Can dietary fatty acid supplementation aid reproduction? Challenges and opportunities.

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Introduction. Feeding fats to aid dairy cow reproduction is of considerable interest at the present time, both to scientists and the agricultural industry. This interest is based on several reasons; first, the well documented reduction in reproductive performance of dairy cows throughout the world has driven the development of nutritional strategies to reverse this trend; second, the use of dietary fat supplements will intensify as nutritionists strive to increase the energy density of diets to meet requirements of the high producing dairy cow; and third we now recognise that fatty acids (FA), both of dietary and rumen origin, can have specific and potent effects on ruminant metabolism. The objective of this paper is to provide an overview of lipid metabolism in the dairy cow and how it relates to dairy cow reproduction. Our focus will include biological processes and quantitative changes during the metabolism of FA in the rumen and the effect this has on FA availability to the dairy cow and the various areas in which FA can impact reproductive processes.

Dietary Fats and Rumen Lipid Metabolism. As well as being derived from specific fat supplements, FA in the dairy cow's diet are also present in forages and concentrates. Each fat source is composed of a different mix of individual fatty acids. Generally, most cereal grains and seeds contain a high concentration of linoleic acid (18:2 n-6), whereas linolenic acid (18:3 n-3), is typically the predominant fatty acid in forage sources. For example, corn, cottonseed, safflower, sunflower, and soybean oils are high in linoleic acid, whereas linseed is high in linolenic acid. Fish oil contains eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), two very long chain n-3 FA. Extensive metabolism of dietary lipids occurs in the rumen and this has a major impact on the profile of fatty acids available for absorption and tissue utilization. This is a result of bacterial biohydrogenation (BH) of unsaturated FA, resulting in the conversion of unsaturated FA to saturated FA, mainly stearic acid (18:0), through a series of BH intermediates (conjugated 18:2 and *trans* 18:1 FA). The major substrates are linoleic and linolenic acids and the rate of rumen BH is in the range of 70-95% and 85-100%, respectively; thus stearic acid, under typical feeding situations is the predominant fatty acid available for absorption by the dairy cow. This extensive metabolism by the rumen bacteria has made the study of dietary fat effects on reproduction challenging.

Effect of Fat Supplementation on Reproduction. Available scientific literature shows that a variety of fat supplements have benefited conception rates of lactating dairy cows. Feeding fat is a common strategy to increase the energy density of the diet; the energy status of the cow, however, is usually not improved because of a slight to moderate depression in feed intake and/or an increase in milk production. As a result, in many situations an improvement in reproductive performance has occurred without improving the energy status of the experimental animals. Therefore, fat supplementation is likely improving reproductive performance via effects of specific FA impacting metabolism and function of the ovary and uterus, rather than simply having a caloric effect. This has resulted in an increased interest in various oil seeds and in designing rumen inert fat sources that will deliver specific unsaturated FA to the lower gut for absorption. When cows fed fats containing mainly saturated and monounsaturated FA have been compared against a no supplemental fat control, the fat-supplemented cows generally have better conception rates. However, results comparing saturated and monounsaturated FA supplements in head-to-head comparisons with fat supplements containing a greater amount of polyunsaturated FA indicate that polyunsaturated FA-rich fats are more effective. Fat sources enriched in n-6 FA (e.g. most plant oils) or n-3 FA (e.g. linseed oil and fish oil) that deliver these fats to tissues beyond the rumen may therefore be the most effective ones to feed. Recently, the potential benefits of rumen-protected sources of conjugated linoleic acids (CLA) have also been of interest. Most data indicate that improved conception rates of fat-supplemented cows have been associated with an improved progesterone status of the cow by increasing the performance of the dominant follicle and corpus luteum and by helping the corpus luteum survive and continue to produce progesterone during the early days of pregnancy. These improvements have been proposed to be mediated via specific FA by: i) helping meet the animals' essential FA requirement in early lactation; ii) through the development of healthier ovarian follicles; iii) improving the quality of embryos produced; and iv) reducing embryonic mortality through suppression of uterine $PGF_{2\alpha}$. An additional and unique avenue through which CLA supplements may also assert their benefits on reproduction is via a reduction in milk fat synthesis, thereby sparing nutrients which may be used for other purposes by the animal. When considering individual FA and different fat supplements it is important to realise that different families of FA (e.g. n-6 vs. n-3 FA) most likely impact reproductive processes via different pathways. For example, n-3 FA have been shown in vitro and in vivo to have a suppressing effect on $PGF_{2\alpha}$ synthesis, whereas linoleic acid (n-6) promotes $PGF_{2\alpha}$ synthesis.

Conclusion. A variety of fat supplements have been tested for their effect on reproductive performance in lactating cows. Fats often improve pregnancy rates though there is large variability in responses observed; results, however, are rarely negative. Most data indicate that the observed improvements in reproductive parameters are independent of energy balance, while inconsistencies observed in the literature may be explained by variation in the availability of the specific fatty acids for incorporation into uterine tissues as a result of the extensive metabolism of dietary FA in the rumen. More research is needed to better identify the most effective fat sources and specific FA, whether from seeds and oils of plant origin, animal-derived fats, or commercially-available rumen-inert fat sources. The amount and type of supplement to be fed and the optimum window for supplementation will depend on the goals of the nutritional strategy employed and on the post-rumen delivery of specific FA from the supplement.