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Enrollment of Rumen Microbiota in Utilization of the Dietary Lipids and Synthesis of Cis 9 Trans 11 Conjugated Linoleic Acid: A Review

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Abstract

Utilization, extraction of energy and synthesis of various micronutrients through dietary lipids in ruminants is solely dependent upon rumen microbial efficacy. Rumen microbes are not only the pioneer of lipid digestion, but also the key factor to decide the physical & biochemical characteristics of input dietary lipids owing to the lipolysis and followed by biohydrogenation of dietary lipid through rumen microbes. Optimal microbial balance and proper scientific requirement of dietary lipids influences the digestibility and utilization of dietary lipids. Thus, aforesaid article developed to discuss key insight considerations of rumen microbes to utilizedietary lipidsin ruminants.

Keywords: Ruminants; Rumen microbes; Dietary lipids.

Introduction

Conventional ration for the lactation purpose rarely contain greater than 3.5% fat (ether extract). Moreover, this fraction represents up to 50% proportions from forages (green forages) and remaining 20% from grains (energy rich concentrates). In plant leaves, the major non-fatty acid lipid components are waxes, pigments (chlorophyll) etc. and other non-saponifiable material. Lipids from forages, mainly consist of glycolipids, galactolipidsand richer source oflinolenic acid (C18:3 n-3); other feed contain a whole range of fatty acids, from short and medium chain in coconut oil to fatty acidswith 20-22 carbons in fish oil. The main sources of nutraceutical fatty acid viv. Cis 9 trans 11 linolenic acid (CLA) supplementations are linseed, canola (mustard), soybeans, nuts and dark green forages. Omega-3 (ω3) fatty acids are mainly from animal origin and mainly found in cold water and salt water fishes viz. salmon, trout, mackerel and sardines. The main sources of linolenic acid (C18:2 n-6) are sunflower seed, safflower, soybean, nuts and sesame seed. γ-linolenic acid (C18:3 n-6) is found in evening primrose oil and grape seeds. Dihomogama-linolenic acid (C 20:3 n-6) is found in maternal milk while arachidonic acid (C20:4 n-6) occurs mainly in meat and animal products. Oleic acid (C18:1) is found in olive, almond, ground nut, cashew and butter (Sukhija and Palmquist, 1988).

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Digestion and Metabolism of Dietary fat in Ruminants

The utilization of fat by ruminants is characterized by serial events in the rumen before they are digestive and absorbed in the intestine. During their stay in the rumen, fat are biohydrogenated (Fig. 1) so that the amount and composition of fat leaving the rumen differs from that of its intake.

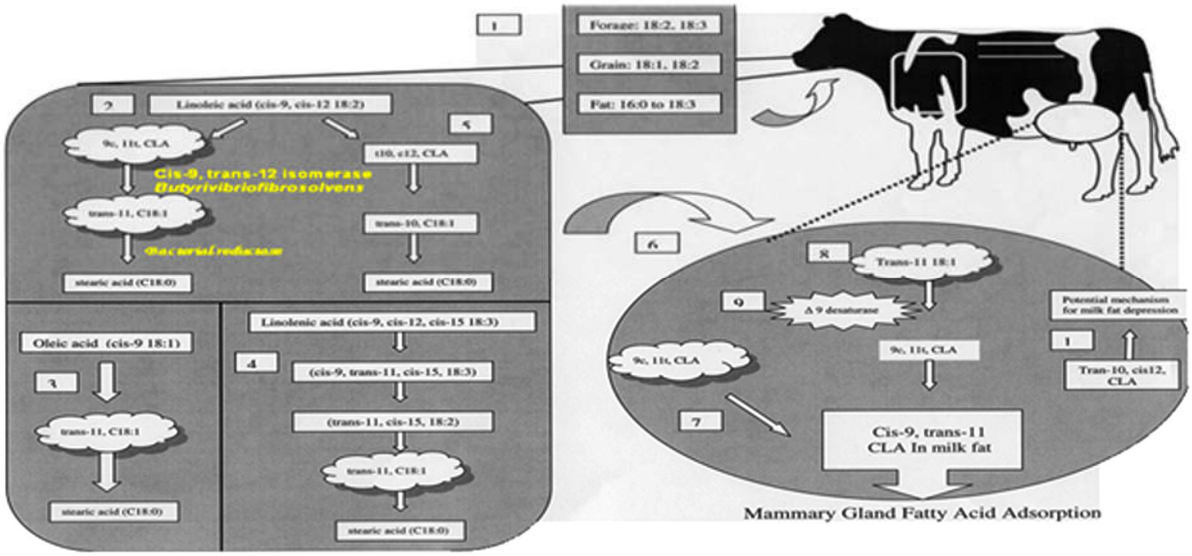

Fig. 1: Biohydrogenation pathway and fate of fatty acids in the rumen.

Lipolysis in Ruminants

Esterified plant lipids, shortly after consumption are hydrolysed extensively by microbial lipases causing the release of constituent fatty acid (Fig. 1; Fig. 2) Anaerovibriolipolytica, identified as the best known rumen bacteria for its lipase activity produces a cell bound esterase and a lipase (Harfoot, 1978). Fay et al. (1990) identified 74 strains of ruminal bacteria that were capable of hydrolyzing the ester bond in P-nitrophenylpalmitate. Known lipolytic microbial strains including Anaerovibriolipolytica and Butyrivibriofibrisolvens, had low hydrolysis in that assay. The ruminalprotozoal population (Harfoot and Hazelwood, 1988) also showed extensive lipolytic activity. Hydrolysis of galactolipids and phospholipids is attributed to a variety of galactosidases and phospholipases (including phospholipase A, phospholipase C, lysophospholipase and phosphodiesterases) produced by ruminal microbes (Harfoot and Hazzelwood, 1988).

The lipase is an extra cellular enzyme present in membranous particles and composed of protein, lipid and nucleic acid. This lipase hydrolyzes the acylglycerols completely to free fatty acids (FFA) and glycerol with little accumulation of mono or diglycerides (Hawke and Silcock, 1970). Glycerol is fermented rapidly, yielding propionic acid as major end product.

The extent of hydrolysis is approximately 85-95% for most unprotected lipids (Bauchart et al., 1990). This proportion is higher for the diets richer in fats than for conventional diets in which the most lipids are components of cellular structure. Hydrolysis seems to be the highest for diets richer in protein (Gerson et al., 1983). Some factors have been found to decrease lipolysis viz. antimicrobial supplementations and low pH (VanNevel and Demeyer, 1995). This later factor explains why lipolysis is reduced with diet rich in starch (Gerson et al., 1985).

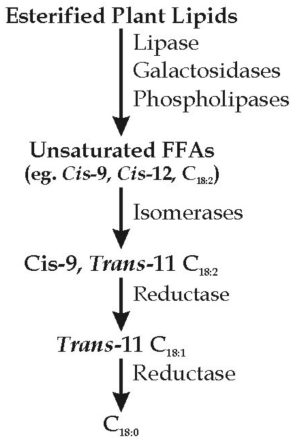

Fig. 2: Key steps in conversion of esterified plant lipid to the saturated fatty acids by lipolysis and biohydrogenation in the ruminal contents.

Biohydrogenation of Lipids

The unsaturated free fatty acids have relatively shorter half life span in ruminal contents because they are rapidly hydrogenated by microbes to the more saturated end products. Hydrogenation generally takes place at a slower pace than lipolysis, but few PUFA are present in the rumen (Doreau and Chilliard, 1997). On contrary to the extensive debate, biohydrogenation contributessomewhat as a hydrogen sink, as only 1-2% of metabolic hydrogen is used for this purpose (Czerkawski and Clapperton, 1984).

The initial step of biohydrogenation is isomerization reaction that converts the cis-12 double bound in unsaturated fatty acids to a trans-11 isomer. The isomerase is not functional unless the fatty acid has a free carboxyl group and in the case of polyunsaturated fatty acids such as C18:2 a cis-9, cis-12 diene double bond configuration is present (Kepler et al., 1970). The requirement of free carboxyl group establishes lipolysis as a pre-requisite for biohydrogenation. Once, the trans-11 fatty acid bond is formed by the action of isomerase, their hydrogenation of cis-9 bond in C18:2 occur by a microbial reduction. Butyrivibriofibrisolvense and Ruminococusalbus species are among the important microbes responsible for biohydrogenation (Kemp et al., 1975). Harfoot and Hazelwood, (1988), investigated various pathways for the reduction of fatty acids by hydrogenases. The end product of hydrogenation of C:18 fatty acid is stearic acid. However, when large amounts of linolenic acid are available, hydrogenation generally stops before this final step, leading to the formation of various cisand trans isomers of monoenoic fatty acids (Harfoot, 1978). The most important is trans-vaccenic acid (C18:1 n-7). The extent to which dietary unsaturated fatty acids escape hydrogenation appears to depend on microbial growth conditions that influence rate of lipolysis and biohydrogenation. Grain feeding suppresses the ruminalbiohydrogenation and promotes increased unsaturation of the carcass fat and milk. This effect is attributed to decreased lipolysis resulting from lower ruminal pH (Latham et al., 1972; Kemp et al., 1991). Diminished rate of lipolysis and hydrogenation is caused by low dietary N2 supplementations (Gerson et al., 1983), small feed particle size (Gersonet al., 1988) and maturity of forages (Gerson et al., 1986).

Bacteria incorporate fatty acids and are also able to synthesize a wide variety of fatty acids, those with 15 and 17-C atoms being the more characteristic. Synthesis occurs mainly from volatile fatty acids, branched chain fatty acids arise from isoleucine and leucine (Doreau and Chilliard, 1997). Bacterial cisand trans monounsaturated fatty acids may result from desaturation of the saturated fatty acids. Linoleic acid can also be synthesized (Demeyer and Hoozee, 1984). The extent of this de-novo synthesis is lower than the extent of dietary fatty acids incorporation and decrease when the ruminal fatty acids concentration increases (Demeyer et al., 1978). Protozoa (Emmanuel, 1974) and rumen fungi (Kemp et al., 1984) can also incorporate and synthesize fatty acids. Synthesized and assimilated fatty acids are esterified as phospholipids as sterol esters, and constitute structural lipids. When large amounts of fatty acids are fed, they are stored as free fatty acids in cytosolic droplets (Bauchart et al., 1990). These droplets are especially richer in linoleic acid which thus escapes the biohydrogenation.

Conclusions

Traditional ration of ruminants, especially green fodder and concentrate mixture are the richer source of lipid. Liplysis followed by biohydrogenation of dietary lipid through rumen microbes fulfill the requirement animal body for various biosynthesis and energy generating mechanism. Microbial digestion of dietary lipids reshuffles the shape and configuration of dietary lipids. Thus, meeting of dietary lipid requirement and microbial balance enhances the utilization of dietary lipids in ruminants.

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