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Popular Article

Alteration in Rumen Microbial Dynamics Due to PUFA Oil Rich Diet in Dairy Cows

Sushil Kumar[1], Vivek Saharan[1], Narender Singh[2] and Sajjan Sihag[1]
[1]Department of Animal Nutrition; [2]Department of Livestock Production Management, LUVAS, Hisar-125004
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Different type of oil/ oil-seeds has long been incorporated in the diet of ruminants for increasing the dietary energy density. Unsaturated fatty acids (Ω-3 and Ω-6) in oil and oil seeds not only provide energy, but they also have a number of beneficial effects on the dairy cows' biological systems, depending on their fatty acid profile. Safflower, cottonseed, sesame, soybean and sunflower oil-seeds are rich in Ω-6 fatty acids while linseed/ flaxseed and fish oil have high content of Ω-3 fatty acids. Palm oil is rich in mono-unsaturated fatty acid and canola/ mustard oil has good amount of monounsaturated (60-65%), Ω-6 (15-20%) as well as Ω-3 (6-8%) fatty acids. Animal nutritionists have recently conducted extensive research and documented the role of polyunsaturated fatty acids (Ω -3 and Ω -6 PUFA) in regulation of various biological processes. It has been reported that a variety of PUFAs play a crucial role in regulating biological metabolism, endocrine function, and disease prevention in various tissues. Dairy animals need a lot of food to grow and be productive, as well as to perform reproductive functions like the early onset of puberty and the ovarian cyclicity. However, fatty acids must first pass through the highly reducing environment of the rumen, which is made up of millions of microbes, in dairy animals before they can be absorbed. If the rumen's reducing environment is well maintained, these microbes play a significant role in digestion. Additionally, because unsaturated fatty acids are toxic to the rumen microflora, they are hydrogenated with the assistance of microbes (bio-hydrogenation) to less harmful saturated fatty acids. A number of intermediate fatty acids are also synthesized during this biohydrogenation. This chapter sheds light on the potential benefits and fate of fatty acids in the digestive system of ruminants.

Fate of dietary lipids in the rumen ecosystem

From the perspective of ruminant nutrition, it is essential to emphasize that forages contain approximately 2% lipids, primarily in the form of galactosyl diglycerides and phospholipids, with a small

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thescienceworldmagazine@gmail.com
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amount of tri- and di-glycerides. C18:3 (60–70%) and C18:2 (around 20%) are the FAs in forages that are found in the greatest quantities. When seed-derived products are fed to dairy cows, triglycerides are the predominant lipid form. Lipids in the rumen, when delivered through rumination and microbiota action, go through two significant cycles: lipolysis and biohydrogenation.

Lipolysis

Rumen bacteria releases lipases in the rumen that break the dietary esterified FA. *Anaerovibrio lipolytica* break down mainly the triglycerides while *Butyrivibrio* spp. are responsible for hydrolysis of phospho- and galacto-lipids. Lipases present in fresh plant materials remain active for up to 5 h in the rumen and also aid in the lipolysis. The relative abundance of lipases producing bacteria increases early postpartum when the diet is enriched with large amounts of fat, such as cottonseed and rumen inert fat. Galactosidases and phospholipases from the plants also participate in releasing FA. The use of FA to produce energy is minimal by rumen microbes, and that too is done mainly by protozoa.

Biohydrogenation

In the rumen, bacteria undergo a process called biohydrogenation in which they transform USFA into SFA. As a result, the fatty acids that emerge from the rumen are highly saturated. Ruminal bio-hydrogenation is a significant obstacle for the delivery of PUFA in ruminants. In fact, the ruminal microflora hydrogenates more than 80% of dietary PUFA. However, feeding increased amounts of PUFA has been shown to alter tissue composition, influencing production and reproduction. The FA released by lipolysis are almost completely hydrogenated by bacterial isomerases followed by reductases. Increased biohydrogenation takes place due to attachment of FA to food particles in the rumen. More than 60% of free FA gets adsorbed onto the surface of the feed particles. Protozoa accumulate dietary FA as lipid droplets in their cells. Protozoa also provide around 30-40% of intermediates of biohydrogenation process, e.g. CLA and vaccenic acid. The vast variety of fatty acids in milk of dairy cows is the consequence of various positional and geometric isomers of CLA from rumen. The main CLA synthesized by biohydrogenation of PUFA are cis-9, trans-11 and trans-9, trans-11 and trans-11 from C18:1 (MUFA). It has recently been reported that forages contain relatively more complex PUFA lipids, such as phospholipids and cholesterol esters, which get less bio hydrogenated compared to PUFA esterified to triglycerides found abundant in seeds and derived oils. On a supplemental-fat-free diet, about 20% (15 g/kg of OM digested) of the lipids available at small intestinal level is of microbial origin. For de-novo synthesis of microbial lipids, acetate and glucose are used to produce even-chain FA (mostly C18:0 and C16:0 at a ratio of 2:1) and propionate for the synthesis of odd-chain FA (C13:0, C15:0, and C17:0). In the peripheral tissues (mammary gland and adipose tissues), acetate it is the major precursor for de novo FA synthesis. Monounsaturated FA accounts for about 20% of bacteria's de novo synthesized FA. Increasing the level of dietary fat (especially UFA) reduces the de novo synthesis of FA because supplemental fat can reduce the fermentation either due to a coating of feed particles FA or toxic effect of FA on microbes by disrupting bacteria membranes. Appropriately, biohydrogenation has been proposed as the primary process by which bacteria reduce the toxicity of unsaturated types of FA. The toxicity of saturated FA to rumen bacteria is generally limited to small extent. Palmitic and stearic acid are toxic only to propionate producers (*Prevotella ruminicola*) and some strains of *Butyrivibrio fibrisolvens* (acetate and butyrate producers). The issues with giving ruminants essential fatty acid supplements is two-fold. In the rumen, fatty acids first undergo lipolysis and biohydrogenation, due to which very little UFA is available in the intestine for absorption. Secondly, rumen microbes are poisoned by unsaturated fatty acids.

Positive aspect of supplementing PUFA in ruminants

Although, high dietary PUFA levels lead to negative effects on rumen-microbial activity, appropriate levels of PUFA rich oil in the ruminant diets can optimistically alter the kinetics of rumen fermentation, too. Fiorentini *et al*. (2013) supplemented soybean oil in the dietary regimen of dairy cows and observed reduced rumen ammonia-N concentrations and numbers of fungi and protozoa, leading to improved efficiency of microbial protein synthesis.

Ivan *et al*. (2001) observed that dietary fats with higher levels of UFA cause greater variability on ruminal pH, and are more subjected to hydrolysis by rumen bacteria. A moderate reduction in the rumen pH to below 6.0 reduces the fiberolysis, but the population of fibrolytic microorganisms is not usually adversely affected. Protection of fats can further alter the rumen microbial population. Animals fed a rumen Ω-3 protected fatty acid rich diet had larger numbers of ruminal protozoa and fungi than animals fed diets supplemented with unprotected PUFA rich oils. This is due to defaunation process caused by the consumption of unsaturated fatty acids. The defaunation process improves the efficiency of microbial protein synthesis because of decreased competition between bacteria and protozoa for nutrients. A decreased protozoa concentration also reduces the NH_3-N concentration in the rumen, which is due to a reduction in the proteolytic activity of the protozoa. Additionally, defaunation breaks the symbiotic relationship between protozoa and methanogenic archaea, leading to reduced growth of methane producing bacteria. Methanogenesis is a wasteful process that leads to loss of around 7% of feed gross energy. PUFAs have little influence on microbial protein synthesis, and the efficiency of microbial protein synthesis increases more frequently when there is a reduction in the number of ruminal protozoa. Dewhurst *et al*. (2000) depicted that dietary unsaturated fats can affect microbial protein synthesis directly by replacing fermentable energy sources for the microorganisms or indirectly by promoting defaunation and consequently increasing bacterial-origin protein synthesis.

Abbreviations used

Ω-3 FA: omega- fatty acid; Ω-6 FA: omega-6 fatty acid; PUFA: polyunsaturated fatty acid; UFA: unsaturated fatty acid; SFA: saturated fatty acid; NH_3-N: ammonia-nitrogen; FA: fatty acid; MUFA: mono-unsaturated fatty acid; CLA: conjugated linoleic acid; OM: organic matter.

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