FATS AND PROTEINS RESEARCH FOUNDATION, INC.

Director's Digest

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FAT IN DAIRY COW RATIONS

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INTRODUCTION

The early lactation or high producing dairy cow is normally in a negative state of energy balance. Energy intake is controlled by the amount of feed a cow consumes and by the energy density of that ration. Since the amount of feed a cow can consume is limited, the only realistic method of increasing energy intake is by increasing the energy density of the diet. Increasing the grain portion of the diet will increase the energy density. However, increasing the concentrate portion of the ration to levels above 55-60% often results in problems such as off-feed, acidosis, founder, and depressed milk butterfat levels. In addition to increasing the energy density of the ration, energy from fat is used more efficiently for milkfat synthesis than energy carbohydrate sources. (12, 13). This increase in energetic efficiency is due to the combined effect of direct incorporation on long chain fatty acids into the milkfat and the decreased metabolism requirements when fat is used as an energy source. (10). Fat, which contains from 2.25 to 2.5 times the energy of cereal grains, offers the potential to increase energy density in the ration while maintaining adequate fiber levels for adequate rumen function. One pound of fat can replace 3 to 3 1/2 lbs. of grain on a net energy basis and supply the energy to produce 7 lbs. of milk.

Cows of high milk production potential often do not achieve their maximum potential in early lactation. Maximum peak is important because each daily pound increase in peak yield may be expected to increase total lactation yield by 200 lbs. In many cases, failure to achieve potential may be explained by inadequate absorbed protein to utilize fat mobilized from adipose stores. Cows are increasingly fed supplemental fat to accelerate return to positive energy balance in early lactation, to increase peak yield and to improve persistency of lactation. Often cows in early lactation have delayed response to the supplemental fat and some scientists believe this condition is influenced by the improper relationship of undegradable protein intake and the supplemental fat.

If the diet does not provide sufficient nutrients, the energy demands of lactation force the animal to burn body fat, with weight losses of one kilogram a day common during the first one hundred days of lactation. If energy needs are not met, milk yields and fat tests will drop, ketosis may develop, and reproductive performance may decline.

Researchers at Ohio State observed the following benefits from adding fat to the diet: (1) an increase in milk yield of 5 to 8 per cent, (2) enhanced ability to meet energy needs while maintaining optimum levels of starch and fiber in the ration, and (3) greater metabolic efficiency (less energy needed to incorporate dietary fat directly into milk fat than if the cow synthesized fat from other feed sources).

DIGESTION AND ABSORPTION OF LIPIDS IN RUMINANTS

Cellulose and carbohydrates are converted to short chain fatty acids by microbial fermentation. The principle fatty acids in descending order of amounts are acetic, propionic, butyric, isobutyric, valeric, isovaleic, and traces of other various higher acids. The three major short chain fatty acids (acetic, propionic and butyric) are absorbed from the rumen and used as energy sources in the animal. Butyric acid is extensively (50%) converted to beta-hydroxbutyrate and some propionic acid is converted to lactate by rumen epithelium. (9, 10).

Lipid materials entering the rumen undergo two major processes, lipolysis and hydrogenation. The net result of these processes on esterfied dietary lipids (galactolipids, phospholipids, tri, di and monoglycerides) is the release of glycerol and free fatty acids (unesterified) and the hydrogenation or saturation of most free fatty acids with hydrogen ions. Hydrogenation of unsaturated fatty acids is conducted by certain bacteria with stearic acid (18:0) the predominant end product. During the hydrogenation process, the position of double bonds in unsaturated fatty acids are altered and converted to the more stable trans form rather than cis. Since trans fatty acids are hydrogenated with more difficulty than cis some intermediate trans unsaturated fatty acids accumulate in the rumen, particularly the 18:1 trans-11 acids. These acids are involved in low milk fat syndrome. The long chain fatty acids (16 carbons or greater) are not soluble in rumen fluid but pass from the rumen attached to bacteria and feed particles.(10).

Seventy to eighty percent of the fatty acids entering the small intestine are unesterified and more saturated than those in the diet. Soaps (potassium, calcium and magnesium) of fatty acids are commonly found in the digesta entering the small intestine but the low pH of the proximal duodenum helps solubilize the soap complexes. The secretions of pancreatic lipase and bile lecithin into the small intestine hydrolyze any rumen bypassed triglycerides and help stabilize lipid particles for micelle formation. The micelles containing long chain fatty acids are absorbed through the intestinal wall where conversion into triglycerides for transport via the lymphatic system occurs. (9, 10).

MILK FAT SYNTHESIS

Milk fat is almost entirely in the form of triglycerides (97%). The fatty acids found in milk normally come from either of two sources: (10) de novo synthesis within the mammary gland from acetic acid or B-hydroxybutyrate, or (17) direct uptake of blood triglycerides by the mammary gland. Short chain fatty acids (4 to 16 carbons) are normally derived from de novo synthesis. Blood triglycerides are the normal source of the long chain fatty acids (16 carbon or greater) found in milk. Normally, about 50% of the milk fatty acids are derived from de novo synthesis, 40 to 45% from blood triglyceride resulting from dietary fat intake and less than 10% from breakdown of body adipose tissue. Comprehensive reviews of milk fat synthesis have been conducted (9,19).

Generally, feeding or management practices which favor high propionic:acetic acid rations (low fiber/high carbohydrate, etc.) tend to depress milk fat percentage (2). Feeding of unsaturated oils also tends to depress milk fat due to lowered fiber digestibility in the rumen. (9).

Fat may be used with great efficiency by the lactating cow as an energy source and as a precursor for milkfat synthesis. Fat addition is normally limited to no more than 5% of ration dry matter because of the depressing effect of fat on fiber digestion and interference with normal rumen microbial activity. With this added fat level, typical dairy rations will contain from 5 to 8% total fat. However, it has been shown that the mammary system becomes most efficient when 15 to 20% of the metabolizable energy is supplied by dietary long chain fatty acids. (4, 5, 12). A total of from 8 to 10% dietary fat is necessary to achieve this optimal level of metabolizable energy from long chain fatty acids.

As mentioned earlier, dietary fat may also reduce the incidence of ketosis. Ketosis is described as the presence of excessive amounts of ketone bodies (usually acetone) in the blood resulting from the incomplete metabolism of fatty acids resulting from breakdown of body adipose tissue by the cow to supply the additional energy requirements of the high producing dairy cow. Dietary long chain fatty acids absorbed from the intestine and used as an energy source are not ketogenic. (14).

ENERGY AND REPRODUCTION IN DAIRY COWS

One of the major losses experienced by dairy producers is the early culling of their best cows due to breeding difficulties. Feeding energy deficient diets after parturition is one factor that plays a role in this problem.

Parturition is accompanied by changes in lipid, carbohydrate, protein and mineral metabolism to provide nutrients for milk synthesis (3, Table 1). The intense postpartum drive for milk secretion has a higher metabolic priority than reproduction (18). Consequently, uterine involution, return to cyclic sexual functions, conception and early embryonic development may be impaired during the early stages of the lactation cycle to adversely affect reproductive efficiency. (8).

In the past 25 years, milk production of cows in the U.S. has increased at the rate of about 200 lbs/yr. During this period fertility has decreased. This has lead to the preposition that high levels of milk production decreases fertility. (8). Chalupa proposes that milk production per se is not the primary cause of reduced fertility. It is caused by feeding strategies that do not provide sufficient nutrients for high yields of milk, thus causing the cow to draw on reserves of body nutrients, or by feeding strategies designed to maximize production which may have negative impacts on reproduction. (8). Intake requirements for maintenance and production, and balances of energy for a 650 kg cow producing 20,000 lbs. of 3.5% FCM in 305 days of lactation are in Figure 1. During the first 12 weeks of lactation, net energy for maintenance and milk production exceeds net energy intake from feed to cause body weight loss and results in negative balances of energy. In the well fed cow, however, negative balances of energy begin to decrease at about week 4 of lactation. (8).

First ovulation usually occurs at 17 to 42 days after parturition (6). While days to first ovulation are related to milk yield, stronger correlations are found with average energy balance (cumulative daily calculated energy balance divided by days in milk) during the early postpartum period (6, Figure 2). As shown in Figure 2, each Mcal of daily negative energy balance during the first 20 days of lactation increased time to first ovulation by 2.7 days.

The amount of energy needed in rations is determined by requirements and feed intake. So that fiber concentrations are not compromised, rations to support more than 35 kg/d milk need to contain supplemental fat. Palmquist of Ohio State suggests that the upper limit of dietary fat is equivalent to the amount of fat in milk (i.e., 88 lb/d milk with 3.5% fat = 3 lbs. dietary fat). In a high producing cow about 5-8 percent fat in the ration dry matter should produce optimum results.

EFFECT OF MULTIPLE ENERGY SOURCES ON PERFORMANCE OF PRIMIPAROUS HOLSTEIN CATTLE

Currently, primiparous (first calf) cows in many dairy herds are consistently demonstrating extremely high milk production capabilitieis (>22,000 lbs/ lactation). Beyond excellent genetics on these farms three common management practices exist. 1) Heifers are large, weighing 1350-1450 lbs. at calving. 2) Heifers carry some visible adipose at parturition. 3) Heifers are fed extremely energy-dense diets postpartum. These management practices are in contrast to traditional research concepts and Extension recommendations. Research trials have not examined the effects in increasing adipose tissue post puberty and allowing primiparous cattle to utilize that deposition postpartum. This concept has been extremely effective in body condition management schemes on multiparous cows. Similarly, field observations by dairymen indicate beneficial effects of supplemental fat on lactation performance of primiparous cows.

Approximatly 35% of dairy cattle lactations are from primiparous cows. These cattle thus represent a large fraction of the total U.S. milk production. Research efforts to define nutrient requirements of primiparous dairy cattle are extremely disproportionate to their importance. Dairymen generally manage primiparous cows under a multiparous model. This is regrettable as primiparous cows are known to respond differently than multiparous cows to many dietary manipulations.

As an example, primiparous cows respond marginally to feeding schemes such as undegradable protein or dietary incorporation of branched-chained volatile fatty acids, etc., which are generally effective in multiparous animals. Reasons for this lack of response likely centers on the distinctly different early prepartum phase of the primiparous cow versus the multiparous cow. This transitional horizon (primiparous) includes not only lactation metabolism but body growth and secretory gland maturation. Therefore, feeding strategies designed for the early lactation multiparous cow may have limitations due to the distinctly different physiology in the early lactation primiparous cow.

Two logical strategies exist to improve performance of the primiparous cow during the postpartum transitional period. First is to assure that maximum 24 month skeletal growth has taken place before parturition. This should reduce nutrient partitioning towards growth postpartum and might be accomplished by increasing the nutrient plane of the gestating heifer to the point of adipose deposition. While a crude indicator of maximum skeletal growth, little other applied technology exists. Secondly, to implement feeding strategies that are not totally dependent or responsive just in early lactation. Supplemental fat is a logical strategic approach as current evidence suggests lactation responses at all stages of lactation. Thus, the Fats and Proteins Research Foundation plans to conduct research to determine the need to incorporate pre- and postpartum management schemes and examine possible interactions to more fully understand the nutritional dynamics of the primiparous cow in the transitional horizon.

Short and long term benefits of this type of research would be three-fold. First, to clarify time and degree of lactational response to supplemental fat in primiparous cows and make management and marketing information available to the dairyman and feed industry respectively. Secondly, we will examine a large number of primiparous cattle under intensive nutritional management to determine if dietary energy is a limiting factor in early lactation primiparous cows. This information is needed to set future research directions and to assist industry in helping clientele understand nutritional dynamics of 2 year old cattle. Third, establish optimum nutrition management practices for the gestating heifer. At minimum this may help alleviate current growth deficiencies.

NUTRITION AND MANAGEMENT OF THE HEAT-STRESSED COW

Heat-stress has a major impact on the economic productivity of dairy farms in the Southeastern and Southwestern United States for five to six months of the year and three to four months in the Middlewest. When the thermoneutral zone of a cow (comfort zone) is exceeded (upper critical temperature), physiologic reponses occur in an attempt to maintain the cow's comfort. Feed consumption declines, water intake increases, body temperature usually rises, and respiratory rate increases. Some of these effects are antagonistic to milk production and must be overcome to sustein high production in the summer. Unfortunately, the problem becomes more severe as the production of the cow increases. Thermal stress is more severe in early lactation among cows in high production, and an increase of 1.8°F or less in body temperature may reduce animal performance (McDowell, 1972). Thus, continued improvement in genetic capability of the cow and new technologies which stimulate greater production will further accentuate the need for methods to minimize heat stress and maintain feed consumption.

One of the first physiological responses to heat stress is a voluntary decrease in intake in an attempt to reduce the heat generated during ruminal fermentation and tissue metabolism. As a result of the depressed intake, subsequent decreases in energy intake and productivity, especially milk yield are usually observed.

An obvious solution to reducing dietary energy consumption is to increase feed intake, a difficult task because of high environmental temperature. The next most logical step is to increase the energy density of the diet. This may be accomplished through the use of fat or oil products, which have a high energy content. An added benefit from using fat products is the lower heat increment of fat. Digestion of fat creates very little metabolic heat because it is absorbed and used directly for energy or milk fat. As a result, feeding fat has the potential to improve the efficiency of energy utilization and lower body temperature of heat-stressed cows.

Feed additives such as supplemental fat increase the cost of dairy rations. Profitable use of additives depends in part on the identification of conditions which maximize the likelihood of a favorable response. Recent data indicates that cows respond more favorably to dietary fat supplementation during warm temperatures than during cool temperatures and when there is a proper relationship of undegradable protein intake with the supplemental fat.

FAT AND PROTEIN LEVELS AND RELATIONSHIP IN HIGH PRODUCING DAIRY CATTLE

Most forages contain 2-3 percent ether extract, which is eighty percent fat. Grains' lipid content will range from 1 1/2 to 4%, therefore most conventional lactating dairy cow diets contain no more than 2 1/2 to 3% crude fat. To feed a 5-6% fat ration, the diet will have to contain approximately 3 lbs. of fat.

About one-third (1 lb.) of dietary fat will come from common feed ration ingredients. Another third (1 lb) can come from whole oil seeds and the remaining third from animal fat.

Suggested feeding levels for oilseed supplements are listed below:

Raw Soybeans	- 3 to 5 lbs per cow per day
Heat-treated Soybeans	- 4 to 6 lbs per cow per day
Whole Cottonseed	- 5 to 7 lbs per cow per day
Sunflower Seed	- 2 to 3 lbs per cow per day
Rapeseed	- 2 to 3 lbs per cow per day

Many dairy consultants in Wisconsin and Minnesota recommend feeding whole oilseeds, when they are economically feasible, but 2 lbs of animal fat when the oilseeds are not cost effective. To reach the 8% fat content of ration dry matter, it would be necessary to feed an additional 1 lb. of fat. This fat source should be fed in the form of ruminally inert fats (i.e., Booster Fat, Megalac, Energy Booster, Allifat). It is suggested that when feeding the very good cows (100 lbs. milk, 3.5% BF) that the fat content of their ration (dry matter content) not exceed 8% which equates to approximately 4 pounds of fat per head per day.

We have known for some time that a fraction of the crude protein (CP) in feeds is degraded by rumen microbes to peptides, amino acids and ammonia with the remainder escaping microbial degradation. Non-protein nitrogen (NPN) and degraded intake protein can then be assimilated into microbial protein which can flow to the small intestine for digestion and utilization by the ruminant. The amount of microbial protein synthesized depends on the amount of non-protein nitrogen (NPN) and degradable protein consumed by the animal and on the amount of energy (fermentable carbohydrate) available to the microbes. Microbial protein production is important to the ruminant because it is an excellent source of high quality protein. Even under the most optimal conditions however, microbial protein production will not supply enough protein to meet the needs of the high producing dairy cow in early lactation. Research and on farm experiences have generally indicated positive results from feeding high producing cows protein sources that are resistant to degradation in the rumen. Although a popular concept, we have not had a protein system that recognized protein degradabilty until recently. The Dairy NRC Update (1989) includes undegradable intake protein (UIP) and degradable intake protein (DIP) recommendations for dairy cows. In theory, the new protein system provides a framework for deciding when or when not to consider bypass protein and how best to utilize NPN in diets for lactating dairy cattle. As mentioned earlier, strategic use of protein supplements that escape rumen fermentation can best be determined if diets are designed to maximize microbial growth and protein synthesis. The supplement selected should be of high quality and complement microbial protein in supplying amino acids to the small intestine. Meat and bone meal, blood meal and hydrolyzed feather meal are examples of protein ingredients that contain high concentrations of high quality undegradable proteins and can be easily formulated into diets of high producing cows in early lactation.

Because ruminal microbes do not use fat as a source of energy for growth, diets that contain more than 3% fat should contain more undegraded intake protein (UIP) than calculated from NRC (15, 16). Chalupa (8) recommends providing an additional 72g UIP per Mcal net energy from fat above 3% of the diet. Some nutritionists suggest that high producing dairy cattle diets, with supplemental fat, should contain at least 35 to 40% of UIP, depending on genetic milk production potential of cows. Other dairy consultants suggest increasing the UIP percentage in the ration by 1% for each 2 percent of added fat to the ration dry matter. Dr. Richard Zinn of the University of California suggests maintaining the undegradable ruminal intake protein:caloric ratio when adding fat to cattle rations. Most conventional rations will contain .14 grams of undegradable intake protein (UIP) per gram of fat. When adding fat to dairy rations maintain this same .14 grams UIP to 1 gram of fat ratio. Meat and bone meal is being successfully formulated in total mixed ration at 1 to 2 lbs. per head per day in large dairy operations in the upper Midwest of the United States.

TYPES OF FAT

Both animal fats and vegetable oils contain fatty acids and are comparable in energy value, but they differ in composition, affecting how the body is able to use the energy. Animal fats such as tallow contain relatively large amounts of saturated fatty acids that are more efficiently used by dairy cattle than are unsaturated fats. Vegetable oils such as soy and corn contain unsaturated fatty acids that are toxic to the rumen organisms and can alter the production of volatile fatty acids (VFA) in the rumen and decrease fiber digestibility, which can lower fat test and feed utilization. (17).

Stabilized animal tallow with a maximum unsaturated/saturated fatty acid ratio of 1.5 to 1 is recommended when the supplemental fat is fed to corn based diets. If milo, barley or other low fat grains are the predominant starch source utilized in a total mixed ration, than any type of stabilized feed grade animal fat, blended animal fat or hydrolyzed animal-vegetable blends can be fed successfully. (11).

MANAGEMENT CONSIDERATIONS

1. The fat content of the ration dry matter should not exceed 8%. Six percent of the fat in the ration dry matter can be supplied by the fat in the forage and grains (2%), whole oil seeds (2%) and stabilized animal tallow (2%). Where oil seeds are not economically available, some nutritionists are utilizing up to three percent liquid animal tallow in total mixed rations. Any supplemental fat above 5 to 6% of the ration dry matter should be fed in the form of ruminally inert fats.

2. Feed adequate amounts of fiber to maintain rumen digestion. 21% Acid Detergent Fiber, 17% Crude Fiber and 28-30% Neutral Detergent Fiber.

3. Maintain higher levels of calcium, 0.9 to 1.0 percent and magnesium, 0.25 to 0.30 percent, in the total ration dry matter because they can form soaplike products with the fat, thus lowering their availability as nutrients.

4. Increase the Undegraded Intact Protein (UIP) as recommended previously.

5. Gradually increase the fat in the ration, allowing 2 to 3 weeks to reach recommended levels. To avoid a decline in milk production, remove the fat gradually because abrupt withdrawal can alter feed acceptability.

6. A properly balanced ration is essential for supplemental fat to be effective, so consult your feed supplier or dairy consultant for assistance when adding fat to diets of high producing dairy cattle.

7. ENERGY VALUES OF SELECTED FEEDSTUFFS FROM 1988 NRC Nutrient Requirements Of Dairy Cattle:

	Growing Dairy Cattle Net Energy Maintenance NEM Mcal/lb	Net Energy Growth NEG Mcal/lb
FATS AND OILS	2.65	2.65
Alfalfa Hay Sun Cured Early Bloom	.60	.34
Blood Meal	.69	.42
Corn Dent Yellow	.88	.59
Cottonseeds w/lint	1.10	.77
Meat and Bone Meal	.76	.48
Soybean Meal Sol. Ext.	.94	.64
Soybean Seeds	1.03	.71

	Lactating Cows Net Energy Lactation NEL Mcal/lb	TDN %
FATS AND OILS	2.65	177
Alfalfa Hay Sun Cured Early Bloom	.61	60
Blood Meal	.68	66
Corn Dent Yellow	.84	80
Cottonseeds w/lint	1.01	96
Meat and Bone Meal	.74	71
Soybean Meal Sol. Ext.	.88	84
Soybean Seeds	.96	91

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Table 1. Metabolic changes associated with lactogenesis in ruminants (5).

Physiological Function	Metabolic Change	Tissues Involved
Milk synthesis	Increased use of nutrients	Mammary
Lipid metabolism	Increased lipolysis Decreased lipogenesis	Adipose
Glucose metabolism	Increased gluconeogenesis Increased glycogenolysis	Liver
	Decreased use of glucose Increased use of lipid	Body tissues (general)
Protein metabolism	Use of protein reserves	Muscle
Mineral metabolism	Increased absorption and mobilization of Ca	KIdney, liver gut, bone

1. Bauman and Currie (5)

FIGURE 1

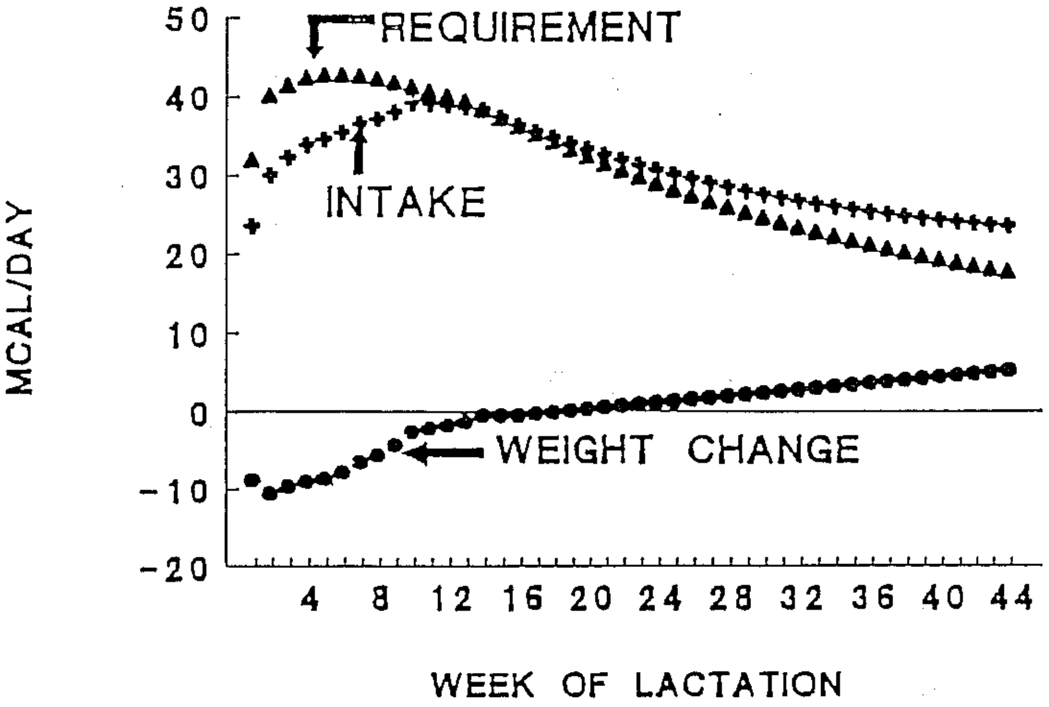

FIGURE 2