linseed in the Ruminant Diet

ADDING LINSEED TO FEED ENHANCES THE FAT PROFILE OF MILK

Written by Dr. Diane H. Morris. Reviewed by Dr. Essi H. Evans.

Summary

Feeding dairy cows a ration containing whole flax seeds (linseed), flax (linseed) oil or milled, extruded or micronized linseed has five beneficial effects on the fat profile of cow's milk: (**1**) increasing the content of alpha-linolenic acid (ALA); (**2**) increasing the content of conjugated linoleic acid (CLA); (**3**) decreasing the omega-6/omega-3 ratio; (**4**) decreasing the overall saturated fat content; and (**5**) increasing the proportion of stearic acid relative to other saturated fatty acids. These enhancements to the fat profile of milk give consumers value-added foods with good sensory qualities and a healthier fat profile.

Glossary of Flax (Linseed) Terms

Flax – a term used in clinical research and the consumer marketplace to describe the oilseed rich in omega-3 fat, dietary fibre and lignans.

Linseed – the term for flax used in the feed industry and also by researchers carrying out animal studies.

Linseed meal or linseed cake – the protein- and fibre-rich material that remains after flax seeds are pressed to express the oil.

Linseed oil – obtained by crushing flax seeds; linseed oil is rich in fat, particularly omega-3 fat, but it contains virtually no dietary fibre, protein or lignans.

Rolled linseed – obtained by processing whole seeds to reduce their size; in one study rolled linseed had a particle size of 1300 μm compared with milled linseed, which had a particle size of 700 μm.[4]

Introduction

Food processors continue to think of innovative ways of adding flax to their food products. In addition to traditional flax breads, muffins, bagels and cereals sold in supermarkets, flax-containing products as diverse as energy bars, pizza, smoothies and meatless vegan meals are now available.[1] But processors do not stop there. They add flax (often referred to as linseed) to livestock rations, the aim being to increase the content of healthy fats in eggs, meat, poultry and dairy products.

The dairy industry has learned that adding linseed to the rations of dairy cows improves the fat profile of their milk. Most research in ruminant nutrition in North America has been undertaken on cattle, although studies have also shown beneficial effects of linseed on the fat profile of goat milk.[2,3]

The Challenge of Changing the Fatty Acid Profile of Milk

The fact that ruminants digest their food in stages presents challenges for dairy farmers, the main one being the process of biohydrogenation – the chemical reactions whereby microorganisms in the rumen transform the polyunsaturated fatty acids found in animal feed into saturated fatty acids. Ingested feed first enters the rumen, a digestive compartment that works much like a fermentation vat (see box page 2). The ingested dietary fats undergo many chemical changes carried out by bacteria, protozoa and fungi.[5] However, rumen bacteria cannot break down dietary fats. To enrich milk with polyunsaturated fatty acids like alpha-linolenic acid (ALA), the essential omega-3 fatty acid, and its long-chain metabolites, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), the dietary supply of these fatty acids must be protected from rumen biohydrogenation. Various methods of interfering with the bacterial metabolism of long-chain fatty acids in cattle and goats have been tried, including the following:[6]

- Feeding whole linseeds with their seed coat intact to slow the release of fatty acids in the rumen and protect against their oxidation;
- Heating whole seeds by micronization, which is an intensive heat treatment that involves exposing the seeds to infrared radiation for a few minutes;[7]
- Heating whole seeds by extrusion, a process in which a food is heated under pressure and then forced (extruded) through fine pores in a die head;
- Treating whole seeds with formaldehyde; and
- Preparing calcium salts of the fatty acids, a process whereby an oil is mixed with sodium hydroxide to form a sodium soap, which is then dissolved in hot water, saturated with calcium chloride, filtered and air dried, forming calcium salts of the fatty acids which are believed to be insoluble in the rumen.[8]

Ruminants Are Different from Humans!

Ruminant animals have four stomach-like compartments for digesting grasses and other vegetation, whereas humans, chickens and pigs have only one. In ruminants, ingested material enters the rumen, where the digestive process begins. The material mixes with rumen contents and is acted on by rumen microbes. Another rumen compartment, the reticulum, helps in the formation of boli – lumps of partially digested material commonly called "cud" – which are regurgitated and chewed slowly to break down the particle size. After the boli are reswallowed, they are further fermented in the rumen before passing into the omasum – a trap which blocks large particles from exiting. They then travel into the abomasum and finally into the small intestine.[9]

These approaches have proven successful in protecting polyunsaturated fatty acids from biohydrogenation in the rumen. The methods have achieved favourable changes in the fatty acid content of milk, as described in the sections below.

Dietary Linseed Enhances the Fat Profile of Milk

Cow's milk naturally contains low amounts of omega-3 fats – one cup of 2% milk contains only 20 mg of ALA and virtually no EPA or DHA[10] – and high levels of saturated fats, particularly palmitic acid (16:0), which raises blood cholesterol.[11] Milk and milk products like cheese and ice cream are relatively rich sources of conjugated linoleic acid (CLA). Natural cheeses, for example, contain 2.9 to 7.1 mg CLA/g of fat, while processed cheeses average about 5 mg CLA/g of fat. Milk contains about 5.5 mg CLA. The main CLA isomer in cow's milk is *cis*-9, *trans*-11-CLA (c9,t11-CLA), accounting for more than 82% of the total CLA.[12] This section describes how the ALA and CLA content of milk can be increased, the omega-6/omega-3 ratio reduced, and the saturated fat content decreased by supplementing the rations of dairy cows with linseed.

Increasing ALA Content

Adding whole linseed or linseed oil to the diet of dairy cows increases the ALA content of their milk between 29% and 88%.[8,13-17] Increases in the ALA content of milk as high as 2- to 3-fold have been reported when dairy cows were fed raw whole or micronized linseed,[11,18] linseed oil,[19] or milled linseed.[20] In one study,[21] the ALA concentration in milk doubled when formaldehyde-treated whole linseed was fed to dairy cows in their rations; it increased from 1.0% to 13.9% when 500 g/day of linseed oil was infused directly into the stomach, thus bypassing the rumen.

Decreasing the Omega-6/Omega-3 Ratio

In two studies,[18,22] adding whole linseed to the rations of dairy cows resulted in the lowest omega-6/omega-3 ratio in milk compared with when the cows ate micronized soybeans or sunflower seeds. The omega-6/omega-3 ratio was highest (8.5:1) in the milk from cows fed a ration supplemented with Megalac, which is rich in palmitic acid (16:0), and lowest (3.5:1) in milk samples from cows fed a ration supplemented with whole linseed.[18] The ratio in milk fat was lower in samples obtained from cows fed whole linseed (1.7:1 to 2.3:1) than in samples obtained from cows fed whole sunflower seed (about 8:1). Treating seeds with formaldehyde did not affect the ratio.[22]

Benefits of Reducing the Omega-6/ Omega-3 Ratio

Human diets rich in omega-6 fats result in a high omega-6/ omega-3 ratio. A high dietary omega-6/omega-3 ratio is linked with low-grade chronic inflammation that contributes to diseases such as Alzheimer disease, cancer, coronary heart disease, metabolic syndrome, obesity, type 2 diabetes, osteoporosis and even dry eye syndrome.[23] Reducing the omega-6/omega-3 ratio helps decrease inflammatory reactions and lowers the risk of chronic disease. A dietary ratio between 4:1 and 10:1 is recommended.[24] Improving the ratio can be achieved by eating less omega-6 fats, eating more omega-3 fats or doing both. Buying milk and meat products with a low omega-6/omega-3 ratio helps improve the dietary mix of fatty acids in the human diet.

Increasing CLA Content

Feeding linseed oil to dairy cattle increased the c9,t11-CLA content of cow's milk between 26% and 318%.[11,19,25] In two studies, the CLA content of milk was 4- to 5-fold greater in dairy cows fed linseed oil plus vitamin E[14] or linseed oil prepared as a calcium salt[15] than in the corresponding control groups. Supplementing dairy cattle rations with a combination of linseed oil and fish oil resulted in a 49% increase in the c9,t11-CLA concentration of cow's milk compared with a diet containing added fish oil and saturated fats.[13] These findings suggest that adding linseed oil to dairy cattle rations results in significant increases in the CLA content of milk.

Decreasing Saturated Fat Content

Supplementing dairy cow rations with linseed oil decreases the overall saturated fatty acid content of milk,[8,14,15,17,19] while increasing the stearic acid content.[11,14,15,17] The levels of medium-chain fatty acids like myristic acid (14:0) and palmitic acid (16:0) in milk decreased 28.1% when Holstein cows were fed a ration supplemented with linseed oil and vitamin E. The milk concentrations of short- and other medium-chain fatty acids were decreased significantly with flax oil and

vitamin E supplementation compared with a control diet.[14] Significant reductions in milk saturated fat content have been achieved by feeding dairy cows rations containing combinations of
linseed oil with fish oil[13] or rapeseed oil;[16] by supplementing the rations with raw milled, micronized or extruded linseed;[11] or by preparing calcium salts of fatty acids from linseed oil for adding to rations.[8]

Good Reasons for Adding Linseed to the Diets of Dairy Cows

Adding linseed to dairy cow rations increases the content of two polyunsaturated fatty acids – specifically, ALA and CLA – and decreases the content of saturated fatty acids in milk. Given the nutritional importance and popularity of milk and milk products such as cheese, yogurt and ice cream, these enhancements give consumers another food option for improving their intake of healthy fats.

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FLAX COUNCIL OF CANADA

Flax Council of Canada, 465–167 Lombard Ave., Winnipeg, MB, Canada R3B 0T6 flax@flaxcouncil.ca www.flaxcouncil.ca 06.2008