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# *A 100-Year Review:* Fat feeding of dairy cows[1]

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## ABSTRACT

Over 100 years, the *Journal of Dairy Science* has recorded incredible changes in the utilization of fat for dairy cattle. Fat has progressed from nothing more than a contaminant in some protein supplements to a valuable high-energy substitute for cereal grains, a valuable energy source in its own right, and a modifier of cellular metabolism that is under active investigation in the 21st century. Milestones in the use of fats for dairy cattle from 1917 to 2017 result from the combined efforts of noted scientists and industry personnel worldwide, with much of the research published in *Journal of Dairy Science*. We are humbled to have been asked to contribute to this historical collection of significant developments in fat research over the past 100 years. Our goal is not to detail all the work published as each development moved forward; rather, it is to point out when publication marked a significant change in thinking regarding use of fat supplements. This approach forced omission of critically important names and publications in many journals as ideas moved forward. However, we hope that a description of the major changes in fat feeding during the past 100 years will stimulate reflection on progress in fat research and encourage further perusal of details of significant events.
**Key words:** fat, conjugated linoleic acid, energy, 100-year review

## HUMBLE BEGINNINGS—FATS ARE AN AFTERTHOUGHT

Concepts of feeding fat to dairy cows precede the limits of the past century. Research on feeding oilseeds commenced early; Wood (1894) reported effects of feeding oils from cottonseed, palm, and coconut, as well as oleo oil, corn gluten meal and stearin, concluding that the first effect of feeding oils was to increase milk fat percent. Reports on feeding oils and seeds are found throughout the literature from that time (Henry and Morrison, 1916, "Feeds and Feeding").

Reid (1956) succinctly summarized previous knowledge in his *Journal of Dairy Science* review of the first 50 years of the American Dairy Science Association as follows:

> "After publication of Jordan's reports in 1897 and 1901 that milk fat can be produced from carbohydrates, the viewpoint developed that fat is merely a source of energy exchangeable on an isodynamic basis with other nutrients. As a consequence, for some years thereafter very little attention was given to the fat content of the rations of cows. However, in Germany, Fingerling and his associates between 1904 and 1907 published data which, though showing that sheep and goats can make milk fat from carbohydrates, suggested that fat itself is more efficiently used than is carbohydrate. They also indicated that within certain limits the percentage of fat in milk is influenced by the amount of fat in the ration. These results provoked extensive studies with cows at ten experiment stations in Germany, which were reported by Kellner in 1907. However, since the low-fat rations used provided almost as much fat as was produced in the milk, these experiments provided very inconclusive information."

In the first decade of papers published in *Journal of Dairy Science*, very few addressed the topic of feeding fat (Appendix Table A1). Discussion of oils began inadvertently in early issues in studies that focused on how protein meals altered milk fat content, eventually raising questions about the possible role of their contaminating oils on observed responses. Palmer and Crockett (1917) reported that feeding cottonseed meal to cows increased melting point and long-chain fatty acids of milk fat, and caused an oily flavor of the milk that could be reversed by feeding corn silage but not hay. McCandlish (1921) continued work on cottonseed meal and milk fat percentage, but rejected reports that

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the amount of oil or fat in a ration affects milk fat percentage stating, "that there is no direct evidence it will do so"—a statement that was eventually proven to be profoundly wrong. Later studies by Woodward (1923) compared feeding linseed oil versus linseed oil meal and concluded that the principal factor causing an increase in milk fat test was the oil rather than the meal. Other studies were concerned mainly with the effect of short-term (1–3 d) feeding of fat on the official tests for milk fat (Nevins et al., 1926). However, these studies were of short duration, involved few cows, lacked proper experimental design, and used poorly described diets, thus proscribing any conclusions as to usefulness of supplementing fats for milk production.

## EFFECTS OF FATS ON LACTATION ARE EXPLORED

From 1929 until 1943, Maynard and coworkers at Cornell University studied the importance of fat in the ration of dairy cattle (Maynard et al., 1941; Loosli et al., 1944). They found that when an isodynamic amount of fat is replaced by starch, milk yield declines. Although the effect was not great, slightly more milk was produced by cows consuming concentrate mixtures containing 5 to 7% ether extract than by those consuming concentrates containing from 0.7 to 4%. In the first edition of his classic textbook *Animal Nutrition*, Maynard (1937) concluded that milk production of cows fed less fat than was produced in the milk yielded less milk. When additions of fat as corn oil, soybean oil, or fatty acids were made to low-fat rations, milk yield did not respond, suggesting that the value of the fat is depressed by extraction from the seed.

Numerous studies in the 1930s reported feeding fats of varying composition to study the effects primarily on milk fat composition, but some also investigated fat yield. Brown and Sutton (1931) fed up to 400 g daily of menhaden oil to one low-producing Holstein cow; within 4 d of feeding, both milk yield and fat percentage decreased precipitously. The authors showed by chain length and unsaturation measures that fish oil fatty acids were incorporated into the milk fat. Other authors evaluated effects on milk fatty acid composition of feeding other fish oils (McCay and Maynard, 1935), corn oil (Sutton et al., 1932), or fats of varying degrees of unsaturation (Maynard et al., 1936). In the latter study, milk fat iodine number changed in the direction of the supplement within 24 h of feeding. Moore et al. (1945) briefly reviewed effects of supplemental fats and oils on milk fat percent and undertook studies on amounts and frequency of feeding cod liver oil. They observed that more saturated fats tended to increase milk fat percent, whereas more unsaturated fats lowered milk fat percent and the milk fat was more unsaturated, confirmed by measuring iodine number. Cod liver oil depressed fat percent, or when hydrogenated, did not change fat percent. When cod liver oil was fed in 12 doses/d, milk fat percent of most cows was not changed. Moore et al. (1945) concluded that cows can hydrogenate unsaturated oils to some extent during digestion and absorption, but are unable to accommodate large amounts, which, in principle, was confirmed by later research. With considerable variability noted in the 1930s and 1940s among fat sources and their effects on lactation, later research on fat feeding turned to understanding the key metabolic differences among fat sources that account for this variability.

Shaw and Ensor (1959) reevaluated the effect of supplementing cod liver oil on milk fat yield. Whereas Hilditch (1956) had attributed the depressing effect to the long-chain (>C18) UFA of cod liver oil poisoning the fat synthesis mechanisms in the udder (because hydrogenation of cod liver oil eliminated the fat-depressing effect), Shaw and Ensor (1959) showed that both cod liver oil and linoleic acid depressed rumen acetate proportion and milk fat percent, contributing to a growing body of studies exploring relationships between ruminal production of volatile fatty acids, acetate:propionate ratio, and milk fat depression (Van Soest, 1963).

## FAT SOURCES BECOME MORE WIDELY AVAILABLE

As petroleum-based detergents became available after World War II, the availability of tallow increased greatly and prices were low, resulting in increased opportunities for its use in animal feeds, among other uses. At the same time, vegetable oils (especially the soapstocks) generated in refining of corn and soybean oils were competing for animal feed use. Although the latter were quickly adapted by the broiler industry, they gained some limited use in ruminant diets, convenient to some because they could be handled as liquids. Also gaining attention as fat supplements for ruminants were whole seeds, especially whole cottonseed and soybeans. Later came studies on whole sunflower, canola, and flax seeds. Whole cottonseed quickly became a favorite supplement in dairy rations, because in addition to being a good source of protein and energy, it promotes stable rumen function or improves it (Coppock et al., 1987).

Schingoethe and Casper (1991) summarized several lactation studies to show that supplementing TMR with extruded soybeans, sunflower seeds, or whole sunflower increased milk yield when fed from 4 to 16 wk of lactation, although both milk fat percent and protein percent were decreased. Interestingly, the fat supplement effects carried over, resulting in higher mature-equivalent milk yield over a 305-d lactation. Extruding whole oilseeds