THE BENEFITS AND LIMITATIONS OF FAT IN DAIRY RATIONS

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Increase Ration Energy Density While Maintaining Fiber Intake

The onset of lactation induces dramatic physiological changes in high-producing dairy cows. Shifts in endocrine status poise the cow to redirect body energy stores to the mammary gland, thus supporting high milk production at the expense of body tissue (Bauman and Currie, 1980). Increased incidence of metabolic disorders and poor reproductive performance can occur from inadequate energy intake during early lactation (Grummer and Carroll, 1991).

To counter this problem, cereal grains replaced forages in dairy rations over the last thirty to forty years to increase energy density and milk production (Coppock et al., 1981). However, to avoid metabolic stresses associated with low fiber diets, like ruminal acidosis, fat has been replacing grain in recent years. Palmquist and Conrad (1980) evaluated two fat-feeding strategies for increasing energy density of lactation rations while maintaining fiber intake. One approach was to substitute fat for grain on an equal energy basis which held energy intake constant, but increased ration ADF from 15.3 to 19.5%. The second strategy was substituting fat for corn on a weight basis, which increased ration NE_L from 1.8 to 2.0 Mcal/kg and only slightly increased ADF (15.3 to 16.2%). The latter approach is used more often since it has the potential of increasing milk yield without further risk of digestive disorders or depressed milk fat. Milk yield increases of 1 to 3 kg/day from added fat have been achieved in many lactation trials.

The energy value of fat supplements is determined almost exclusively by the type and amount of fatty acid present in the supplement. Most fat supplements are comprised of different proportions of 5-8 common fatty acids, all of which have similar energy values (approximately 9.4 kcal/g). Therefore, fatty acid content (g fatty acid/100 g fat supplement) is much more important than fatty acid composition (g fatty acid/100 g total fatty acids) in determining GE value of the supplement.

Fatty acid content of fat supplements can be diluted by nonfatty acid components that have lower energy or perhaps no energy value. Fat content has traditionally been determined as the ether-extractable component of the feed. When defined in this manner, there can be considerable variation in fatty acid content among feed fats. Among the lowest is the ether extract in grains and forages. In addition to extracting fat, ether also extracts some carbohydrate, vitamins, and pigments. Therefore, fatty acids in corn grain are only 65% of the ether extract, and in alfalfa hay are only 40% of the ether extract (Palmquist and Jenkins, 1980). Because of the problems inherent with ether extract, many laboratories have moved to determining fatty acid content of feeds instead of ether extract.

With only a few exceptions, most fat supplements used in dairy rations contain a high percentage (usually 90 to 100%) of fatty acids. The impurities extracted from animal or plant tissue, such as water and pigments, are removed during refining leaving the commercial plant (soybean oil, canola oil, corn oil, etc.) and animal (tallow, grease, etc.) fats with mainly triglycerides consisting of 90-93% fatty acids. The remaining 7-10% is referred to as unsaponifiables and is mainly glycerol. Glycerol is readily utilized as an energy source, but only contains the energy of carbohydrates. Caution is advised when obtaining fats from unknown vendors to be sure that considerable impurities do not still remain in the product that lower the fatty acid and energy content. Rather than guessing, it pays to have a sample of the fat analyzed for fatty acid content and profile.

Alleviate Heat Stress

Animals exposed to high temperature and humidity must make physiological adjustments that lower metabolic heat in order to offset increased heat gain from the environment (Fuquay, 1981). Reductions in feed intake and exercise are both important animal responses for achieving lower metabolic heat. Along with reduced energy intake, energy for production may be further lessened by increased maintenance requirements attributable to enhanced tissue metabolism at elevated body temperatures, as well as additional energy expenditure to increase heat dissipation (Morrison, 1983).

Environmental modifications such as providing shade, evaporative cooling, and increased air movement are used routinely to alleviate heat stress in cows. Metabolic heat can be reduced by formulating rations with feed ingredients that have lower heat losses from alimentary tract fermentation and tissue metabolism (Beede and Collier, 1986). Fat is especially useful for reducing metabolic heat since it undergoes little catabolism in the rumen (Wood et al., 1963; Wu and Palmquist, 1991), and has a high efficiency of ME utilization in ruminants (Garrett, 1980).

The value of fat supplements in alleviating heat stress during animal trials has been inconsistent. A lactation study conducted by Skaar et al. (1989) showed increased milk yield from fat supplementation during summer but not during winter months. However, a number of other studies concluded that feeding fat had similar benefits on milk production whether fed in hot or cold conditions (McDowell et al., 1964; Moody et al., 1967; Knapp and Grummer, 1991).

Fat is limited in ruminant diets to relatively low levels to prevent problems with ruminal fermentation. Only a small savings in metabolic heat can be expected from low levels of fat supplementation. Andrew et al. (1991) found no change in heat production by lactating cows when 2.95% fat was added to the diet. Using data from their study, the theoretical maximum reduction in heat production from 5% added fat was calculated, assuming 100% retention of fat ME (i.e., no heat increment loss from fat). This amount of added fat only reduced heat production from 30.5 to 27.5 Mcal/day or 9.8%. The actual reduction in heat loss from 5% added fat will be less considering that retention of fat ME was less than 80% when determined in animal trials (Andrew et al., 1991).

Improve Reproductive Performance

In a few studies, feeding fat to lactating dairy cows has improved reproductive performance, implying alleviation of stress and possible benefits on lifetime production potential. Reported improvements of reproductive performance from added fat include: higher conception rates (Schneider et al., 1988; Sklan et al., 1989; Ferguson et al., 1990), increased pregnancy rates (Schneider et al., 1988; Sklan et al., 1991), and reduced open days (Sklan et al., 1991). However, supplemental fat has had little or no benefit on reproductive efficiency in other studies (Carroll et al., 1990; Schingoethe and Casper, 1991).

The mechanism of how fat supplements alter reproductive performance is not clear. Fat may function in one capacity by providing additional energy during early lactation to support improved productive functions, including reproduction. Negative energy balance delays ovulation and the initiation of the first normal luteal phase (Butler et al., 1981). However, recent studies also suggest that the mechanism involves an energy independent response to fat.

When an equal quantity of energy from glucose, saturated animal fat (tallow), or unsaturated fat (yellow grease) were infused into lactating dairy cows via the abomasum, the fat but not carbohydrate decreased plasma estradiol and increased progesterone (Oldick et al., 1997). The study by Oldick et al. (1997) also demonstrated the potential to decrease $PGF_{2\alpha}$ synthesis by supplying elevated concentrations of polyunsaturated fatty acids (**PUFA**). These results were similar to previous reports that intravenous infusion of unsaturated fatty acids from a soy oil emulsion increased plasma $PGF_{2\alpha}$, and number and size of follicles (Lucy et al., 1990, 1991). Ovarian follicular growth was also stimulated more in Brahman x Hereford cattle by fat compared to equal energy from carbohydrate, with a greater effect observed for fats with higher PUFA (Thomas et al., 1997). Further support of the role of PUFA on reproductive function in ruminants was published by Hinckley et al. (1996). Dispersed bovine luteal cells had a dose-dependent decline in progesterone production and an increase in production of prostaglandin as PUFA in the media increased.

THE LIMITATIONS OF FAT IN DAIRY RATIONS

Considering the high energy value of feed fats and their high efficiencies of utilization, why is fat content of dairy rations limited to relatively low levels (less than 10%)? The answer, ironically, is that feeding high energy fat to ruminants can, in some cases, reduce the energy available for milk production. Adding fat will always increase energy density, or kcal per lb of feed, but will not necessarily increase total kcal NE_L for production. Total NE_L for production is reduced if the fat supplement reduces feed intake, interferes with feed digestion, or is poorly digested. As an illustration, a reasonable intake of digestible energy for cows consuming 38 lb/day (DM basis) of a typical lactation ration is 58 Mcal/day. If one lb of this ration is replaced with fat, intake of digestible energy increases to 60 Mcal/day if energy digestibility remains constant at 75% for both diets. However, fat only needs to reduce energy digestibility from 75 to 73% in this example and most of the energy benefit of the added fat is lost.

Fat Can Reduce Feed Digestibility

Feeding fat reduces fiber digestion by inhibiting microbial fermentation that occurs in the largest stomach compartment, or rumen, of the animal. Fiber also is a major energy source for milk production, provided that it is fermented by gut microorganisms to yield energy substrates that can be used by the mammary gland. If the ability of the microorganisms to ferment fiber is inhibited by fat, then fiber energy is lost in feces. This is illustrated by an experiment that infused 0, 13, 26, and 40 ml oil per day into the rumen of sheep resulting in fiber digestibilities in the rumen of 44, 28, 18 and 14%, respectively (Ikwuegbu and Sutton, 1982). The fiber digestibility depression in the whole digestive tract is often less severe due to some limited hindgut fermentation. Depression of fiber digestion is most severe for fat sources high in unsaturated fatty acids, which inhibit growth and function of ruminal microbes more than saturated fatty acids (Jenkins, 1993b). The exact mechanism of how fat interferes with microbial fermentation is not known, but believed to result from either coating of feed particles or a direct toxic effect on the ruminal microorganisms.

A useful way to categorize fat supplements for dairy rations is based on how they affect ruminal fermentation and fiber digestion. One group includes fats that were specifically designed to avoid digestibility problems, such as calcium salts of fatty acids and hydrogenated fats. These are available commercially and have the added advantage of being dry fats that are easily transported and mixed with other feed ingredients. This group is best referred to as *rumen-inert* fats to emphasize the fact that they have little, if any, negative effects on fiber digestion in the rumen.

The second group of fat supplements includes the unaltered extracts from plant and animal sources that can cause digestion problems in dairy cattle to varying degrees. Included in this group are fats of animal origin (tallow, grease, etc.), plant oils (soybean oil, canola oil, etc.), whole oilseeds (cottonseeds, soybeans, etc.), and high fat by-products, such as residues from food processing plants. These will be referred to as *unprotected* fats to identify their potential to cause significant problems with digestion in the rumen.

The distinction between the two groups is not always clear. At normal levels of supplementation, some unprotected fats, such as tallow, are fed to dairy cows without evidence of consistent problems with fiber digestion. Even whole oilseeds help to lessen the severity of digestion problems by encapsulation of antimicrobial fatty acids within their hard outer seed coat. However, classification according to ruminal digestion is better defined at high levels of supplementation, where the frequency of digestibility problems for tallow and oilseeds is much greater than for the rumen-inert fats.

Fatty Acids Can Be Poorly Digested

Another factor that can lower NE_L intake of fat-supplemented diets is poor fatty acid digestibility. Intestinal digestibility of fatty acids has been examined as a function of both level and source of fat added to the diet. There are reports that fatty acid digestibility is reduced at higher levels of fat feeding. According to Bauchart (1993), true fatty acid digestibility decreases progressively from 95 to 75% as fatty acid intake increases from 200 to 1400 g/day. Other studies report less severe declines in fatty acid digestibility with increasing intake (Palmquist, 1991). Within normal levels of fat added to dairy rations, fat source is probably more important than fat level in defining the NE_L value.

Reduced digestibility of fatty acids is generally attributable to the nature of its fatty acid composition. Under certain circumstances, digestibility can be lower for saturated fatty acids than for unsaturated fatty acids. Firkins and Eastridge (1994) showed that iodine values (**IV**) that were 50 or above had little effect on fatty acid digestibility. However, digestibility declined as IV declined below 50, especially as IV dropped from 27 to 11. To confirm this relationship, several digestibility studies with lactating cows were summarized to determine true fatty acid digestibilities for fats greater and less than 40 IV. True fatty acid digestibilities were determined from the slopes relating fatty acid digested to fatty acids consumed. At low fatty acid intakes, true fatty acid digestibilities were 89% and 74% for fats with IV >40 and <40, respectively. However, fatty acid digestibility declined more with increasing intake for fatty acids having IV >40.

Fats with low IV have increased in popularity because their high content of saturated fatty acids cause fewer problems with ruminal fermentation and digestion. However, fatty acid digestibility in the small intestine can be compromised if the fats become too hard. When yellow grease was fully hydrogenated, digestibility by lactating Holstein cows declined from 67.8 to 47.4% (Jenkins and Jenny, 1989). Partial hydrogenation of tallow also was shown to reduce fatty acid digestibility (Eastridge and Firkins, 1991). Among the saturated fatty acids, beneficial effects of higher C_{16}:C_{18} ratios were reported for fatty acid digestibility (Firkins and Eastridge, 1994). Similar observations were reported by Weisbjerg et al. (1992), where fatty acid digestibilities of a stearic acid-rich supplement were lower than a palmitic acid-rich supplement at two levels of intake.

Fat Can Reduce Feed Intake

Fat added to dairy rations can reduce feed intake, which can greatly reduce or even eliminate a positive milk response. Any boost in energy density of the ration from added fat does little to increase energy for milk if it is accompanied by reduced consumption of total feed. For instance, in a study by Jenkins and Jenny (1992), 5% added fat increased NE_L from 1.67 to 1.88 Mcal/kg for the control and 5% canola oil diets, respectively. Dry matter intake of the control diet was 18.8 kg/d or 31.4 Mcal NE_L. If cows fed the canola oil diet had also consumed 18.8 kg/day, then NE_L intake would have increased to 35.3 Mcal/d. Net energy intakes of the two diets, however, would be the same if intake of the canola oil diet was reduced to 16 kg/day. Actual intake of the canola oil diet was 18.2 kg/day meaning that canola oil increased NE_L intake by only 2.8 Mcal/day instead of the theoretical maximum of 3.9 Mcal/day.

Several causes for the depression in feed intake by added fat are under consideration. These include physiological mechanisms to maintain constant digestible energy intake, which is more prevalent for diets of high energy concentration; poor acceptability of the fat which may improve with adaptation; increased ruminal distention from lower fiber digestion; and a negative relationship between intestinal flow of unsaturated fatty acids and level of feed intake. Most likely, these work in combination rather than singly to reduce feed intake when certain fat sources are added to dairy rations.

Basal Ration Composition Can Affect Fat Limitations

Optimal forage in the basal ration has been recommended to enhance the benefits of added fat on milk yield and composition (Palmquist, 1984). Higher fiber had no advantage on yield responses when rumen-inert fat sources were supplemented (Canale et al., 1990; Klusmeyer et al., 1991). However, milk fat depression caused by the addition of 6% added grease to dairy rations was less when the basal diet contained higher fiber (Tackett et al., 1996).

Type of fiber also appears to influence yield responses to added fat. Smith et al. (1993) reported increased milk yield and FCM yield from cows fed whole cottonseed or tallow when alfalfa hay replaced corn silage in lactation rations, even when the fiber concentration was held constant. Those researchers (Smith et al., 1993) proposed that ruminal fermentation was inhibited more by fat supplements when they were added to rations based on corn silage than when they were added to rations based on alfalfa hay, perhaps because of greater accessibility of silage to coating effects of lipids.

Particle size of forage was evaluated in a recent study (Jenkins et al., 1998) to determine if it may explain why type of forage was reported in previous studies to alter lactation responses to added fat. The effects of tallow on milk yield and milk composition of Holstein cows were the same regardless of hay particle . size in the ration. However, there was a tendency for an interaction of tallow and hay particle size for FCM.

THE MILK RESPONSE TO ADDED FAT

Unfortunately, milk yield does not continually increase as higher amounts of fat are added to dairy rations. It sometimes even occurs that milk yield can decrease when fat is added to the ration. A model that explains this relationship is shown in Figure 1. As fat is increased in dairy rations, three significant changes in milk production occur. The first change, referred to as phase I, is a steady increase in milk production with increasing fat in the diet. In phase II milk production remains stable despite increasing fat concentrations in the diet, and in phase III milk yield declines with increasing dietary fat concentration. All fat sources conform to this model, but may differ in the amount of response in each phase and the fat levels corresponding to each phase. Fats with greater unsaturation would be expected to have a smaller phase I and phase II compared to saturated fats fed at the same level.

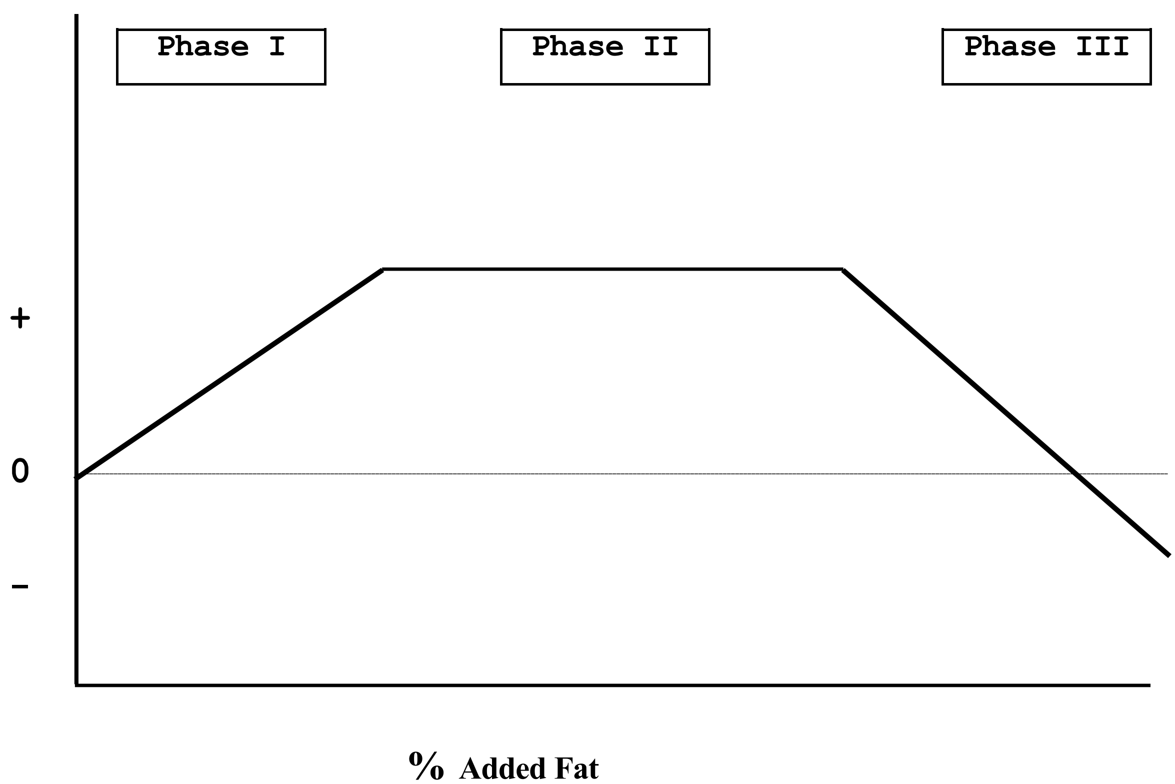

Figure 1: A hypothetical model describing changes in milk yield as fat content is increased in diets of lactating dairy cows. Compared to a control diet, the added fat can cause milk to increase (+), decrease (-), or stay the same (dotted line). It is proposed that milk initially increases with dietary fat (phase I) as energy density of the diet increases, then levels off and remains stable (phase II) as negative effects of the fat offset increased energy, and finally declines (phase III) as these negative effects exceed the increased energy.

Milk yield increases in phase I because of greater diet energy density from the added fat. The failure of milk yield to increase with increasing dietary fat in phase II is due to the additional fat energy being offset by negative effects of the fat supplement such as reduced digestibility of the diet, reduced feed intake, poor digestibility of the fat supplement, and perhaps negative metabolic effects. In phase III, these negative effects dominate over the increased energy supply, yielding an overall decrease in milk output. Therefore, the maximum milk increase realized by adding fat to dairy rations occurs at the point where phase I and phase II meet. Addition of fat above this level is not cost effective since it is not accompanied by a further increase in milk production.

The data of Clapperton and Steele (1983) illustrate how increasing levels of tallow in dairy rations fit the above model. They fed diets containing 0, 2.4, 3.8, 4.2, and 6.7% added tallow with milk yields of 20.67, 22.32, 22.01, 21.73, and 22.68 kg/day, respectively. Maximum milk production occurred, for all practical purposes, at 2.4% added tallow. Higher tallow concentrations reached phase II, where no additional improvement in milk yield occurred. Tallow levels were not high enough in their study to reach phase III, where milk yield declined with increasing dietary fat.

Feeding Rates For Fat Supplements

With all the strategies that have been written on feeding fat to dairy cows, perhaps the most important, yet most elusive of these, might be the proper amount to feed. To effectively utilize the vast array of fat products available, it is essential that practical guidelines be developed for matching sources of fat with proper levels of supplementation. Proper feeding rates for fat may be the single most important management tool affecting the success of using fat supplements.

Deciding on the proper level first requires an analysis of what the fat is expected to accomplish. For the most part, fat is included in dairy rations with the expectation that an increase in milk yield will follow. Perhaps someday the value of added fat will be judged by criterion other than just increased milk yield. Other benefits of fat have been proposed e.g. alleviation of heat stress, improved reproductive performance, and reduced incidence of some metabolic diseases, but economic returns from these noncaloric effects are inconsistent and not well defined. For now, fat supplements are judged by their success in enhancing milk production, and feeding rates for fat should be developed with this goal in mind.

Feeding Rate For Total Added Fat

If the above model applies, and there actually exists a level of fat beyond which little or no additional milk response occurs, then identification of this level is critical for the profitability of fat-feeding. After reviewing 20 published lactation studies that included 60 observations on fat feeding, there were only 3 instances where the fat supplement increased FCM more than 3.5 kg/day. Added fat in these studies ranged from 1.5 to 6.8% of the ration dry matter and IV ranged from 11 to 139. The net energy in 3.5 kg 4% FCM is 2.56 Mcal, which can be supplied by 443 g fat, assuming 5.84 Mcal NE_L/kg fat (NRC, 1989). This equates to 738 g dietary fat, assuming 80% fatty acid digestibility and 75% mammary uptake of absorbed fatty acids (Palmquist and Eastridge, 1991).

According to Kronfeld (1976), milk production reaches its maximum efficiency at 16% of the metabolizable energy (**ME**) from fatty acids. For typical high-producing cows this equates to approximately 600 to 700 g added fat[1], which agrees closely with the 738 g estimated above. Taking into account both estimates, the maximum milk response or phase II is reached when the ration is supplemented with approximately 1.5 lb of fat, provided that net energy content of the fat supplement is 5.84 Mcal/kg and the fat does not severely limit feed intake or nutrient digestion. If unprotected fats are used to meet a portion of this added fat, they must be limited to avoid digestibility problems.

An alternative recommendation for deciding on the amount of fat to feed is to set total fat in the ration from all sources equal to the grams of milk fat produced (Palmquist and Eastridge, 1991). This approach is useful for accounting for fat in the basal ration and for adjusting dietary fat content according to milk production. Using the production data shown in footnote 1 as an example, total fat fed equals 1,278 g

[1] For a 636 kg cow producing 36.5 kg milk at 3.5% fat, ME required equals 58.6 Mcal/day. Therefore, 16% or 9.4 Mcal should come from fatty acids. If intake of the basal diet is 25 kg (dry matter basis) containing 2.5% fatty acids, then .625 kg times 7.3 Mcal/kg equals 4.6 Mcal from basal fatty acids. Added fatty acids then equal 4.8 Mcal or 658 g.

(36.5 x .035). The basal diet supplies 625 g (25 x .025), leaving the remaining 653 g as added fat. This estimate also agrees closely to the 1.5 lb (681 g) added fat recommendation discussed above.

Feeding Rate For Unprotected Fat

Jenkins (1993a) compiled data from ten published lactation studies to determine the dietary factors that maximized the milk response to added fat. Because there were several groups of cows fed fat in each study, the data set contained a total of 22 observations. Diets contained (dry basis) from 16 to 26% ADF, 25 to 49% NDF, and 2 to 6% added fat, consisting of seven different fat sources ranging in IV from 11 to 132.

Using this data set, the relationship between level of added fat and milk response (milk yield of the fat diet minus milk yield of the basal diet) was evaluated. Adding fat increased milk production up to 2.7 kg/day. There were, however, instances where the milk response changed little, or was negative when adding fat to the diet. Overall, there was no significant relationship ($r^2 = -0.31$, $P = 0.16$) between the two variables, which is expected when data is combined from all three phases in the model. Therefore, fat-feeding recommendations based on a single level of supplementation for all fat sources are just as likely to reduce milk yield as to increase it. The single level of inclusion recommended earlier (1.5 lbs/day) would be useful for all fat sources only if its composition is adjusted by blending unprotected and rumen-inert fats to minimize digestion problems.

A number of diet (ADF, NDF, and CP) and fat (IV, % added total fat, % added polyunsaturated fat, % added unsaturated fat) variables were then examined singly, and in combination to determine which factors correlated with milk response. The best predictor was the ratio of added unsaturated fatty acids to ADF (UFA/ADF) in the diet. Correlation of milk response with UFA/NDF was slightly less. This agreed with two established trends on fat-feeding (Jenkins, 1993b):

1) unsaturated fatty acids are more detrimental to ruminal digestion than saturated fatty acids, and

2) increased fiber is beneficial in reducing fermentation problems associated with feeding fat.

Because milk response was inversely related to UFA/ADF, and unsaturated fatty acids are known to interfere with digestibility more than saturated fatty acids do (Jenkins, 1993b), then it is assumed that digestibility problems were the primary factor that reduced milk response. The reduction in milk response was minimal at UFA/ADF of .04 to .06, or UFA/NDF of .025 to .04. Using the upper values of .06 and .04, and then rearranging, feeding rate for unprotected fats can be estimated as:

Added Fat (% of ration DM) = (6 x ADF)/UFA
or, **(4 x NDF)/UFA** **Equation I**

where ADF and NDF are expressed as a percent of the ration dry matter, and UFA is unsaturated fatty acids (18:1 + 18:2 + 18:3) expressed as a percent of total fatty acids in the supplement.

The values of 6 and 4 for ADF and NDF, respectively, were selected from visual inspection of curves relating milk response to either UFA/ADF or UFA/NDF. Values on the upper end of the range were chosen to allow for greater utilization of unprotected fats. Some depression in ruminal fermentation can be tolerated without depressing milk response because of compensation of fiber digestion by hindgut fermentation. The equation based on NDF generally allowed for greater levels of added fat, but the milk response was also more variable compared to calculations based on ADF.

Using Equation I, recommended tallow (46% UFA) levels range from 2.5 to 3.0% for rations containing 19 to 23% ADF, respectively. For the highly unsaturated canola oil, supplementation must be limited to 1.3 to 1.5% in rations with 19 to 23% ADF in order to optimize the milk response.

Table 1 shows UFA values for several fat sources often added to dairy rations. As with any tabular data on feed composition, there can be instances of extreme variability. Tallow may be more consistent in its fatty acid composition than other fat sources (such as blended fat or yellow grease), but it still varied in UFA from 43 to 53% in a small sample of published lactation studies. A fine tuned fat-feeding program will

Table 1: Individual and total unsaturated fatty acids (UFA) values for fat sources used as energy supplements in dairy rations.[1]

Fat	18:1	18:2	18:3	UFA
	--------------------- % of total	-------------------		
Tallow	42	3		45
Animal-vegetable	34	16	2	52
Palm	43	10		53
Poultry fat	41	19	1	61
Restaurant grease	48	20	3	71
Cottonseed	19	53		72
Soybean	25	53	7	85
Corn	29	55	1	85
Canola	60	20	10	90

[1]Taken from Grummer (1996) and Rouse (1996).

require analysis of fatty acids and UFA in all fat supplements by gas chromatography.

Limitations and Applications of Equation I

Equation I is presented as a guideline for estimating an appropriate level of unprotected fat to avoid digestibility problems in dairy cows. It undoubtedly will be modified with time as more information becomes known about the utilization of fat for milk production. The equation only applies to unprotected fats with IV greater than 40. Fats with very low UFA are regarded as rumen-inert.

From the previous discussion, added fat in dairy rations should be limited to 1.5 lb to avoid reaching phase II where little additional milk response occurs. For a maximum milk response, this 1.5 lb added fat should not severely limit feed intake, fiber digestibility, or fatty acid digestibility. Depressed feed intake, lowered fatty acid digestibility, or high fat supplement costs often make it difficult to feed the entire 1.5 lb as rumen-inert fat. On the other hand, digestibility problems restrict the use of most sources of unprotected fat. A useful approach to minimize these problems and take advantage of lower fat costs would be to combine unprotected and rumen-inert fats.

Below is a three-step approach to determining the proper combination of unprotected and rumen-inert fat for the 1.5 lb supplement. The example assumes that the source of unprotected fat was animal-vegetable fat containing 52% UFA and that ration ADF was 19%.

1. **Determine the level of unprotected fat from Equation I**. For the animal-vegetable fat in this example, 6 times 19 divided by 52 equals 2.19% of the ration dry matter.

2. **Determine g of unprotected fat**. Multiply % unprotected fat (2.19) times dry matter intake (assume 20 kg) giving 438 g.

3. **Determine g of rumen-inert fat**. Subtract g unprotected fat (438 g) from the total recommended added fat[2] (681 g) which gives 243 g. Therefore, the cows should be fed 681 g (1.5 lb) added fat each day consisting of 438 g yellow grease (64%) and 243 g rumen-inert fat (36%).

In some situations, unprotected fat may comprise the majority of the fat supplement, such as adding tallow with lower UFA to diets with higher ADF. If tallow contained 43% UFA and the diet contained 23% ADF, then step 1 equals 3.21%, step 2 equals 642 g, and step 3 equals only 39 g rumen-inert fat, an amount probably too little to bother with.

Similar calculations can be applied to the use of oilseeds with one additional step. Keep in mind that no allowance is made for possible protection of oilseed fatty acids by the outer seed coat. Therefore, these calculations will likely underestimate the amount of oilseeds to include in dairy rations. However, if they are

[2] Total added fat can also be determined by subtracting fat in the basal ration from total milkfat produced (Palmquist and Eastridge, 1991).

extruded or ground, a more conservative estimate is wise. If whole cottonseed contained 65% UFA and ration ADF was 21%, then step 1 equals 1.94%, step 2 equals 388 g (again assuming 20 kg DMI), and step 3 equals 293 g. The extra step for oilseeds is:

4. **Determine g oilseed**. Divide the result from step 2 (388 g) by the fat content of the oilseed (assume 20%) which equals 1,940 g. If needed, multiply by .0022 to convert to lbs. giving 4.3 lbs whole cottonseed and 293 g rumen-inert fat as the final answer.

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