed either corn silage or corn silage and hay from birth through two lactations. Both groups were on pasture during the summer after one year of age. Production of milk, butterfat, and breeding efficiency were similar for both groups.

Research by Hammes (71) showed that use of corn silage for fattening steers gave gains similar to those of a high grain ration and lowered the cost of fattening.

Corn silage was compared to alfalfa hay using different combinations by Brown (34). Five groups of lactating cows were fed either corn silage ad libitum, corn silage plus 10 pounds of hay, corn silage plus twenty pounds of hay, corn silage plus thirty pounds of hay or ad libitum hay. The average daily milk production was 36.1, 38.2, 34.7, 36.0, and 34.8 pounds of milk, respectively. The differences among ration groups in persistency of milk production were not statistically significant. With increasing amount of hay in the ration, dry matter consumption increased, so that dry matter from corn silage was used more efficiently for milk production than dry matter from hay. Body weight changes followed a similar trend to that of dry matter consumption.

Vandersall (176) also found dry matter intake was increased slightly by addition of hay to cows consuming corn silage ad libitum but milk production was lowered.

In investigations, Thomas et al (170) and Rumsey (155) used cows at a higher level of milk production than the ones previously cited. The difference in milk production of cows producing 50 pounds of milk was not significant between groups fed different ratios of corn silage and hay. Brown (35) concluded that corn silage can adequately support high milk production.

Hillman (80), in reviewing the literature, stated that the roughage portion of corn silage (stalks and leaves) is equivalent in milk production value to clover hay. Also the grain in the corn silage is as valuable for milk production as corn fed as dry corn and cob meal. The grain in the silage increased the TDN value over silage with the grain removed, the difference being from 59 to 69 percent. Supplementation of corn silage with urea can reduce the cost of corn silage even lower than the value for hay.

Hemken et al (75) reported that differences in the grain to stalk ratio of two varieties of corn failed to significantly affect digestibility or milk production. However, the differences may have been masked in their experiment since the silage having low grain content was supplemented with additional grain to compensate for this difference. The data seem to indicate that cows fed well-eared corn silage produced an equal amount of milk and gained more weight when fed 2.4 kg less grain than cows fed silage with a low grain content.

Wintering brood cows fed all Pro-Sil treated corn silage (a proprietary mixture of anhydrous ammonia, molasses, minerals, and water) versus an all-hay ration in Michigan (68) resulted in three pregnant beef cows wintered per acre on the corn silage ration versus one pregnant beef cow wintered per acre on the all-hay ration. Dry matter consumption was 19.5 pounds per head daily for those fed all hay versus 13.1 for those fed corn silage. There was no difference in the average weight gain.

In another experiment, (69) wintering pregnant heifers were fed an all silage versus a silage plus hay ration and similar results were obtained. Pro-Sil treated corn silage performed just as well as when hay was added to the ration.

In an experiment done the following year (67) wintering brood cows were fed either an all corn silage or an all alfalfa grass silage ration. The animals ate 10.0 pounds of dry matter of Pro-Sil corn silage per head per day versus 23.1 pounds of dry matter of alfalfa grass silage per head per day. At the end of the experiment the cows on corn silage gained 81 pounds whereas the cows on alfalfa-grass silage lost 39 pounds.

These studies show that Pro-Sil treated corn silage may successfully support pregnant beef cows as the sole source of energy.

The value of corn silage has been under-rated. Over-wintering of beef cattle on 90 percent of NRC requirements was successful in at least maintaining body condition. This was a savings of 1.8 pounds of TDN per head daily.

Tyrrell et al (175) reported that feeding an all corn silage and liberal grain ration for 3 complete lactations resulted in lower survival rates of lactating dairy cows compared to cows receiving corn silage plus hay and grain. Tyrrell concluded that liberal grain feeding had no significant effect on the high cow losses. The cows receiving only corn silage and grain, however, produced more milk than the other cows receiving some hay during the first and second lactation.

The influence of feeding forages that are finely chopped, high in moisture content, and fermented on microbial synthesis in the rumen and interactions with level of grain feeding has not been adequately studied. More conclusive work needs to be done on what effect an all corn silage ration has on longevity and health of the dairy cow.

Corn silage is a rich source of energy. The TDN content ranges from about 60 to 70 percent on a dry basis and averages about 68 percent. This is higher than most other forages and is equivalent to excellent quality hay.

The estimated net energy value of dent stage corn silage is 71.2 megacalories per 100 pounds of dry matter according to Morrison (131). ENE values for corn silage containing more than 28.5 percent dry matter are not listed in Morrison. Typical corn silage in the midwest contains about 32 to 35 percent dry matter, therefore is more mature, contains a higher proportion of grain, and may be higher in net energy value than shown in Morrison's tables.

Protein

Protein content of corn silage is relatively low compared to legume hay or silage. Michigan corn silage normally contains 7 to 10 percent protein on a dry basis. Nitrogen fertilization has increased the crude protein content of corn silage as well as crop yields (2, 136). However, if fertilization rate is held constant and plant population is increased the protein content of the silage will decrease. Protein levels in corn silages also vary as the amount of available moisture and other environmental conditions differ from year to year (80).

The addition of urea, non-protein nitrogen (discussed in a later section), is one way to increase the nitrogen content of ensiled corn silage with very little added cost.

Minerals

Corn silage is low in calcium and sodium and often low in phosphorus, cobalt, and iodine. Sulfur may be low in high silage rations particularly if urea is added and natural protein withdrawn. Supplementation of these minerals may vary for different moisture conditions, soil types, stages of harvest, and the types of drinking water supplied to the animals (80).

Vitamins

The quantity of carotene (pre-Vitamin A) in corn silage is usually sufficient for lactating cows unless the harvested corn forage was too mature, had few leaves, had severe frost damage, or was overheated during storage. Vitamin D supplementation to a high corn silage diet usually is not necessary unless the silage is made from immature green corn (80).

Urea in Rations of Lactating Dairy Cows

Early work with urea in dairy cattle rations was with low producing cows which had low dry matter intakes. The high producing cow of today requires different feeding practices (89).

Willett et al (182) experimented with feeding 1.25 and 2.5 percent urea in the ration. The main roughage was chopped napier grass. They found that when urea replaced SBOM in the concentrates, milk yields were depressed.

Lassiter et al (113) reported no detrimental effect on lactating cows fed from 25 to 33 percent of their total ration nitrogen concentrate as urea. The cows' milk production was from 24.2 to 39.6 pounds daily.

Rupel et al (156) in 1943 recommended that urea should not be fed at a greater rate than one percent of the total dry matter of the ration (3 percent of the concentrate). The rate of feeding grain was 1:3.5 pounds of milk. These cows were only producing at an average of 27.9 pounds of milk, so total urea consumption was low.

Conrad and Hibbs (50) discovered that one percent

(20 percent of total protein equivalent) urea in the grain ration fed to cows producing from 29.9 to 75.0 pounds of milk per day caused no depression of milk production. When 2.75 percent (60 percent of total protein equivalent) urea was added to the grain ration, feed intake, milk production, and body weights were depressed. They more recently found that cows fed a pelleted alfalfa meal and urea combination did not have depressed milk production.

Bates et al (13) reported that animals were able to grow, mature, and produce milk when fed rations in which essentially all the digestible protein equivalent was supplied by urea. No toxic effect was observed.

Huber et al (87) concluded that when urea was added to the concentrate and furnished from 22 to 25 percent of the total dietary nitrogen fed to lactating cows with corn silage as their principle ration the milk yield was depressed. This would amount to one to 1.25 percent of urea in the concentrate. When urea was increased to 2 percent, then palatability of the concentrates was decreased.

Colovos (49) found in cows fed a low fiber concentrate that 2 percent urea improved digestibility of the fiber, but the opposite effect resulted when fed with a high fiber concentrate. They fed a fair quality timothy hay.

Urea in the Silages

Woodward and Shephard (189) did early work with ensiled corn silage and .5 percent urea which was fed along with low protein concentrates and hay. Another group had the urea mixed with the concentrates. Both groups maintained their production of milk with no differences.

In an experiment by Huber and Thomas (90) cows were fed 6 different rations adding 0 percent urea, 0.5 percent urea, 0.75 percent urea and $CaSO_4$ to corn silage in conjunction with 8 percent, 12 percent, and 18 percent protein in the concentrates. The cows fed untreated control corn silage with 8 percent concentrate produced less milk than those cows fed urea. The highest milk yields were obtained from the cows receiving 50 percent of the supplemental nitrogen from urea added to the corn silage and the balance from soybean oil meal. The authors concluded that a 10 percent increase of income over feed cost was obtained from those cows which received their nitrogen from urea in corn silage and soybean oil meal in grain rather than just from soybean oil meal in grain. These facts emphasized the benefits of adding urea to corn silage at harvest time.

In research done by Schmutz (161) a decrease in silage intake was observed but not a decrease in milk production from cows fed 0.75 percent urea in the corn silage. However, Huber (87) found no significant decrease in milk production of cows fed silage containing 0.75 percent urea. The difference in dry matter intake may have been due to a higher dry matter content of silage in the latter study (87).

Hillman et al (77) suggest that corn silage should contain a minimum of 30 percent dry matter to prevent storage losses of nitrogen from seepage in urea-treated silages.

Huber et al (91) reported that silage dry matter intake increased with the addition of 10 pounds of urea per ton to 30 and 36 percent dry matter corn silage compared to untreated control silages. Milk yields were not affected by urea-treated silage but corn silage yields did decrease with increasing maturity of the forage. As dry matter of the silage increased to 44 percent, there was a high loss of dry matter (15.1 percent) in the silo, and milk persistency was lower than for the 30 and 36 percent dry matter silages. The highest intakes occurred with the urea-treated (36 percent) dry matter silages. Cows fed the untreated corn silage ate less of the lower and higher dry matter corn silage and more of the medium dry matter silage. In these experiments cows fed urea-treated silage (30 and 36% dry matter) and a grain ration containing 13.8 percent protein produced as well as those fed untreated silage and a grain ration containing 18.7 percent protein composed of all natural protein.

More urea can be tolerated in the presence of high carbohydrate feeds such as cereal grains. Urea may produce harmful effects under unusual conditions, such as starved animals, rapid consumption of urea containing feed or in animals that have not adjusted to the urea supplement (116).

No detrimental effect is apparent if the total non-protein nitrogen (NPN) of the diet does not exceed 0.45 kg of urea per 1000 kg body weight. Considering the wide NPN content of forages one should not add more than 0.27 kg per 1000 kg body weight. The recommended level of urea is 0.5 percent when added to the corn forage as ensiled (80). However, favorable results were obtained in one short-term study from adding 0.85 percent urea (87).

Fletcher et al (64) and Campbell et al (42) demonstrated that rumen ammonia levels were more constant when urea-treated corn silage was fed more frequently. This reduced the amount of urea consumed at one time and ammonia concentrations were not as great as when the animal was fed more often. Estimated pounds of TDN required per pound of gain was significantly greater for animals fed silage two times daily than for those fed urea-treated silage four times. This agrees with data of Packett and Groves (139) in relating energy and ammonia utilization.

When urea is correctly used, supplementing dairy cattle rations with urea or non-protein nitrogen can be of financial benefit.

High Moisture Corn as a Source of Energy

There have been some conflicting reports on the use of high moisture corn. Hansen et al (73) in 1959 using 24 (Holstein) heifers and 27 (Holstein and Brown Swiss) cows reported that high moisture corn was not superior to dry corn. The dry corn was ground and the high moisture corn was not because they assumed that moisture made the kernals soft enough to be disintegrated during digestive processes.

Zogg et al (191) in 1961 using 27 cows reported that the efficiency of utilization of dry matter of high-moisture corn increased as the moisture content increased from 22 to 32 percent. This corresponds with work done by Beesen et al (16, 17, 18, 19, 20) and Colbertson et al (53) where corn stored at 31 to 32 percent moisture gave increased feed efficiency for fattening beef cattle over corn stored at 10 to 15 percent moisture.

McCaffree and Merrill (122) compared high moisture corn, dry corn, and a commercial grain mixture. Milk production was not significantly different for cows fed high moisture corn or dry corn but both groups produced more milk than those fed the commercial grain mixture. In another trial (122) high moisture ear corn was compared to high moisture shelled corn. They found no significant difference in milk or butterfat production, or total dry matter intake.

Pratt and Rogers (142) reported that ear corn silage fed to heifers was a satisfactory source of energy for growth and also for preparation for freshening. Milk production could also be sustained by ear corn silage and ear corn silage was as good a source of energy as a mixed dairy ration when adequate protein supplement was provided.

McCaffree and Merrill (17) found no difference in digestibility of shelled high-moisture corn compared to dry corn.

Hillman (78) concluded in a review that cornage (high-moisture corn) is equivalent in feed value to dry corn for milk production and for fattening beef cattle and that cornage is more efficient than dry corn. Cornage should be ground before feeding. Ground ear cornage can support high milk production and at the same time provide 15 percent more nutrients per acre than shelled cornage.

Schmutz (160) et al studied the fermentation and preservation of corn containing various levels of moisture and processed in silos. The lactic acid content of the products was directly related to their moisture content. Consumption of corn dry matter was negatively correlated with the lactic acid content when fed ad libitum to dairy heifers. These findings suggest the possibility of considerable variation in the feeding qualities of high moisture corn and the need for further research to define optimum conditions for storing high moisture corn.

Lassiter et al (111) stored ground high moisture shelled corn at 26, 32, and 40 percent moisture and ground ear corn at 32 and 36 percent moisture and unground high moisture shelled corn at 32 percent moisture. Dried corn, used as a control, was stored at 14 percent moisture. Those cows which received 40 percent ground shelled corn produced 4 percent less milk than cows fed 26 percent ground shelled or 36 percent ground ear corn. When moisture was controlled at 32 percent for ground ear, ground shelled, or unground shelled corn the cows which were receiving the unground shelled corn lost the most weight. This was probably due to the passage of whole kernels into the feces. The high moisture corn in all cases performed equal to if not greater than that of dry corn, based on dry matter content. High moisture shelled corn should be ground before it is fed, this will increase its value.

Schmutz (160) reported that with the exception of one growth study there was no significant difference in weight gain of heifers when fed ground ear corn (24 to 25 percent moisture) or when fed ground dry corn. In two studies animals fed the wetter silages (34 to 35 percent moisture) required less dry matter per pound of gain and they consumed less dry matter.

The use of high moisture corn is becoming more popular in Michigan due to ease of handling and its equal if not better nutritional value when compared to dry corn. In areas where the growing season is short and labor is in short supply the use of high moisture corn should be recommended.

Intake Regulation

The goal for feeding lactating dairy cows is to increase dry matter consumption to the highest possible level in order to maintain high milk production. Some have reasoned that if the cow has a high genetic potential for milk production more frequent feeding of fresh food would increase the animal's consumption.

Martz et al (119) studied the effects of frequency of feeding a blended corn silage concentrate ration containing a pelleted urea-alfalfa combination during a 120-day continual study. Twenty cows were divided into two groups. The first group was fed twice a day and the other group was fed four times a day. At the end of the study the average daily fat-corrected milk, milk fat, solids-not-fat, milk protein, body weight, and dry matter intake was not significantly different. These results indicated that frequency of feeding of a blended corn silage concentrate ration containing pelleted-urea supplement had no effect on performance.

Campbell and Fletcher (42) demonstrated that frequent feeding of a urea-ration four or six times compared to two times daily increased growth and feed efficiency of sheep. Martz (119) suggested these favorable results may have been due to small quantities of urea administered at frequent intervals, theoretically resulted in a more sustained ammonia release. Thus the ruminal microflora may have been able to utilize the ammonia nitrogen to a greater extent for protein synthesis. Huber (89) found that higher levels of urea in the silage did reduce dry matter consumption.

Blaxter et al (28) postulated that animals on a diet made up of long forages regulated voluntary intake so that the gastrointestinal tract fill among rations is constant at the end of the meal. In 1962 Balch and Campling (10) agreed that food intake of ruminants receiving rations of primarily roughages was regulated by the amount of digesta in the reticulorumen.

Balch and Campling (9) in another review stated that palatability is an important factor in the voluntary intake of individual feeds, showing that ruminants have perceptive faculties. Differences in intake in a variety of roughages can be related to that rate at which the undigested residues are removed from the reticulorumen. Montgomery (128) questioned this theory and stated that the gastro-intestinal tract fill increased as dry matter intake increased, and a more accurate system to verify the fill of food intake was needed. Campling (45) stated that meal size in diets of low digestibility may be a controlling factor in rations that have a low fiber and high digestible energy content and that ruminal distention is not a feedback signal in control of meal size.

Bhattacharya and Warner (24) conducted experiments with rumen-fistulated Holstein heifers. Hourly infusions of cold or warm water effected slight changes in rectal and tympanic temperature but had no affect on hay intake. When the infusion of water was increased to every hour a marked change in rectal and tympanic temperature was observed, and rumen temperature remained altered for a long period of time. Compared to a control (30° C) infusion of cold (5° C) water increased ($P < .01$) consumption of an all-pellet diet by 24 percent while a warm (49° C) infusion depressed intake nonsignificantly by 9 percent. This experiment suggested that physiological conditions causing a decline in body temperature could be an important signal for controlling feed consumption in ruminants.

Baile et al (7) found little evidence in their research for hypothalamic temperature changes as a direct feedback signal. They continued by writing that palatability offers little evidence of its importance in determining meal size.

In an experiment by McCaffree and Merrill (121) trials were conducted in which concentrates were increased after calving to essentially ad libitum levels and adjusted weekly to stabilize body weight to postpartum level. Lead feeding was utilized prior to parturition, with daily concentrate increases of 0.45 kg per day until 9.1 kg per day was achieved or parturition occurred. After calving the concentrates were increased to 0.45 kg per day until the cows began to increase beyond the postpartum body weight. Then the grain allowance was reduced. As grain was reduced based on body weight increases, the cows compensated for the energy formerly supplied from the grain by increasing their forage consumption.

Montgomery et al (127) found in ruminants that voluntary intake decreased as proportions of concentrates increased in the diet so the available energy consumption was relatively constant. Cowsert et al (52) also found that ruminants while being fed isonitrogenous rations varying in energy concentrations adjust voluntary feed intake in relation to physiological energy demands if rumen load does not limit their energy consumption.

Donefer (56), Woods and Rhodes (28), and Brent et al (31) while working with sheep found that as the proportion of concentrate was increased in the diet voluntary dry matter intake decreased, so that the available energy consumption was about constant. Cohn and Joseph (48) force-fed rats above their normal diet or intake and the body weight increased by fat deposition. When forced feeding was terminated the rats ate less and body weight decreased by loss of fat. As normal body fat levels were attained voluntary intake was resumed. During obesity, activity of an animal will be reduced by the energy balance signal and the mobilization potential will be reduced (110, 140). Fasting of a normal animal will cause the opposite responses. Reid and Robb (147) stated that accumulation of fat in the abdominal cavity might restrict gastrointestinal capacity and curtail appetite especially in high-forage diets.

Dinius and Baumgardt (55) experimented with voluntary feed and energy intake of rations varying in digestibility and density. When the ration was low in energy density rumen fill limited the intake but as energy density increased then total energy intake remained constant.

Heat stress (4), inadequate protein-digestible energy balance (44, 58) and dehydration (22) may all effect total intake. Baile (6) stated these limiting factors of intake may be put under more stress by very high milk production or a disease.

Feeding high levels of corn silage depresses dry matter intake compared to all hay rations according to Brown et al (35). Similar results have been shown with high moisture grass silages. The causes for this appetite depression are not known.

The above studies indicate that feed intake may be affected by the quality of the ration, energy density of the ration, energy-protein balance, and requirements of the animal.

Literature Resumé

In resumé one concludes that lactating cows must be provided a ration that provides adequately levels of energy, protein, fiber, and the various minerals and vitamins in order to maintain high level milk production. The published NRC nutrient requirement tables appear to be sufficiently accurate to allow optimum performance of cattle when fed according to these standards.

Feeding excessive amounts of energy may result in milk fat depression, excessive fatness of cattle and increase the incidence of health problems at parturition.

Corn silage is a satisfactory forage for lactating and pregnant dry cows when properly balanced with protein, minerals, and vitamins. The maturity, fineness of chopping, and moisture content may affect the nutritive value of corn silage and under some conditions feeding 10 to 20 percent of the ration dry matter as hay may be desirable because of the variation in corn silage. High moisture corn processed through silos is comparable to dry corn in feed value but may be more variable in composition and keeping quality under farm conditions.

Non-protein nitrogen sources such as urea and ammonia can replace 25 to 30 percent of the nitrogen from natural protein sources in the ration of lactating and pregnant dry cows and substantially reduce feed costs.

EXPERIMENTAL PROCEDURE

These experiments took place at the Andrews University Dairy in Berrien Springs, Michigan. The cows were kept in open lot free-stall housing and fed mechanically using tube feeders. Each cow was placed in one of three or four lots according to her daily production soon after the monthly Dairy Herd Improvement Association (DHIA) tests were taken.

The main roughage was corn silage stored in cement stave silos. Minimum quantities of hay were fed in stalls at the end of each barn. High moisture corn was stored in a Herd-King sealed silo, rolled, and weighed at the time of feeding. Feeds were analyzed for protein and dry matter content and these values are reported in Table 1 which also shows the estimated TDN and net energy values calculated from Morrison (131).

A 55 percent pelleted concentrate containing 26.2 percent protein-equivalent from nonprotein nitrogen was stored in a metal bin. As corn silage was being fed, high moisture corn and the 55 percent concentrate were metered into the tube feeders with the corn silage. The quantity of concentrates fed was regulated according to the nutritional requirements of each lot. Thorough mixing occurred as these feeds traveled to the bunks. Soybean meal (SBM)

Table 1

Chemical Composition of Feeds Fed in Experiment I

Forage or Concentrate	Protein	Digestible Protein[a]	TDN[a]	NE[a]	Dry Matter
	%	%	%	MCal per lb.	%
High Moisture Corn	7.75	5.9	72	.85	76.77
55% Concentrate	55	46.6	63	.91	90.00
Alfalfa Hay	15.19	10.8	51	.49	88.40
SBM	45.70	42.0	78	.91	90.0
Corn Silage	3.79	1.7	32	.34	46.0

[a]TDN, NE, and Digestible Protein values were calculated from references 62, 131, 134, and 135.

was fed in the milking parlor to each individual cow based on requirement.

Prior to treatment, daily milk weights were taken on all cows in the herd. Only those cows which were below 30 pounds of milk daily were chosen for the experiment. The milk was recorded daily by reading the quantities from weigh jars.

The calculated requirements for protein and energy of the cows used in Experiment I are shown in Table 2.

Fat test values used were taken directly from the DHIA monthly reports in Experiment II. Feed samples were analyzed by the Department of Biochemistry, Michigan State University.

Table 2

Daily Nutrient Requirements of Lactating Dairy Cows in Experiment I to Maintain 30 Pounds of Milk

	Protein lb.	Digestible Protein lb.	TDN[1] lb.	NE[2] MCal
Maintenance for 1100 pound mature cow	1.40	.66	8.10	9.0
30 Lbs. of Milk	2.10	1.35	9.15	9.3
Total Requirement	3.50	2.01	17.25	18.3

[1]National Research Council, Publication 1349, Nutrient Requirements of Dairy Cattle, National Academy of Sciences, 1966.

[2]F. B. Morrison, Feeds and Feeding, 22nd ed., 1956.

Body weights were taken for Experiment II on a portable platform scale as the cows walked from the parlor after the afternoon milking. Dry matter consumption of corn silage was estimated from the data reported by Brown (34) who measured dry matter intake of cows in late lactation when fed corn silage ad libitum with and without grain. Actual silage intake was not measured in these trials.

Experiment I

The first experiment was conducted to determine the effect of eliminating all concentrates and protein supplement from the ration of cows fed corn silage and limited hay in the late part of lactation.

Forty-eight cows were paired according to age and daily level of milk production (not exceeding thirty pounds of milk per day) from the herd of 180 milking cows. Preliminary milk weights within groups varied not more than two pounds from the average and the age of cows varied not more than three months from the average. Most of the animals were heifers in their first lactation with an average age of thirty-five months.

The paired cows were separated with each cow going into either the control or the experimental lot. Days in lactation for each lot were assumed to be equal due to the dividing of pairs at random. The experimental group went into the dry cow lot (Lot III) and were separated out at milking time. These cows received only free choice corn silage and five pounds of hay per day. Another lot was used to house the cows producing less than thirty pounds of milk per day. Twenty-four of these cows served as the control group. The control group was fed 9 pounds of high moisture corn, free choice corn silage, one pound of 55 percent concentrate, 5 pounds of hay, and 0.75 pound of soybean meal. The concentrates were mixed with the corn silage.

Experiment II

Experiment two was designed to determine the effect of reducing the energy intake while maintaining adequate protein in the ration of cows in late lactation.

Before Experiment II was started there was a two-week preliminary testing for allocation of cows to groups. This period of time was set aside to observe all cows in the Andrews University herd. Milk weights were taken twice each week to determine which cows would be used. At the end of the preliminary testing period a 60-day experiment was begun.

Thirty cows were selected which ranged in milk production from 33.5 to 37.5 pounds daily. The cows were placed alternately in one of the two chosen lots. The cows used for the research were milked and fed the same as the other cows in their respective lots. Cows on test were identified by a red ink mark on their udder.

Lot II (control group) received 14 pounds of high moisture shelled corn, 5 pounds of hay, ½ pound of 55 percent concentrate, ½ pound of soybean meal and free choice corn silage.

The experimental group (low energy) received the same ration as the controls except that the 14 pounds of high moisture corn was eliminated. Fat tests were taken directly from the monthly DHIA report. Milk was weighed five days per week during the eight-week experiment. Body weights were taken at the beginning and end of the experiment, the cows were weighed on a platform scale as they came from the parlor. The concentrates were group-fed by weighing and metering into the tube auger slowly while the corn silage was being fed to each lot. The soybean meal was fed individually in the milking parlor. Table 3 gives the chemical composition of feed and Table 4 gives the daily requirements of a lactating cow producing 35 pounds of milk.

Table 3

Chemical Composition of Feeds Fed in Experiment II

Forage or Concentrate	Protein	Digestible Protein[a]	TDN[a]	NE[a]	Dry Matter
	%	%	%	MCal per lb.	%
High Moisture Corn	6.81	4.70	67	.80	71.13
Alfalfa Hay	18.00	12.78	50	.48	85.53
Corn Silage	3.23	1.54	30	.32	43.05
SBM	45.70	42.0	78	.91	90.0
55% Concentrate	55	46.6	63	.91	90.0

[a]Digestible Protein, TDN, and NE were calculated from references 62, 131, 134, and 135.

Table 4

Daily Nutrient Requirement
of Lactating Cows in Experiment II

	Protein	Digestible Protein	TDN[1]	NE[2]
	lb.	lb.	lb.	MCal
Maintenance for 1200 pound mature cow	1.52	.72	8.8	9.6
35 Lbs. of Milk	2.50	1.57	11.6	10.9
Total Requirement	4.02	2.29	20.4	20.5

[1]National Research Council, Publication 1349, Nutrient Requirements of Dairy Cattle, National Academy of Sciences, 1966.

[2]F. B. Morrison, Feeds and Feeding, 22nd ed., 1956.

RESULTS AND DISCUSSION

Experiment I

The experimental lot (no additional concentrates) started with a weekly average of 0.9 pounds above the control group of cows. At the end of the first week the average daily production had dropped to 25.2 as compared to the control weekly average of 30.1 pounds of milk. The average daily production of the control group remained between 29.4 and 30.1 pounds per day during the first, second, third, and fourth weeks of the experiment as shown in Table 5 and Figure 1. They did not decline as normally expected. One

Table 5

Average Daily Milk Production by Weekly Periods for Control and Experimental Cows in Experiment I

	Control	Experimental
	lb.	lb.
Pre-Experimental	28.7	29.6
Experimental--by week		
1	30.1	25.2
2	30.0	23.0
3	29.4	22.7
4	30.1	20.7
Experimental Mean	29.9	22.9

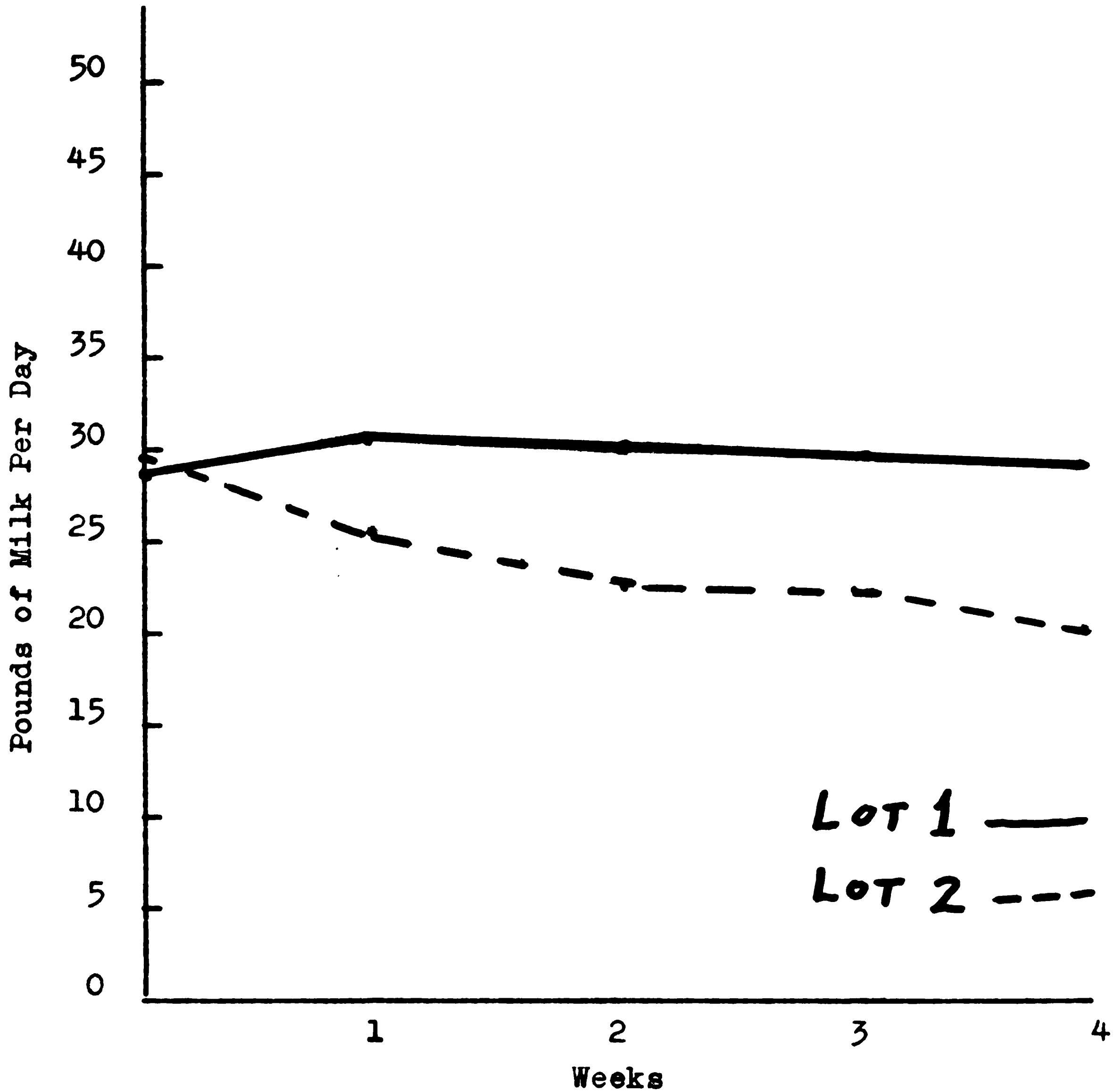

Figure I--Milk Production Curves for Cows Fed No Grain or Protein Supplement (Lot 2) Compared to Controls (Lot 1) Experiment I. (Milk weighed five days weekly).

might conclude that these cows were being over-fed which retarded the normal decline in daily milk production.

The weekly average for the experimental group, at the end of the second, third, and fourth week was 23.0, 22.7, and 20.7 pounds of milk per cow daily, respectively. These values were 7.0, 6.6, and 9.4 pounds of milk below the control group which produced 30.0, 29.4, and 30.1 pounds the second, third, and fourth week, respectively.

Feed costs for the experimental group (Table 6) were 31.5 cents per head per day compared to 53.5 cents per head

Table 6

Average Daily Intake and Feed Costs for Cows on Experiment I

		Control Concentrates		Experimental No Concentrates	
	Cost/lb.	Amount Fed	Total Costs	Amount Fed	Total Costs
	cents	lb.	cents	lb.	cents
Corn Silage	0.5	37.0	18.5	48	24.0
Alfalfa Hay	1.5	5.0	7.5	5	7.5
High Moisture Corn	2.0	9.0	18.0	--	--
55% Concentrates	6.0	1.0	6.0	--	--
SBM	5.0	0.7	3.5	--	--
Total Intake		52.07	53.5	53	31.5

per day for the control lot. An investment of an extra 22.5 cents per day for concentrates yielded 9.4 pounds of milk above the experimental group which at $5.50 per hundred pounds amounted to 30 cents more return above feed cost at the end of the fourth week (See Figures II and III and Table 7).

Table 7

Average Weekly Gross Income and Gross Income Minus Feed Costs for Cows on Experiment I

	Control Received Concentrates			Experimental Received No Concentrates		
Period	Ave. lb. Milk Produced	Gross[1] Income Dollars	Income Minus Feed Costs	Ave. lb. Milk Produced	Gross[1] Income Dollars	Income Minus Feed Costs
X[2]	28.7	1.58	1.04	29.6	1.62	1.30
1	30.1	1.65	1.11	25.2	1.32	1.07
2	30.0	1.65	1.11	23.2	1.27	0.95
3	30.0	1.62	1.08	22.7	1.25	0.93
4	30.1	1.66	1.12	20.7	1.14	0.82

[1]Milk value at $5.50 per hundred pounds.
[2]X = Preliminary period.

Assuming the value of 100 pounds of milk at $6, the extra return above feed cost for feeding grain and protein supplements was $.33 or 152 percent return on the investment for extra feed.

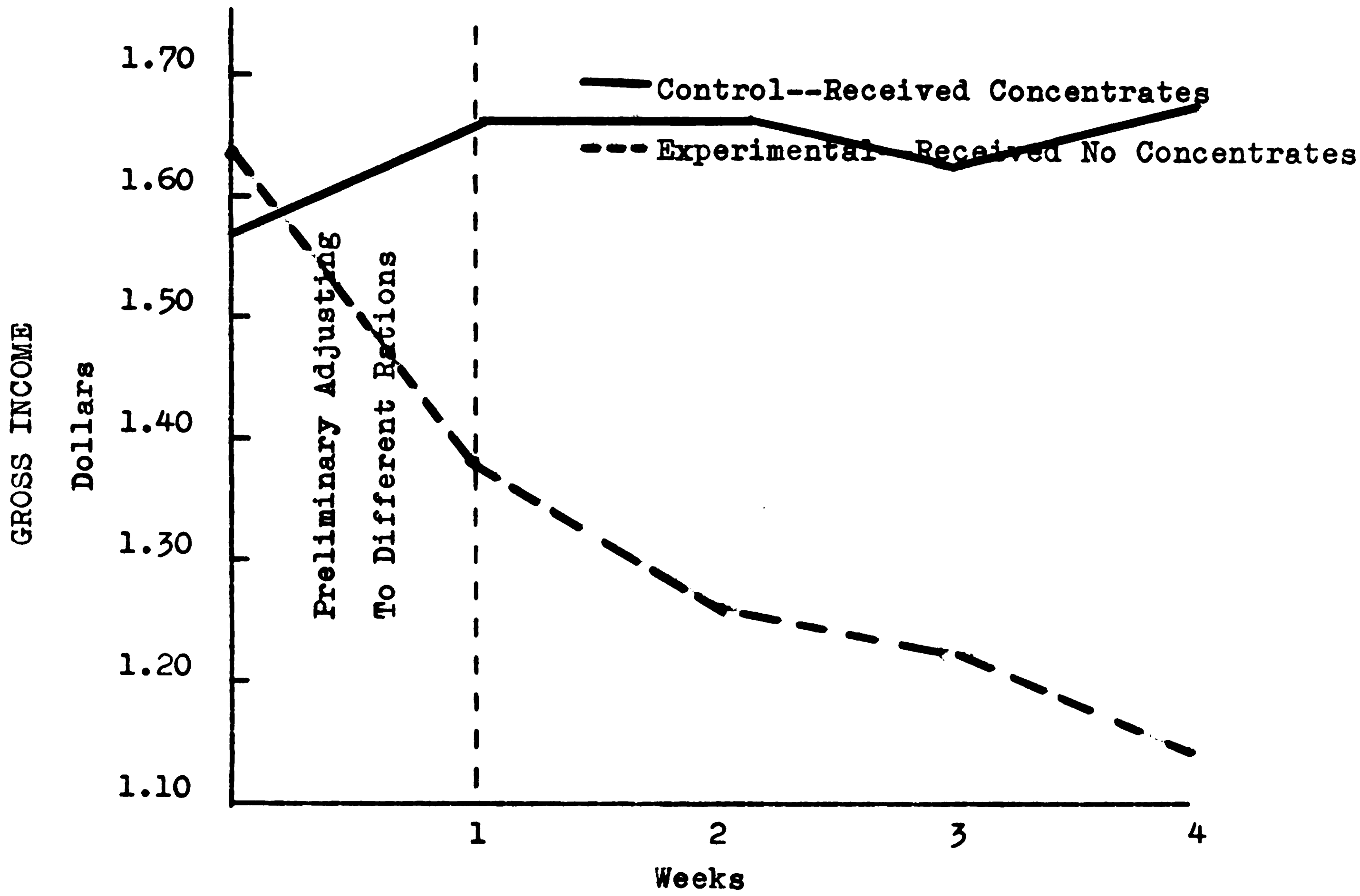

Figure II--Gross Income of Cows on Experimental and Control Ration, Experiment I. (Value of milk, $5.50 per hundred pounds of milk).

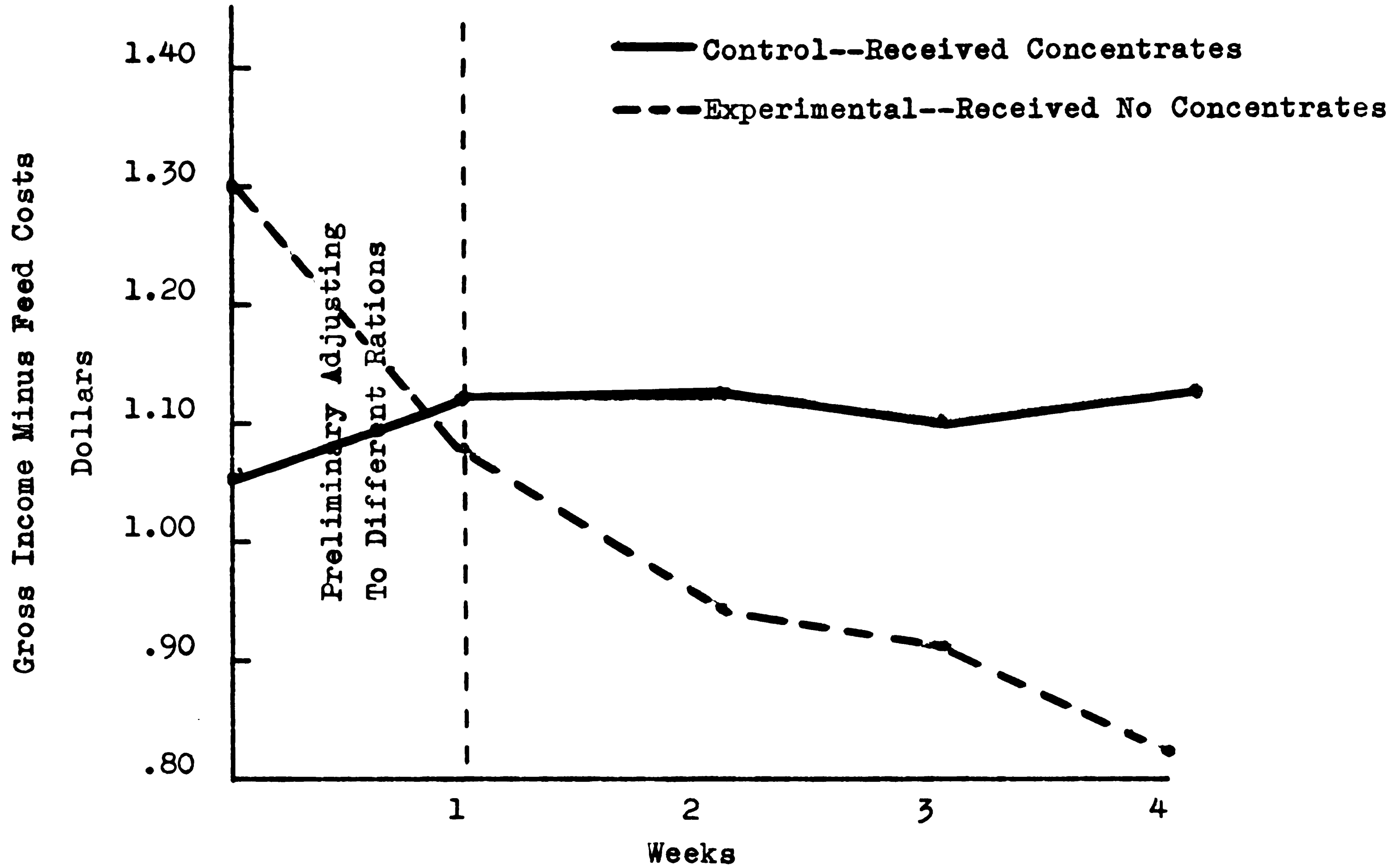

Figure III--Gross Income Minus Feed Cost From Cows on Control and Experimental Ration, Experiment I. (Value of milk, $5.50 per hundred pounds of milk).

The difference in milk production between supplemented and unsupplemented groups was highly significant ($P < .01$). (Table 8).

Table 8

Analysis of Variance Table of Milk Production for Experiment I

Source	d.f.	Sum of Squares	Mean Square	F.	$F_{.01}$
Total	47				
Treatments	1	471.25	471.25	11.79*	7.21
Error	46	1838.53	39.97		

*Significantly different ($P < .01$).

Dry matter consumption was assumed to be 2.7 and 2.4 pounds per hundred pounds of body weight for the control and experimental cows, respectively, based on the data of Brown (34).

The control ration contained 12.5 percent crude protein and the experimental ration 10.0 percent crude protein on a dry matter basis as calculated from chemical analysis and estimated intakes.

The cows which received grain were given sufficient feed to exceed NRC requirements (Table 9) for total digestible nutrients, net energy, digestible protein, and total protein. The group which received no grain received an adequate

Table 9

Daily Nutrient Intake of Dairy Cows in Experiment I

	Control (Received Corn)					Experimental (Received No Corn)				
	Dry Matter Intake	TDN	NE	Protein Dig.	Protein Total	Dry Matter Intake	TDN	NE	Protein Dig.	Protein Total
	lb.	lb.	MCal	lb.	lb.	lb.	lb.	MCal	lb.	lb.
Corn Silage	17.02	11.84	12.6	.63	1.40	22.08	15.36	16.32	.86	1.82
Alfalfa Hay	4.42	2.55	2.4	.54	.75	4.42	2.55	2.5	.54	.75
High Mois. Corn	6.90	6.49	7.7	.53	.70					
55% Concentrates	.90	.63	.91	.47	.55					
Soybean Meal	.63	.55	.64	.29	.30					
Total Intake Per Cow Per Day	29.87	22.06	24.25	2.46	3.72	26.50	17.91	18.82	1.40	2.57
*Required, NRC		17.3	18.3	2.0	3.59		17.3	18.3	2.0	3.59

*Calculated NRC requirements to produce 30 pounds of 3.5 percent milk daily.

amount of energy; however, their protein intake was approximately 25 percent below the NRC requirement.

Theoretically if the 55 percent concentrate and soybean meal were left in the ration and the corn was omitted all calculated nutrients would have been supplied except total protein. This established the basis for designing Experiment II in which only the corn was removed from the ration and the soybean meal and 55 percent concentrate were left in the ration.

Experiment II

Before starting the experiment the previous weekly average production was 35.5 and 35.1 pounds of milk per cow per day for the control and experimental groups, respectively. Cows in the control group (fed corn) averaged eleven pounds more per head in body weight than those in the experimental group. Change in body weight was not significantly different between groups due to treatment (Table 10).

Table 10

Analysis of Variance of Change in Body Weight, Experiment II

Source	d.f.	Sum of Squares	Mean Square	F
Treatments	1	2005	2005	3.54 n.s.
Error	27	15263	565	
Total	28			

From the beginning to the end of the experiment both groups had a significant ($P < .10$) increase in body weight. The experimental group gained an average of 28 pounds as the control group gained 44 pounds but this difference was not significant.

Average daily milk production for the control and experimental groups throughout the length of the trial was 30.4 and 31.6 pounds, respectively (Table 11).

Table 11

Daily Milk Production for Control and Experimental Cows For Three Preliminary Weeks and Eight Weeks of Experiment II

Periods	Control Received Corn Milk Production	Experimental Received No Corn Milk Production
	lb.	lb.
Preliminary Weeks		
1	37.1	35.8
2	37.9	35.6
3	35.5	35.1
Experimental Weeks		
1	32.9	35.5
2	31.4	32.7
3	31.5	31.9
4	31.0	33.5
5	31.3	30.7
6	28.6	29.7
7	28.1	29.2
8	28.5	29.4
Average	30.4	31.6

The difference in milk production between the two groups during the 8 weeks was not significant (Table 12).

Table 12

Analysis of Variance in Milk Production for Experiment II

Source	d.f.	Sum of Squares	Mean Square	F	
Treatments	1	31	31	1.402	N.S.
Period	7	1016	145.1	7.262	
T x P	7	84	12.0	.600	
Cows Per Treatment	28	619	22.1	1.106	
Error	186	3716	19.97		
Total	229	5466			

Current NRC nutritional standards for protein appear to be higher than required. Total protein intake of the control group was 0.37 pounds below the calculated need or 91 percent of the NRC allowance as indicated in Table 13. Digestible protein, however, was in excess. Part of this discrepancy may be due to erroneous assumption in the calculation of digestible protein.

The calculated protein intake of the experimental group was 0.83 pounds less than the NRC allowance. This represents 79.3 percent of the NRC allowance as shown in Table 13.

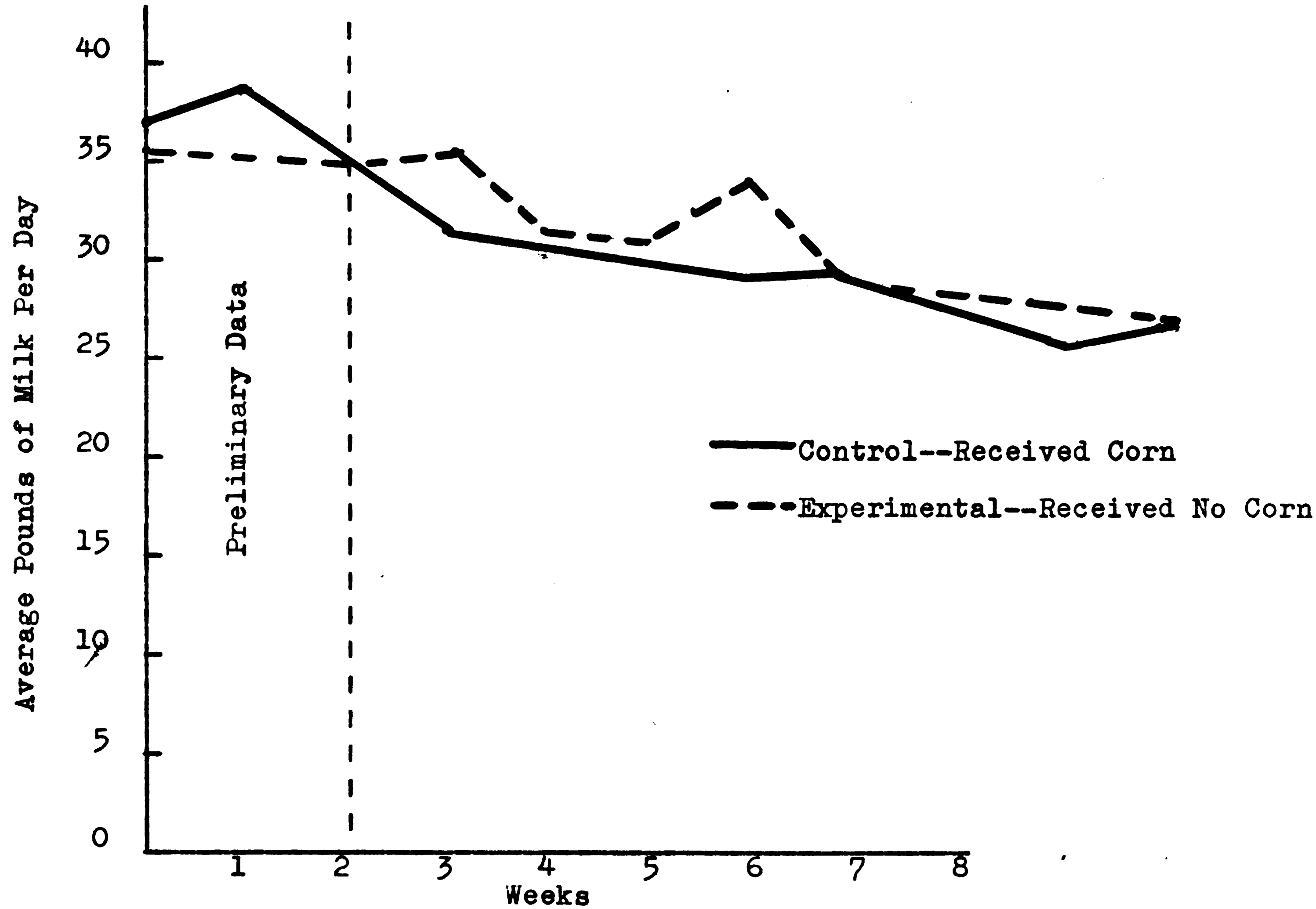

Figure IV--Average Pounds of Milk Per Day for Cows on Experiment II.
(Milk weighed one day weekly).

Table 13

Daily Nutrient Intake of Dairy Cows in Experiment II

	Control (Received Corn)					Experimental (Received No Corn)				
	Dry Matter Intake	TDN	NE	Protein Dig.	Protein Total	Dry Matter Intake	TDN	NE	Protein Dig.	Protein Total
	lb.	lb.	MCal	lb.	lb.	lb.	lb.	MCal	lb.	lb.
Corn Silage	17.22	12.0	12.8	.62	1.29	23.67	16.5	17.6	.84	1.78
Alfalfa Hay	4.28	2.5	2.4	.64	.90	4.28	2.5	2.4	.64	.90
High Mois. Corn	9.95	9.4	11.2	.66	.95					
55% Concentrates	.45	.3	.46	.23	.28	.45	.3	.46	.23	.28
Soybean Meal	.45	.4	.46	.21	.23	.45	.4	.46	.21	.23
Total Intake Per Cow Per Day	32.35	24.6	27.32	2.36	3.65	28.85	19.7	20.92	1.92	3.19
Required, NRC		20.4	20.5	2.29	4.02		20.4	20.5	2.29	4.02

It can be concluded that the amount of protein supplied, according to recommendations, was marginal. The control ration contained 11.3 percent crude protein and the experimental ration 11.0 percent on a dry matter basis.

The experimental group was fed essentially the same as the control group except that 14 pounds of high moisture corn was omitted from the ration. This did not produce any significant difference in milk production or change in body weight, although the cows fed no corn tended to gain less weight. Protein intake was actually below the NRC allowance for the no corn group.

Huber et al (90) and Lassiter et al (112) found that low protein rations can give a reduction in milk flow. Apparently the protein content of rations fed in this experiment was not sufficiently low to depress milk production or elicit a difference in response.

The cost of the two rations differed by 13 cents per cow daily as shown in Table 14. The experimental lot which received no corn produced an equal amount of milk at a lower cost with an increased net return of 21 cents per cow per day (Table 15, Figures IV & V). Theoretically, if 50 cows in late lactation were fed the ration without corn for 3 months, the extra income over feed costs would be $945.

During the next lactation, when all cows received normal herd treatment, milk and fat production

Table 14

Average Daily Intake and Feed Costs for Cows on Experiment II

		Control Corn		Experimental No Corn	
	Cost/lb.	Amount Fed	Total Costs	Amount Fed	Total Costs
	cents	lb.	cents	lb.	cents
Corn Silage	0.5	40	20.0	55	27.5
Alfalfa Hay	1.5	5	7.5	5	7.5
High Moisture Corn	2.0	14	28.0	--	---
55% Concentrates	6.0	.5	3.0	.5	3.0
Soybean Meal	5.0	.5	2.5	.5	2.5
Total		60.0	61.0	61.0	40.5

Table 15

Average Gross Income and Gross Income Minus Feed Cost for Cows on Experiment II

Control Received Grain				Experimental Received No Grain			
Milk Per Cow Daily	Gross Income	Feed Costs	Income Minus Feed Costs	Milk Per Cow Daily	Gross Income	Feed Costs	Income Minus Feed Costs
lb.	$	$	$	lb.	$	$	$
30.4	1.74	.61	1.13	31.6	1.82	.48	1.34

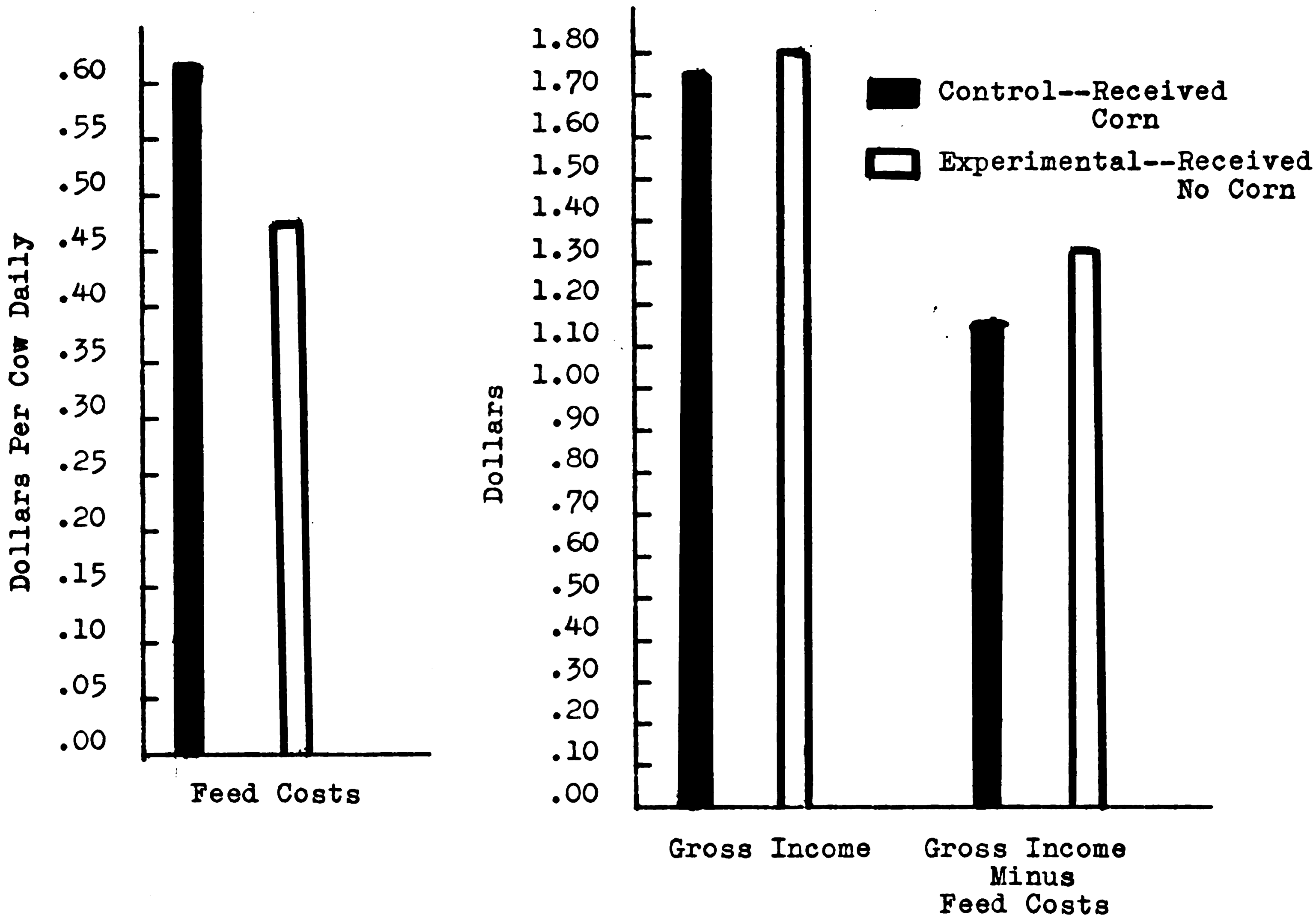

Figure V--Average Daily Feed Costs, Gross Income, and Gross Income Minus Feed Costs for Cows on Experiment II records were not completed to determine the effect of feeding high corn compared to no corn during the last two months of the previous lactation.

Investigation into these records revealed that 11 of 15 cows in the control group (fed corn) were removed from the herd before completing the next lactation. In contrast only two cows in the experimental group (fed no corn during late lactation) had been removed from the herd at the time the records were inspected 13 months after completing the experiment.

The reasons for this difference in rate of removal from the herd are unknown and may or may not be related to the level of feeding during the previous lactation.

SUMMARY AND CONCLUSIONS

Two experiments were conducted to determine the effects of varying the protein and energy intake of dairy cows during late lactation in the Andrews University Dairy herd.

Data from Experiment I indicate that feeding corn silage ad libitum and 5.0 pounds of average quality alfalfa hay was not sufficient to maintain normal production of cows producing 30 pounds of milk daily. The calculated intake of both energy and protein exceeded NRC recommended allowances by 10 to 13 percent in the control group, whereas energy was equal but protein intake was approximately 25 percent less than NRC recommended allowances in the experimental group fed no concentrates or protein supplement. At the end of the fourth week the experimental group produced 9.4 pounds less milk per cow daily than controls. This resulted in a loss of 30 cents per cow daily in gross income minus feed cost.

In Experiment II removal of 14.0 pounds of high moisture shelled corn from the ration of cows producing 35 to 37 pounds of milk daily and fed corn silage ad libitum, 5.0 pounds of alfalfa, and 0.5 pound of supplemental protein, resulted in no significant difference in milk production or body weight. Calculated intake of energy was 33 percent higher and protein 9 percent lower than NRC allowances in the control group, whereas energy intake was equal to NRC but protein intake 21 percent less than NRC recommended allowances in the experimental group. All cows followed a normal lactation curve and gained weight in this experiment. Removing the corn from the ration increased income above feed cost 21 cents per cow daily based on observed milk production, feed intake assumptions, and prices under practical farm conditions.

These results indicate that feeding 9 to 21 percent less protein than the NRC standards had no effect on performance; but feeding 25 percent less protein than these allowances in late lactation significantly reduced milk production. A ration containing 11 percent crude protein on a dry matter basis was adequate to maintain normal milk production of cows producing 35 pounds per day whereas 10 percent crude protein was too low under the conditions of this experiment.

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