FLAX FEED INDUSTRY GUIDE
亚麻籽行业指南

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INTRODUCTION
引言

Flaxseed *(Linum usitatissiumum)* also known as linseed, is thought to be one of the world's oldest cultivated crops with evidence of cultivation dating back thousands of years. The crop is prized for its fibre and oil. The fibre, obtained from the stocks of the plant, is used to make fine linen and paper. The oil is used primarily for industrial purposes. The oil is probably best known for its function in the production of paints and floor covering (linoleum). The by-product remaining after oil extraction – flaxseed meal or linseed meal – is a source of protein used in livestock feeds, especially in the rations of ruminant animals. The seed is also used in livestock production for its medicinal properties, in particular for its functions as a laxative as well as for improving skin and hair quality.

亚麻籽（学名：*Linum usitatissimum*）又叫胡麻籽，是世界上最古老的农作物之一，有迹象表明人类种植亚麻的历史可追溯至数千年前。该作物因其纤维和油而著名：亚麻茎的纤维可用来制做亚麻布和纸；亚麻油主要用于工业用途，最为人所知的大概就是用于生产油漆和地板材料（油毡）。亚麻榨油后的副产品亚麻籽粕或胡麻籽粕可用作家畜饲料，为家畜，尤其是反刍动物家畜提供蛋白质。亚麻籽对畜牧业生产同样具有药用价值：亚麻籽可用作通便剂，也可用来提高家畜皮毛的质量。

Recently there has been a renewed interest in using flaxseed and flax oil in animal rations as it can be used to alter the fatty acid composition of egg and meat products and, therefore, provide functional health benefits for the consumer. The purpose of this guide is to provide practical information to users who wish to feed flaxseed to their livestock.

近年来人们对于在动物饲料中添加亚麻籽和亚麻油越来越感兴趣，因为它可以有效改变蛋类和肉类产品的脂肪酸组成，从而为消费者提供实在的健康好处。本指南旨在为那些想用亚麻籽饲喂家畜的用户提供实用的操作信息。

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ALA (alpha-linolenic acid C18:3n-3), CLA (conjugated linoleic acid), DHA (docosahexaenoic acid C22:6n-3), EPA (eicosapentaenoic acid C20:5n-3), LA (linoleic acid C18:2n-6), Linseed meal (flaxseed product remaining following oilseed extraction), PUFA (polyunsaturated fatty acids).

α-亚麻酸（alpha-linolenic acid C18:3n-3，英文缩写ALA）， 共轭亚油酸（conjugated linoleic acid，英文缩写CLA），二十二碳六烯酸（docosahexaenoic acid C22:6n-3，英文缩写DHA），二十碳五烯酸（eicosapentaenoic acid C20:5n-3，英文缩写EPA），亚油酸（linoleic acid C18:2n-6，英文缩写LA），胡麻籽粕（榨油后剩余的亚麻籽产品），多不饱和脂肪酸（polyunsaturated fatty acids，英文缩写PUFA）。

SECTION 1 – HEALTH BENEFITS
第一节 对健康的好处

Flaxseed has been consumed for centuries for its good flavour and for its nutritional properties. In recent years, as people have become more concerned about health, demand for flax in food and beverages, functional foods and dietary supplements has risen dramatically.
亚麻籽味道好，富有营养，人类食用亚麻籽已有好几个世纪了。近些年，随着人们越来越关注健康，人们对亚麻用于食品、饮料、功能性食物和膳食补充剂方面的需求已大幅上升。

Typically flaxseed contains between 42 to 46% fat, 28% dietary fibre, 21% protein, 4% ash, and 6% carbohydrates. Flaxseed oil has a very healthy fatty-acid profile, with low levels (approximately 9%) of saturated fat, moderate levels (18%) of monounsaturated fat, and high concentrations (73%) of polyunsaturated fatty acids (PUFAs). The PUFA content comprises about 16% omega-6 fatty acids, primarily

as linoleic acid (LA), and 57% alpha-linolenic acid (ALA C18:3n-3), an omega-3 fatty acid (Table 1).

亚麻籽通常含有42%-46%的脂肪、28%的膳食纤维、21%的蛋白质、4%的灰分和6%的碳水化合物。亚麻油的脂肪酸构成比例非常健康，它含有较少的（约9%）饱和脂肪、中等含量的（18%）单元不饱和脂肪以及非常多的（73%）的多不饱和脂肪酸（英文缩写PUFA）。所含的多不饱和脂肪酸中约有16%的欧米茄-6脂肪酸（以亚油酸（英文缩写LA）为主）；及57%α-亚麻酸（ALA C18:3n-3）（一种欧米茄-3脂肪酸，请见表（一））。

Both LA and ALA are essential fatty acids (EFAs) since they cannot be produced by the body and must come from the diet. ALA can be converted in the body to eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) (Burdge and Wootton, 2002; Harper et al., 2006). EPA and DHA are also found in marine oils, primarily in fish oil. Omega-3 fatty acids have been shown to have numerous health benefits including a reduction in inflammation, blood pressure and decreased blood triglyceride levels and incidence of coronary heart disease. Omega-3 fatty acids are a special class of lipids which have a double bond at the 3rd carbon from the methyl end. The unsaturated oil in most plant sources is rich in fatty acids with the first double bond 6 carbons from the methyl end of the molecule (omega-6) and, therefore, Western diets consist predominantly of high ratios of omega-6 to omega-3 fatty acids.

由于人体不能生成亚油酸和α-亚麻酸，而必须从食物中摄取，故它们均为必需脂肪酸（英文缩写EFA）。α-亚麻酸可在人体内转换成二十碳五烯酸（英文缩写EPA）和二十二碳六烯酸（英文缩写DHA）（作者：Burdge和Wootton， 2002年；作者：Harper等，2006年）。EPA和DHA也可见于鱼油等海洋生物油中。已经有证据显示，欧米茄-3脂肪酸对健康有诸多好处，包括减轻炎症，降血压，降低血液中甘油三酸脂水平及减少冠心病的发病率等。欧米茄-3脂肪酸是一种特殊类别的脂质，这些脂质在甲基一端3碳处有一个双键。大多数植物不饱和油富在甲基一端6碳处带有双键的脂肪酸（欧米茄-6脂肪酸），因此，西方饮食摄入欧米茄-6脂肪酸远多于欧米茄-3脂肪酸。

EPA is a 20 carbon fatty acid which has 5 double bonds with the first being 3 carbons from the methyl end (C20:5n-3). DHA comprises 22 carbons, has 6 double bonds with the first being found 3 carbons from the methyl end (C22:6n-3). EPA is a precursor to eicosanoids—compounds produced by the body that exert hormone-like activity. They are involved in the mediation of inflammatory responses, production of pain and fever, blood pressure regulation, induction of blood clotting, control of reproductive functions and regulation of the sleep/wake cycle. Eicosanoids produced from omega-6 fatty acids tend to promote inflammation, increased blood pressure and blood clotting, whereas those produced from omega-3 fatty acids, especially EPA, do not. DHA is also required for the normal growth and development of the fetus and infant.

EPA（二十碳五烯酸）是甲基一端从3碳起有五个双键的20碳脂肪酸（C20:5n-3）。DHA（二十二碳六烯酸）由22个碳组成，甲基一端从3碳起有六个双键（C22:6n-3）。EPA是类花生酸的前体，这些由人体生成的复合物，可以产生类似荷尔蒙的作用，在人体中参与调节炎症反应、产生疼痛和发烧、调节血压、诱导血液凝结、控制生殖功能并调节醒睡周期。由欧米茄-6脂肪酸产生的类花生酸易于促发炎症、血压上升和血液凝结，而由欧米茄-3脂肪酸产生的类花生酸，特别是EPA则不会。胎儿和婴儿正常的生长和发育也需要DHA。

Due to the role of omega-3 fatty acids in human health, the Institute of Medicine recommends that adult males and females consume 1.6 g/day and 1.1g/day of ALA, respectively (Anon, 2002). Traditionally, the primary source of omega-3 fatty acids in the diet was fatty fish but the amount consumed in Western cultures tends to be limited by availability and dietary preferences, so researchers have developed creative ways to incorporate the omega-3 ALA, EPA and DHA into foods found commonly in Western diets. Foods derived from feeding animals flaxseed and flax oil are described in this document.

由于欧米茄-3脂肪酸在人类健康中的作用，美国国家医学院（Institute of Medicine）建议，成年男子每日食用1.6 克α-亚麻酸，成年女子每日食用1.1克α-亚麻酸（作者：Anon，2002年）。在过去的传统饮食上，欧米茄-3脂肪酸的主要来源是多脂肪鱼类，但其食用的量易受获取途径是否方便，以及人们饮食偏好的影响。故研究人员现已开发出多种方法，将α-亚麻酸、EPA和DHA等欧米茄-3脂肪酸，融入到西式膳食中常见食物中内。本文将阐述用亚麻籽和亚麻油饲喂家畜以增加食物中欧米

茄-3脂肪酸含量的方法。

Flaxseed contains approximately 28% dietary fibre in a ratio of soluble to insoluble fibre between 20:80 and 40:60 (Hadley et al., 1992). Flaxseed is also rich in lignans, phytoestrogens which have chemical structures similar to the human hormone estrogen that, despite being much weaker than human estrogens, can help balance hormone levels in the body. Flaxseed is one of the richest sources of lignans, providing 75 to 800 times higher levels than other plant sources (Thompson, 1995).

亚麻籽约含28%的膳食纤维，其可溶性与不溶性纤维的比例介于20:80与40:60之间（作者：Hadley等，1992年）。亚麻籽还富含木脂素、植物雌激素，它们的化学结构类似于人体荷尔蒙雌激素，虽然它们较弱于人体雌激素虽然它们活性比人体雌激素弱，但仍旧可以帮助平衡人体内的荷尔蒙水平。亚麻籽是最好的富含木脂素的来源之一，它的木脂素含量比其他植物来源高出75至800倍（作者：Thompson，1995年）。

The major lignan in flax is seicoisolariciresinol diglucoside, commonly referred to as SDG. Once ingested, SDG is converted in the colon to enterodiol and enterolactone, which have shown promise in reducing growth of cancerous tumors, especially hormone-sensitive ones such as those of the breast, endometrium and prostate (Tham et al., 1998). Lignans and other flax components also have antioxidant properties and, hence, may reduce the activity of cell-damaging free radicals (Prasad, 2001).

亚麻中的主要木脂素是亚麻木酚素, 常被称为SDG。被人体摄取后，SDG会在结肠内被转化成肠二醇和肠内脂，可以有效减弱癌样肿瘤的增长，对尤其是激素敏感性的肿瘤，如乳房、子宫内膜和前列腺癌样肿瘤尤其有效（作者：Tham等，1998年）。木脂素和其他亚麻成分还有抗氧化特性，因此可减少自由基造成的细胞损伤的活动（作者：Prasad，2001年）。

Significant to the animal feed area is the protein component in flaxseed that is very similar to that of soybean protein. Flaxseed also contains a number of important essential minerals and minor amounts of water- and fat-soluble vitamins.

亚麻籽中的蛋白质成分类似于大豆中所含的蛋白质成分，这一特点对于动物饲料非常重要。亚麻籽还含有一些重要的必需矿物质和少量的水溶性和脂溶性的维生素。

Research continues to expand the use of flaxseed for both animal health as well as to develop healthier animal products for humans.

研究人员正在持续推动亚麻籽在动物健康，以及人类健康食品生产上的应用。

TABLE 1. Fatty acid composition of No. 1 Canada Western Flax (10 year average, DeClercq, 2006)

表（一） 特级加拿大西部亚麻的脂肪酸组成（10年平均值，作者：DeClercq，2006年）

FATTY ACID	CHEMICAL STRUCTURE	% IN OIL
Palmitic acid	C16:0	5.2
Steric acid	C18:0	3.4
Oleic acid (omega-9)	C18:1	18.1
Linoleic acid (omega-6)	C18:2N-6	15.0
Linolenic acid (omega-3)	**C18:3N-3**	**57.9**

脂肪酸	**化学结构**	**占油的%**
棕榈酸	C16:0	5.2
硬脂酸	C18:0	3.4
油酸（欧米茄-9）	C18:1	18.1
亚油酸（欧米茄-6）	C18:2N-6	15.0

亚麻酸（欧米茄-3）　　C18:3N-3　　57.9

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Photo courtesy of Saskatchewan Flax Development Commission.
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SECTION 2 – PROCESSING
第二节　加工

The majority of flaxseed is processed to extract oil for use in industrial products such as paints or floor coverings. Therefore, the primary objective of processing is to efficiently extract oil from the seed. Following oil extraction a meal is produced that is concentrated in protein and used in livestock feeds; this product is often referred to as linseed meal. The methods of oil extraction commonly employed are very similar to those used for other high fat oilseeds such as canola. The two most commonly employed processes are prepress solvent extraction and expeller press extraction. Prepress solvent extraction extracts virtually all of the oil using a combination of mechanical extraction and solvent extraction. In contrast, expeller processing relies solely on mechanical pressure to extract oil and leaves residual oil in the meal, typically greater than 5%. Since processing method has such a significant impact on oil content and, therefore, the energy content of the meal, it is important to understand the method of processing used.

大部分亚麻籽都用于榨油以生产工业产品如油漆或地板材料，因此，亚麻籽加工的主要目的是有效地从亚麻籽中榨出油来。榨完油之后，剩下的是亚麻籽粕，它浓缩了蛋白质，可被用作家畜饲料，这种产品又常被称为胡麻籽粕。亚麻籽油的常见的榨取方法与其他高脂肪油籽如油菜籽的榨取方法类似，最常见的两种是预压溶剂萃取法和螺旋压榨法。预压溶剂萃取法结合机械压榨和溶剂萃取两种手段，几乎可榨出所有的油。相比之下，螺旋压榨法主要依靠机械压力榨油，因此通常会有大于5%油残留在亚麻籽粕内。由于加工方法对亚麻籽粕的含油量，以及其作为食物的能量含量影响很大。因此，全面了解亚麻籽的加工方法是非常重要的。

Prepress Solvent Extraction of Flaxseed
亚麻籽预压溶剂萃取法

Prepress solvent extraction uses a combination of mechanical pressure and chemical extraction and is the preferred oilseed extraction method for most large scale plants as it is the most effective method of extracting oil. Figure 1 shows a schematic of standard prepress solvent extraction used in the extraction of oilseeds such as flax and canola. It includes cleaning of the seed, preconditioning, flaking, cooking, expelling, solvent extraction, desolventization, cooling and discharge as final meal product.

预压溶剂萃取法将机械压榨和化学萃取相结合，是最有效的榨油法，也是大多数大型工厂首选的榨油法。图（一）显示的是用来榨油籽如亚麻和油菜籽的标准预压溶剂萃取法的原理图，该图包括清洗油籽、预处理、压薄片、煮制、压榨、溶剂萃取、脱溶剂、冷却并排出最后的亚麻籽粕产品等步骤。

The seed is typically cleaned to remove stones, chaff or dirt to prevent damage or wear on the processing equipment. The seed is then warmed to prevent it from shattering during the flaking stage. Flaking consists of passing the seed through a roller mill comprising two smooth-faced rolls with only a very small gap between them. The seed is fed between the rolls and crushed into a very thin flake. The objective of flaking is to rupture the cell walls and to increase the surface area for oil extraction. The seed is cooked to reduce the viscosity of the oil and to allow it to migrate out of storage bodies in the seed. This step is accomplished by feeding the seed into a stacked cooker which has a series of heated plates onto which the seed sits. The seed is swept over the heated plates and falls to the next plate until it exits the unit heated and, therefore, prepared for extraction.

为了避免损坏或磨损加工设备，通常要先清洗亚麻籽，去除石子、籽壳或沙土，然后将亚麻籽加温，防止在压薄片阶段，亚麻籽被压成粉碎。压薄片工序包括将亚麻籽送入辊磨机。辊磨机由两个光滑表面的滚筒组成，它们之间只有一个非常小的缝隙，亚麻籽被送入这两个滚筒间，并被压成很薄的薄片。压薄片的目的是要破开亚麻籽的细胞壁，并增加表面面积以便榨油。煮制亚麻籽可以降低油的粘度，使油从其蓄油体中流出。进行做这一步时, 亚麻籽会被放入一个带有若干个叠放在一

起的加热板的加热器中。加热时，亚麻籽会从上层加热板，被逐层扫至下层加热板，直到离开这个加热设备，完成加热，以备榨油。

Prepressing is achieved by feeding the flaked, heated seed into a mechanical expeller press. The expeller press consists of a heavy metal screw that forces the seed through a chamber that has fine openings in the wall to allow oil to squeeze through while retaining the solid portions of the seed. The screw is configured such that it pushes the seed against the outer wall of the chamber as it feeds it down the barrel. This compression effect forces the oil out of the small openings in the wall and is collected

(Figure 2). This process extracts approximately half of the oil and prepares a “meal” or “cake” that is suitable for solvent extraction.

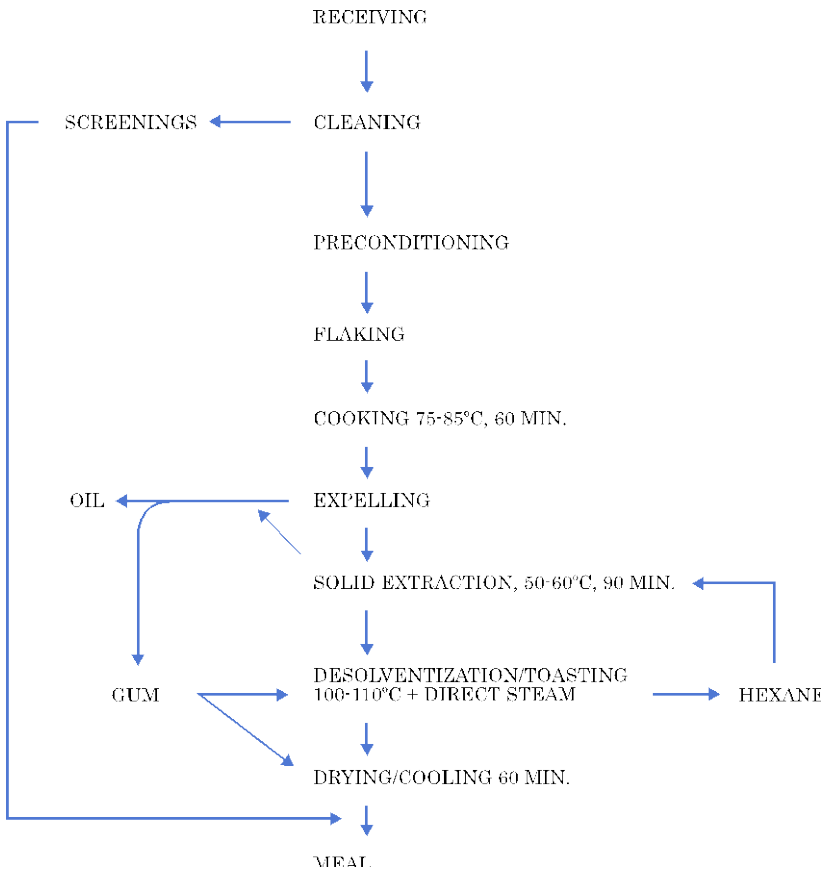
预压是将已被压成薄片并经加热处理的亚麻籽放入机械螺旋榨油机内。榨油机内有一个大型金属榨螺，它将亚麻籽推进榨膛。榨膛壁上有一个个小孔，油受挤压从这些开口处流出，同时留住亚麻籽的固体成分。榨螺装置可以在送料进入圆筒时，将亚麻籽往榨膛外壁方向推挤，这样挤压的效果迫使油从膛壁的小孔流出并被收集起来，请见图（二）。这道工序约榨出一半的油，并制成适合溶剂萃取的亚麻籽粕或饼渣。

The presscake or meal exits the expeller and is conveyed into a solvent extractor. Hexane, a non-polar solvent, is flushed through the cake and solubilizes and absorbs the oil from the flax meal. After the oil extraction is complete, the solvent is allowed to drain out of the meal. The solvent is pumped into an evaporator and the hexane is boiled off leaving the oil for further refining. The solvent-laden meal is then conveyed into a solvent extractor, where it is heated by passing the meal over steam heated plates causing much of the hexane to evaporate. Steam is often purged through the meal in the final stages as well to strip the last remnants of the hexane from the meal. The hexane vapours are cooled, condensed and collected for use again.

饼渣或亚麻籽粕排出螺旋榨油机，并被传送到溶剂萃取机内。无极性溶剂己烷被注入饼渣，溶解并吸收亚麻籽粕中的油。萃取过程完成之后，萃取溶剂会从亚麻籽粕中排出，并被泵入蒸发器。在蒸发器中己烷会被蒸发掉，余下的油则静待进一步精炼。含有溶剂的亚麻籽粕将被送进溶剂萃取机内，放到蒸汽加热板上加热，蒸发掉大部分的己烷。在最后阶段，蒸汽将完全蒸透亚麻籽粕，除去亚麻籽粕中最后残余的己烷，使之净化。己烷蒸汽经冷却、浓缩并回收以备再用。

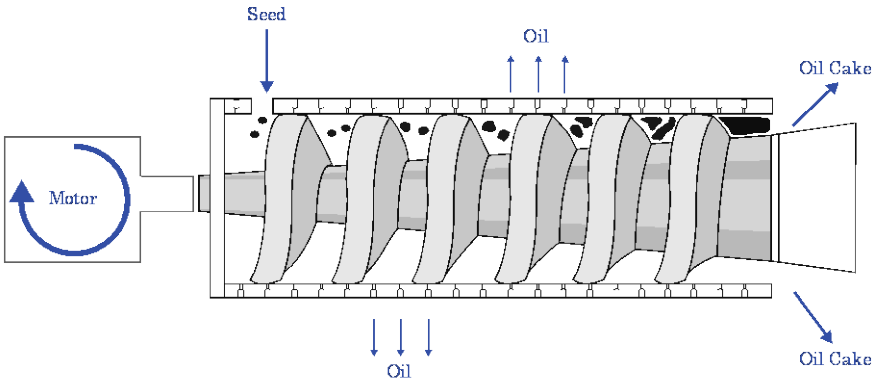
The hot meal is then fed into a cooler where ambient air is blown through in order to cool and dry the meal. The screenings and gums are mixed into the meal which is then hammer milled in preparation for sale as a feed ingredient.

之后，热的亚麻籽粕会被送入冷却机，利用外界冷空气，冷却并吹干亚麻籽粕。最后将筛渣和亚麻胶拌入亚麻籽粕，然后将其锤磨，作为饲料原料以待出售。



	收货	
筛渣	清洗	
	预处理	
	压薄片	
	煮制75-85°C，60分钟	
油	压榨	
	固体油渣，50-60°C，90分钟	
胶	脱溶剂（烘烤） 100-110°C + 直接蒸汽	己烷
	干燥（冷却）60分钟	
	亚麻籽粕	

FIGURE 1: Schematic of standard prepress solvent extraction.
图（一）：标准预压溶剂萃取法的原理图



	亚麻籽		油	油饼
马达				
		油		油饼

FIGURE 2: Cross section of an expeller press.
图（二）：螺旋榨油机截面图

Mechanical Extraction of Flaxseed
亚麻籽机械榨油法

Prepress solvent extraction is employed by most large crushing plants but the cost of building such a plant is very high (between $100 and $200 million) and, therefore, is not practical for small companies. Expeller plants can be economically constructed from small scale (<0.25 T/day) to large scale (1000 T/day) but they do leave residual oil in the meal. With the recent interest in incorporating flax oil into human diets, some choose to sell mechanically extracted oil – often referred to as cold pressed oil – on the basis that a solvent was not used in the process of extraction and this may appeal to some users. In addition, some companies are extracting oil for the local livestock industry to promote the production of omega-3 enriched products. In these cases mechanical extraction is often the method of choice due to the low capital investment required and the potential for small scale extraction. In some cases, feed companies can set up a mechanical extraction press for the production of oil and meal at the feedmill.

虽然大多数大型榨油厂采用预压溶剂萃取法，但是建造这样一座工厂的费用却很高（介于1亿与2亿加元之间），一般小公司通常无法承受。但是建造一座螺旋榨油机工厂却可以很经济实惠，建厂的规模可从小型（<0.25吨/日）到大型（1000吨/日）。不过用这种方法榨油确实会有余油残留在亚麻籽粕内。近年来随着人们对将亚麻油纳入人类膳食越来越感兴趣，一些公司开始选择销售机械压榨出的油（常被称为冷压油），因为它在榨油过程中不用溶剂，更受消费者的欢迎。此外，一些公司开始为本地畜牧业榨油，用以饲喂动物以生产富含欧米茄-3的畜牧业产品。对这些公司而言，机械榨油法所需的资本投入低，有潜力进行小规模榨油，因此常常得到青睐。在某些情况下，饲料公司也可以在饲料加工厂内安装机械榨油机，以生产油和亚麻籽粕。

The meal product resulting from mechanical extraction (expeller meal or presscake) has a residual oil content of over 5% and offers a meal with elevated energy content as compared to solvent-extracted meal.
机械榨油产出的亚麻籽粕产品（螺旋榨油机产出的亚麻籽粕或饼渣）含有超过5%的残油率，与溶剂萃取产出的亚麻籽粕相比，机械榨油产出的亚麻籽粕所含能量更高。

Mechanical extraction is conducted with the aid of an expeller press (Figure 2). Like prepress solvent extraction, the seed is often cleaned, conditioned, flaked and cooked prior to expelling the oil

(Figure 1). However, unlike prepress solvent extraction, the objective is to extract as much oil as possible through mechanical pressure alone. Therefore, it is common practice to install two sets of expeller presses. The first press extracts approximately 50% of the oil; the cake is then fed into a second press and additional pressure is applied to drive out as much of the remaining oil as possible.

机械榨油是用螺旋榨油机来进行的，请见图（二）。像预压溶剂萃取那样，在榨油前，常要先清洗油籽、预处理、压薄片并煮制，请见图（一）。但是有别于预压溶剂萃取的是，它的榨油目的是只靠机械压榨来尽可能多的榨出油。因此，常见的做法是安装两台螺旋榨油机，第一台榨油机约榨出50%的油，然后将饼渣送入第二台榨油机，再加压，尽可能将残余的油榨出。

SECTION 3 – NUTRITIONAL COMPOSITION
第三节　营养组成

The typical nutrient composition of flaxseed, flax oil, expeller meal and solvent-extracted meal is shown in Tables 2-6. Flaxseed is a rich source of protein and energy; however, the seed does contain some unique anti-nutritional components that need to be considered when feeding this product.

表（二至六）显示亚麻籽、亚麻油、压榨过的亚麻籽粕和溶剂萃取过的亚麻籽粕等的典型营养组成。亚麻籽是蛋白质和能量的优质来源，然而它也含有某些独特的抗营养成分。因此在给喂这种产品时，需要对此加以考虑。

TABLE 2. Typical chemical composition and metabolizable energy content[1] of flaxseed and expeller and solvent-extracted meals

表（二） 亚麻籽、压榨过的亚麻籽粕和溶剂萃取过的亚麻籽粕的典型化学组成和可代谢能量[1]

COMPONENT	SEED	EXPELLER MEAL	SOLVENT MEAL	OIL
Moisture	93	91	88	-
Crude Protein (N x 6.25) %	22	31.5	33	-
Ether extract (%)	40.5	5.1	0.5	-
Crude fibre (%)	6.5	9.5	9.5	-
Ca (%)	0.25	0.40	0.35	-
P (%)	0.50	0.80	0.75	-
Ash (%)	-	6.0	6.0	-
Gross Energy (kcal/kg)	6530	4500	-	-
AME (kcal/kg)	3800	1850	1400	8150
AMEn (kcal/kg)	3750	2070	-	8100
TME (kcal/kg)	3960	2240	-	8610
TMEn (kcal/kg)	3750	2070	-	8280

成分	亚麻籽	压榨过的亚麻籽粕	溶剂萃取过的亚麻籽粕	油
水分	93	91	88	-
粗蛋白质（N x 6.25）%	22	31.5	33	-
醚提取物（%）	40.5	5.1	0.5	-
粗纤维（%）	6.5	9.5	9.5	-
钙（%）	0.25	0.40	0.35	-
磷（%）	0.50	0.80	0.75	-
灰分（%）	-	6.0	6.0	-

总能量（千卡/千克）	6530	4500	-	-
表观代谢能（AME）（千卡/千克）	3800	1850	1400	8150
氮校正代谢能（AMEn）（千卡/千克）	3750	2070	-	8100
真代谢能（TME）（千卡/千克）	3960	2240	-	8610
氮校正真代谢能（TMEn）（千卡/千克）	3750	2070	-	8280

[1] *Adapted from Feedstuffs 2008 Reference Issue and Buyers Guide, Lee et al. 1995, and DeClercq, 2006.*

[1]*改编自《饲料2008特辑与买家指南》（Feedstuffs 2008 Reference Issue and Buyers Guide），作者：Lee等，1995年，及DeClercq，2006年。*

TABLE 3. Typical amino acid content[1] (% as received) of flaxseed and expeller and solvent-extracted meals

表（三） 亚麻籽、压榨过的亚麻籽粕和溶剂萃取过的亚麻籽粕的典型氨基酸含量[1]（%按来样计算）

AMINO ACID (%)	SEED	EXPELLER MEAL	SOLVENT MEAL
Methionine	0.37	0.53	0.48
Cysteine	0.42	0.56	0.58
Lysine	0.99	1.18	1.10
Tryptophan	0.22	0.47	0.48
Threonine	0.89	1.12	1.20
Isoleucine	1.07	1.50	1.80
Histidine	0.53	0.60	0.70
Valine	1.43	1.49	1.60
Leucine	1.43	1.87	2.00
Arginine	2.23	2.54	2.70
Phenylalanine	1.15	1.43	1.50

氨基酸（%）	亚麻籽	压榨过的亚麻籽粕	溶剂萃取过的亚麻籽粕
蛋氨酸	0.37	0.53	0.48
半胱氨酸	0.42	0.56	0.58
赖氨酸	0.99	1.18	1.10
色氨酸	0.22	0.47	0.48
苏氨酸	0.89	1.12	1.20
异亮氨酸	1.07	1.50	1.80
组氨酸	0.53	0.60	0.70
缬氨酸	1.43	1.49	1.60
亮氨酸	1.43	1.87	2.00
精氨酸	2.23	2.54	2.70
苯丙氨酸	1.15	1.43	1.50

[1]*Adapted from Feedstuffs 2008 Reference Issue and Buyers Guide and Lee et. al. 1995.*

[1]*改编自《饲料2008特辑与买家指南》（Feedstuffs 2008 Reference Issue and Buyers Guide），作者：Lee 等，1995年。*

TABLE 4. Amino acid digestibility (%) of flaxseed and expeller and solvent-extracted meals
表（四） 亚麻籽、压榨过的亚麻籽粕和溶剂萃取过的亚麻籽粕的氨基酸消化率（%）

COMPONENT	SEED[1] TAAA[2]	SEED[1] AAAA[3]	EXPELLER MEAL[1] TAAA[2]	EXPELLER MEAL[1] AAAA[3]
Methionine	76	73	79	76
Lysine	81	70	80	69
Threonine	71	61	74	65
Isoleucine	83	76	82	76
Histidine	85	78	79	72
Valine	80	72	80	74
Leucine	85	75	81	75
Arginine	87	81	88	82
Phenylalanine	83	78	85	80

成分	亚麻籽[1] TAAA[2]	亚麻籽[1] AAAA[3]	压榨过的亚麻籽粕[1] TAAA[2]	溶剂萃取过的亚麻籽粕[1] AAAA[3]
蛋氨酸	76	73	79	76
赖氨酸	81	70	80	69
苏氨酸	71	61	74	65
异亮氨酸	83	76	82	76
组氨酸	85	78	79	72
缬氨酸	80	72	80	74
亮氨酸	85	75	81	75
精氨酸	87	81	88	82
苯丙氨酸	83	78	85	80

[1]*Lee et al. 1995.*

[2]*TAAA=True Amino Acid Availability.*

[3]*AAAA=Apparent Amino Acid Availability.*

[1]*作者：Lee等，1995年。*

[2]*TAAA=真氨基酸有效性。*

[3]*AAAA=表观氨基酸有效性。*

TABLE 5. Typical vitamin content of flaxseed and expeller and solvent- extracted meals
表（五） 亚麻籽、压榨过的亚麻籽粕和溶剂萃取过的亚麻籽粕的典型维生素含量

VITAMINS	SEED[1]	EXPELLER	SOLVENT

		MEAL[1]	MEAL[1]
Vitamin A (IU/g)	-	0.3	-
Vitamin E (mg/kg)	18.9	7.7	5.8
Thiamin (mg/kg)	7.0	2.60	6.6
Riboflavin (mg/kg)	4.5	4.10	4.10
Pantothenic acid (mg/kg)	-	16.5	16.5
Folic acid (ug/kg)	-	2900	1300
Choline (mg/kg)	3150	1672	1760
Niacin (mg/kg)	41.0	37.4	32.8

维生素	亚麻籽	压榨过的亚麻籽粕[1]	溶剂萃取过的亚麻籽粕[1]
维生素A（国际单位/克）	-	0.3	-
维生素E（毫克/千克）	18.9	7.7	5.8
硫胺素（毫克/千克）	7.0	2.60	6.6
核黄素（毫克/千克）	4.5	4.10	4.10
泛酸（毫克/千克）	-	16.5	16.5
叶酸（微克/千克）	-	2900	1300
胆碱（毫克/千克）	3150	1672	1760
烟酸（毫克/千克）	41.0	37.4	32.8

[1]*Feedstuffs 2008 Reference Issue and Buyers Guide* .

[1]*《饲料2008特辑与买家指南》（Feedstuffs 2008 Reference Issue and Buyers Guide）*

TABLE 6. Typical mineral content of flaxseed and expeller and solvent-extracted meals
表（六） 亚麻籽、压榨过的亚麻籽粕和溶剂萃取过的亚麻籽粕的典型矿物质含量

MINERALS	SEED[1]	EXPELLER MEAL[1]	SOLVENT MEAL[1]
Sodium (%)	0.08	0.11	0.14
Potassium (%)	1.50	1.24	1.38
Magnesium (%)	0.50	0.58	0.60
Sulphur (%)	-	0.39	0.39
Manganese (ppm)	-	39.4	37.6
Iron (ppm)	236	200	300.0
Copper (ppm)	22	26.4	25.7
Zinc (ppm)	91	-	-
Selenium (ppm)	-	0.5-1.0	0.5-1

矿物质	亚麻籽[1]	压榨过的亚麻籽粕[1]	溶剂萃取过的亚麻籽粕[1]
钠（%）	0.08	0.11	0.14
钾（%）	1.50	1.24	1.38
镁（%）	0.50	0.58	0.60
硫磺（%）	- 0.39	0.39	
锰（百万分率）	- 39.4	37.6	
铁（百万分率）	236	200	300.0
铜（百万分率）	22	26.4	25.7
锌（百万分率）	91	-	-
硒（百万分率）	-	0.5-1.0	0.5-1

[1]*Feedstuffs 2008 Reference Issue and Buyers Guide.*

[1]*《饲料2008特辑与买家指南》（Feedstuffs 2008 Reference Issue and Buyers Guide）*

Anti-Nutritional Components

抗营养成分

Flax contains the cyanogenic glycosides called linustatin, neolinustatin and linamarin. These compounds are degraded by ß-glucosidase in the large intestine and may cause the release of hydrogen cyanide, albeit in small amounts. Hydrogen cyanide is a powerful respiratory inhibitor if absorbed in sufficient quantities. The primary cyanogenic glycoside in flaxseed is linamarin and it ranges from 0 to 300mg/kg. Heat treatment of the seed such as that encountered during oil extraction tends to denature the ß-glucosidase preventing the formation of hydrogen cyanide. Shen et al. (2005) suggests that part of the positive effects of heat treatment of flaxseed may be due to the denaturation of ß-glucosidase and, therefore, the prevention of any negative effect of linamarin. However, in most cases, mature flaxseed is fed without heat treatment with little or no impact of linamarin being observed. Linamarin is, however, concentrated in immature seeds and could have a negative impact on animal performance if fed without heat treatment.

亚麻含有多种生氰糖苷，它们被称为β-龙胆二糖丙酮氰醇、β-龙胆二糖甲乙酮氰醇和亚麻苦苷。这些化合物在大肠内被β-葡[萄]糖苷酶降解，可释放出氢氰酸。虽然由亚麻产生的氢氰酸释放量很少，但是如果吸入足量的氢氰酸，它会是很强的呼吸抑制剂。亚麻籽里主要的生氰糖苷是亚麻苦苷，它的含量介于0至300毫克/千克。对亚麻籽进行热处理加热（如在榨油时的热处理），可促使β-葡[萄]糖苷酶变性，防止产生氢氰酸。Shen等（2005年）提示说，对亚麻籽进行加热处理产生的正效应可能部分由于它改变了β-葡[萄]糖苷酶的性质，从而防止了亚麻苦苷的生成及其负作用。然而，在大多数情况下，对于成熟亚麻子而言，即使我们使用未经加热的亚麻籽来喂食动物，在大多数情况下我们也不会观测到任何亚麻苦苷的产生负影响。但是，在未成熟的亚麻子中通常含有高浓度的亚麻苦苷，如果未经加热处理就给喂，可能会对动物产生负面影响。

Flax contains a vitamin B_6 (pyridoxine) antagonist called linatine. The concentration typically ranges from 20-100 mg/kg. Occasionally symptoms of vitamin B_6 deficiency can be observed in broiler chickens fed flax and, therefore, it is recommended that diets containing flaxseed or meal be supplemented with additional pyridoxine to offset the potential negative effects of linatine on this vitamin.

亚麻籽含有被一种被称为N-谷酰胺脯氨酸的维生素B_6（吡哆醇）拮抗剂，其浓度通常介于20-100毫克/千克范围。偶尔可观测到喂食了亚麻的肉鸡出现维生素B_6缺乏的症状，因此，建议含亚麻籽或亚麻籽粕的饲料应增补吡哆醇，以抵消N-谷酰胺脯氨酸对这种维生素可能产生的负作用。

Flax has been commonly used for its therapeutic effects in livestock including alleviation of constipation and enhanced digestive tract functions. Mucins (mucilage) are water soluble, indigestible, mucilaginous

carbohydrates composed of galactose, xylose, arabinose, rhamnose and galacuronic acid sub-units that absorb water and increase intestinal viscosity. These mucins are likely responsible for the therapeutic effects of feeding flaxseed. Mucilage is found in the outer hull of the seed and accounts for approximately 8% of the weight of the seed. Feeding flaxseed can result in reductions in poultry performance, especially when fed to young birds. Increased digesta viscosity due to the consumption of high levels of mucilage is likely the cause of the losses in performance (Alzueta, et al. 2003). Slominski et al. (2006) examined the potential to increase nutrient utilization with a combination of fibre-degrading enzymes. They demonstrated a reduction in viscosity and increased performance using a cocktail of enzymes; however, they concluded that an enzyme that specifically targets flax mucilage is required and to date no such enzyme is currently commercially available. Since young animals are most sensitive to the negative affect of increased intestinal viscosity, flaxseed or meal inclusion in young poultry diets should be avoided. In addition, flaxseed should be introduced gradually to prevent digestive upsets.

亚麻同样常用于治疗家畜疾病，其功能包括减轻便秘，加强消化道功能等。这是由于亚麻籽含有一种叫做粘质物素（粘质物）的水溶性、难消化、黏性的碳水化合物。它由半乳糖、木糖、树胶醛醣、鼠李糖和半乳糖醛酸基亚基组成，可以吸收水分并增加肠内消化物粘度。粘质物常见于亚麻籽的外壳，约占亚麻籽重量的8%。有时给禽类喂食亚麻籽可导致其生产性能下降，尤其是在给幼雏喂养亚麻籽时。其原因也可能是因为进食了高含量的粘质物而引起消化物粘度增加（作者：Alzueta等，2003年）。Slominski等（2006）研究了用复合纤维素降解酶来提高营养素利用率的可能性。他们证明了使用复合纤维素降解酶可降低消化物粘度并提高生产性能。但是他们同样指出，要达到最佳效果，需要一种专门针对亚麻籽粘质物的酶，但是目前市面上还没有这种酶。由于幼雏对肠消化物粘度增加的副作用最为敏感，因此应该避免在幼雏饲料中添加亚麻籽或亚麻籽粕。此外，添加亚麻籽时应该逐步少量添加，以防消化不良。

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SECTION 4 – POULTRY
第四节　家禽

Flaxseed and meal have traditionally been used primarily in equine and bovine diets and laying hen rations. However, flax can be included in poultry diets if used in the proper proportions and formulated appropriately. Several companies are now marketing poultry products that are enriched in omega-3 through the feeding of flaxseed. The most popular commercial product is omega-3 eggs available in most grocery stores throughout North America. Research is also being conducted with flax to produce omega-3 enriched poultry meat products.

在传统上，亚麻籽和亚麻籽粕主要被用于马、牛和蛋鸡的饲料里。但是，如果比例合适，配方恰当，亚麻籽也可加入其他禽类的饲料中。不少公司已经开始通过给家禽喂食亚麻籽的方法，来生产并推广富含欧米茄-3的禽类产品。其中最受欢迎的，就是在整个北美地区大多数食杂店里都能找到的欧米茄-3鸡蛋。此外，对于利用亚麻籽来生产富含欧米茄-3的家禽肉制品的研究，也正在进行中。

Laying Hens
蛋鸡

Flaxseed meals can be fed to laying hens as a source of protein and energy. It is very similar to canola meal in protein and energy content but tends to be limiting in lysine. The amino acid digestibility is less than that of soybean meal, so it is important to formulate on a digestible amino acid basis. Flax meal, however, should be limited to 3% of the diet in young birds and 10% in the laying ration due to the potential anti-nutritional effects of mucilage, linatine and linamarin (see page 10).

亚麻籽可作为蛋白质和能量的来源，添加到蛋鸡的饲料中。其蛋白质含量和能量近似于油菜籽粕，只是赖氨酸含量较低。由于它的氨基酸消化率小于大豆粕，因此需要注意以在可消化氨基酸为标准进行饲料配制。但是，由于粘质物、N-谷酰胺脯氨酸和亚麻苦苷可能产生的抗营养作用（请见第10页），亚麻籽粕在幼雏饲料中不应超过3%，蛋鸡饲料中不应超过10%。

Given the many positive effects of omega-3 fatty acids, many consumers are looking for convenient ways to incorporate them into their diets. Consuming eggs enriched with omega-3 fatty acids is a convenient way to do so. The fatty acid profile, including the omega-3 content of eggs is affected by dietary fat source. Research studies consistently demonstrate an increase in the omega-3 fatty acid content of eggs, especially ALA, when laying hens are fed flax oil or flaxseed. For example, Bean and Leeson (2003) conducted a long term feeding study with 10% flaxseed in a laying hen ration consisting primarily of corn and soybean meal. Flax increased the total omega-3 content of the eggs from 99.8 to 415.4 mg/50g egg. ALA increased from 38.5 to 306.3 while DHA increased from 53.3 to 83.7 mg/50 g egg, when fed 10% flaxseed.

鉴于欧米茄-3脂肪酸的健康功效，许多消费者正在寻找各种方法将其纳入日常膳食中。进食富含欧米茄-3脂肪酸的鸡蛋就是一种很方便的做法。鸡蛋的脂肪酸组成以及其欧米茄-3含量，受饲料中脂肪源的影响很大。已有多项研究证明，给蛋鸡喂食亚麻油或亚麻籽时，鸡蛋的欧米茄-3，尤其是α-亚麻酸的含量会有所增多。例如，Bean和Leeson（2003年）做了一项长期喂食研究，在以玉米

和大豆粕为主的蛋鸡饲料中添加10%亚麻籽，结果这种鸡蛋总的欧米茄-3含量从每50克蛋含99.8毫克升到415.4毫克，α-亚麻酸含量从每50克蛋含38.5毫克升到306.3毫克，二十二碳六烯酸（DHA）从53.3毫克升到83.7毫克。

Several studies have demonstrated that feeding flaxseed can potentially reduce feed intake, body weight and egg production, especially in the early stages of production. However, Bean and Leeson (2003) demonstrated that feeding 10% flax did not impact egg production if the flaxseed is phased into the diet over a three week period starting at 28 weeks of age. At weeks 28, 29 and 30 the hens were fed 4, 8 and 10% flax respectively. Similarly at 54, 55 and 56 weeks of age the flax was phased out of the ration. Other studies that did not phase the flax into the diet did observe negative effects in performance. In some cases the metabolizable energy content of the seed was overestimated and likely contributed to the reductions in performance as well. Therefore, it is recommended that flax be introduced in a gradual manner and only after the birds have reached maturity and that a conservative value for metabolizable energy be utilized.

一些研究证明，给鸡喂食亚麻籽，尤其是在鸡生长初期喂食亚麻籽，可能会降低鸡的采食量、体重和蛋产量。但是，Bean和Leeson（2003年）证明，如果在鸡龄28周时，开始在三周内逐渐将亚麻籽添加到饲料中，那么喂食10%亚麻籽并不会影响蛋产量。在他们的实验中，蛋鸡在第28、29和30周时，分别喂食4%、8%和10%亚麻，然后在第54、55和56周时，以类似的方法逐渐减少饲料中的亚麻添加量。在其他没有逐步添加亚麻的实验中，则确实能够观测到对蛋鸡生产性能的副作用。同样在一些情况下，饲养者高估了亚麻籽做为饲料的可代谢能量，从而造成了生产性能的下降。因此，我们建议应逐渐的添加亚麻，并应当利用代谢能的保守值来计算饲料能量。

Flax oil can be fed to laying hens to increase the omega-3 content of the eggs with no negative effects on performance. Grobas et al. (2001) found that ALA increased from 6.3% to 40.2 and 48.3% of the total fat when laying hens were provided 5% and 10% flax oil, respectively. Unfortunately, flax oil is not commonly available to the livestock industry so feeding flaxseed is the more common practice.

给蛋鸡喂食亚麻油，也可以在不产生副作用的情况下，提高鸡蛋的欧米茄-3含量。Grobas等（2001年）发现，在给蛋鸡分别喂5%和10%亚麻油时，α-亚麻酸占总脂肪的比例从6.3%升到40.2%和48.3%。不幸的是，亚麻油不常供给畜牧业，故喂食亚麻籽是更常见的做法。

Some studies have indicated an increased incidence of liver hemorrhage in laying hens fed flaxseed or oil (Schumann et al., 2000). It is believed this effect is likely due to the increased level of oxidation of the polyunsaturated fats like ALA. Other studies, however, such as the one conducted by Bean and Leeson (2003) did not observe this effect. Leeson et al. (2007) observed a reduction in liver hemorrhage when supplementing a flax diet with 250 ppm lutein, suggesting the addition of anti-oxidants to the diets of laying hens may prevent liver hemorrhage and is therefore recommended.

一些研究表明，在喂食亚麻籽或油的蛋鸡中，肝出血发病率有所上升（作者：Schumann等，2000年）。研究人员相信，这种影响可能是因为多不饱和脂肪如α-亚麻酸使得体内氧化反应水平升高。但是其他研究如Bean和Leeson（2003年）所做的研究并未观测到这种影响。Leeson等（2007年）观测到，在亚麻饲料补充250百万分率叶黄素可降低肝出血情况。这表明在蛋鸡饲料中添加抗氧化剂可防止肝出血，所以我们也建议这样做。

Typically flaxseed comprises between 10 and 20% of the diet in order to produce omega-3 enriched eggs. In Canada, food products must contain greater than 300 mg of omega-3 fatty acid per serving in order to be labeled as an omega-3 enriched product. Since one 50g egg is considered a single serving, eggs from laying hens fed 15% flaxseed would qualify since they normally contain approximately 400 mg total omega-3 fatty acid/50g egg. Feeding greater than 20% flaxseed is not recommended as the potential for reduced performance due to anti-nutritional components is too great.

为了要产出富含欧米茄-3的鸡蛋，通常亚麻籽要占饲料的10%到20%之间。在加拿大，每份食品所含欧米茄-3脂肪酸量必须大于300毫克，才可被标为富含欧米茄-3的食品。以一枚50克鸡蛋为一份，通常喂食了15%亚麻籽的蛋鸡所下的蛋即符合这一标准，因为它们通常约含400毫克总欧米茄-3脂肪酸/50克蛋。不建议喂食大于20%亚麻籽，因为其抗营养成分很可能会导致蛋鸡生产性能的下

降。

Broilers
肉鸡

Flaxseed and meal products can be fed to broiler chickens in small amounts. Solvent-extracted meal tends to be limited in energy and lysine for broiler chickens. In addition, feeding flaxseed or meal has been shown to depress growth performance and promote diarrhoea in broiler chickens. The depressed growth rate is likely due to the negative effects of linatine, a vitamin B_6 antagonist, combined with the effects of the intestinal viscosity caused by mucilage. Therefore, the maximum recommended inclusion of flaxseed or meal in broiler diets is 3%. If more than 10% flax is incorporated into the diet, supplementation with additional vitamin B_6 is recommended to overcome the negative effects of linatine.

亚麻籽和籽粕产品可以小量地添加到肉鸡饲料中。但是喂养溶剂萃取后的籽粕易于限制肉鸡的能量和赖氨酸摄取量。此外，也有证据显示大量喂食亚麻籽或籽粕会抑制肉鸡生长，并引起腹泻。其原因可能来自亚麻籽中N-谷酰胺脯氨酸（一种维生素B_6拮抗剂）的负作用，以及粘质物引起的肠道消化物粘度增加作用。因此，建议在肉鸡饲料中添加亚麻籽或籽粕的最大量为不超过3%。如果饲料中添加超过10%亚麻，建议应增补维生素B_6，以抑制N-谷酰胺脯氨酸的负作用。

Flax oil can be used to increase the omega-3 content of the broiler carcass without negatively affecting bird performance. Rymer and Givens (2006) demonstrated an increase of ALA from 30 to 99.4 and 139 mg/100g of white meat when broilers were fed 2 or 4% flax oil, respectively. EPA increased from 7.2 to 7.8 and 16.8 mg/100 g white meat when fed 2 or 4% flax oil, respectively. However, feeding flax oil had no effect on DHA content of the white muscle in the same study. Similarly, feeding flax oil increases the omega-3 fatty acid content in dark muscle. ALA content of dark meat increased from 57 to 158 and 233 mg/100g when broilers were fed 2 or 4% flax oil, respectively. EPA increased from 6.2 to 7.9 and 16.1 mg/100 g in white meat when fed 2 or 4% flax oil, respectively.

亚麻油可用来提高肉鸡体内欧米茄-3的含量，而不对鸡的生长产生负作用。Rymer和Givens（2006年）证明，在给肉鸡分别喂食2%或4%亚麻油时，每100克鸡胸肉中所含α-亚麻酸的量从30毫克升到99.4毫克和139毫克，二十碳五烯酸的量（EPA）从7.2毫克升到7.8毫克和16.8毫克。但是，在同一研究中，喂食亚麻油并未影响鸡胸肉的二十二碳六烯酸(DHA)含量。类似地给喂亚麻油可增加鸡腿肉中的欧米茄-3脂肪酸含量。在给肉鸡分别喂食2%或4%亚麻油时，每100克鸡腿肉中所含α-亚麻酸的量从57毫克升到158毫克和233毫克。，在分别喂食2%或4%亚麻油时，每100克鸡胸白肉中所含二十碳五烯酸（EPA）的量从6.2毫克升到7.9毫克和16.1毫克。

González-Esquerra and Leeson (2000) fed 10% flax to broiler chickens and demonstrated an increase in ALA from 11 to 54 mg/100g cooked skinless breast meat and from 43 to 183mg/100g cooked skinless thigh meat. The long chained omega-3 fatty acid content also increased from 17 and 0 to 89 and 23 mg/100g of cooked skinless breast meat and thigh meat, respectively. However, bird performance is typically reduced by feeding this level of flaxseed. Therefore, feeding greater than 3% flaxseed to broilers is not recommended unless a sufficient premium for the product can be achieved.

González-Esquerrat和Leeson（2000年）给肉鸡喂食10%亚麻，发现每100克去皮熟鸡胸肉所含α-亚麻酸的量从11毫克升到54毫克，每100克去皮熟鸡胸肉所含α-亚麻酸的量从43毫克升到183毫克，每100克去皮熟鸡胸肉和鸡腿肉所含的长链欧米茄-3脂肪酸量也分别从17毫克和0毫克升到89毫克和23毫克。但是，通常在喂食这样水平的亚麻籽后，鸡的生产性能会降低，因此，我们不建议给肉鸡喂食大于3%亚麻籽，除非这样的产品可以达到足够的溢价。

Processing of the Seed
亚麻籽加工

Processing of seed improves nutrient utilization and can potentially reduce the negative impact of anti-nutritional components such as linatine. Grinding the seed also improves the metabolizable energy by as much as 16%.

亚麻籽加工可提高其营养利用率，并有可能降低抗营养成分如N-谷酰胺脯氨酸的产生的负作用。磨碎亚麻籽可使亚麻籽增加多至16%的可代谢能量。

Shen et al. (2005a) fed broiler chickens 12% flax from 1-21 days and 15% from 22-40 days. Feeding whole flax reduced body weight, feed intake and feed efficiency but feeding flaxseed that had been previously pelleted and mashed significantly improved body weight gain, feed conversion efficiency and feed intake. However, the overall bodyweights of birds fed 12 and 15% processed flaxseed were less than the control diet indicating the inclusion level was too high even with effective processing.

Shen等（ 2005年a）从鸡出生后第1至21天，给肉鸡喂食12%亚麻，从第22至40天，喂食15%亚麻。他们发现如果喂食全亚麻籽，鸡的体重会下降，采食量会减少，饲料效率会降低；但是如果喂食包过衣并拌成糊的亚麻籽，鸡体重则会增长、饲料转化率和进食量会大幅提高。然而，给鸡喂了12%和15%加工过的亚麻籽后，这些鸡的总体重增加仍轻于给喂受控制对照饲料的鸡，这表明即使亚麻籽经过了有效加工，但12-15%的添加水平仍然太高。

Shen et al. (2005b) examined the effects of processing including pelleting, autoclaving, and microwave roasting on nutrient utilization in leghorn roosters. Pelleting the seed three times increased fatty acid retention by 29%. Microwaving for four minutes increased fatty acid utilization by 39% and autoclaving increased fat utilization by 20%, demonstrating the positive effects of heat treatment on flaxseed utilization. Nitrogen retention was also significantly improved by heat and/or physical processing.

Shen等（ 2005年b）测试了亚麻籽包衣、高压蒸煮和微波烘烤等加工方法对来亨鸡营养利用率所产生的效果。亚麻籽包衣三次可使脂肪酸保持力提高29%；微波烘烤四次可使脂肪酸利用率提高39%；高压蒸煮可使脂肪利用率提高20%。这证明热处理对亚麻籽利用率有正效应。加热和（或）物理加工也可使氮保持力得以大幅提高。

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SECTION 5 – SWINE
第五节　猪

Flax products can be fed to swine; however, it has traditionally been directed into ruminant diets. Due to recent interest in the production of meat products enriched in omega-3 fatty acids and the potential to improve sow productivity and piglet health, flax products are now being used in swine diets with increasing frequency.

亚麻也可用于猪的喂食，虽然在传统上亚麻多被用于反刍动物饲料中。由于近期人们对富含欧米茄-3脂肪酸的肉产品，以及利用亚麻来提高母猪繁殖力和小猪健康越来越感兴趣，现在人们已经开始越来越普遍在猪饲料里添加亚麻产品。

Starter Rations
小猪日粮

Flax meal can be included in starter rations up to 3% without adverse effects on growth and feed intake. However, feeding greater quantities to very young stock can result in reduced performance due to the negative effects of mucilage, linatine and linamarin. Jansman et al. (2007) substituted 8.5% expeller meal or 12.5% seed into the diets of newly weaned pigs in an attempt to study the potential positive effects of the ALA and phenolic compounds present on gut health and the immune system. However, when flax was included at these levels, weight gain was depressed. It is believed that young animals have limited capacity to overcome the negative effects of the anti-nutritional factors present in flax
(see page 10).

我们可以在小猪的日粮里添加多至3%的亚麻籽粕，而不会对小猪的生长和采食量产生不良反应。但是，由于粘质物、N-谷酰胺脯氨酸和亚麻苦苷产生的负作用，给非常幼小的家畜喂食亚麻更容易降低其生产性能。Jansman等（2007年）曾为了研究α-亚麻酸和酚类化合物对肠道健康和免疫系统可能产生的正效应，将8.5%压榨亚麻籽粕或12.5%亚麻籽代入刚断奶小猪的饲料里。但是当亚麻以这些水平添加进时，猪的体重的增长开始受到抑制。现在人们普遍认为幼畜对抗亚麻中抗营养因子的抵抗能力比较有限。（请见第10页）

Flax oil can be used in all hog rations including the starter ration without negatively affecting

performance. It has been hypothesized that the supplementation of starter rations with omega-3 fatty acids may improve the health status of the animal due to their effects on the immune system via regulation of eicosanoids (Turek et al., 1996). However, further study is required to determine the effectiveness of this approach.

我们可以在所有猪的日粮（包括小猪的日粮）中加入亚麻油，而不会对其生产性能产生负面影响。人们推测，由于欧米茄-3脂肪酸可通过调节类花生酸从而对免疫系统产生作用，将亚麻油添加进小猪的日粮里还可提高猪的健康状况（Turek等，1996年）。不过这一推测还有待进一步的研究来证明。

Grower and Finishing Rations
生长猪和育成猪日粮

Generally flaxseed and meals can be fed up to 10% of the diet to grower and finishing hogs without negative effects on performance. Flax is an intermediate source of protein with a composition very similar to that of canola. However, the amino acid balance of flax is poorer than canola meal as it is deficient in lysine and tryptophan and, therefore, cannot be used as a sole source of supplemental protein in cereal-based diets. Numerous studies have demonstrated the inclusion of flax products in the diets of growing hogs without negative effects on performance. Early studies indicated flax meal could be included in swine rations up to 25% of the diet without affecting performance. More recently Matthews et al. (2000) fed 30 kg pigs diets with 5 or 10% flaxseed without affecting production performance. However, Thacker et al. (2004) examined the impact of feeding a 50/50 flaxseed/pea mixture that had undergone an extrusion process and indicated reductions of performance when included at 30% of the diet. Feeding 22.5% of the flax/pea mixture in the grower diet had no effect on animal performance, however. Batterham et al. (1991) fed a diet containing 30% prepress solvent-extracted flax meal to hogs from 20 kg to 45 kg body weight and observed reductions in body weight, indicating flax should not be fed at this level to pigs under 45 kg. Batterham et al. (1991) concluded that the hogs under 45 kg were negatively affected by the anti-nutritional factors present in the meal.

一般来说，给生长猪和育成猪喂食多至10%饲料量的亚麻籽和籽粕，不会对其生产性能产生负作用。亚麻可提供中等质量的蛋白质，其组成类似于油菜籽。但亚麻的氨基酸平衡要差于油菜籽粕，因为它缺乏赖氨酸和色氨酸。故在以谷物为基础的饲料中，不可以用它来作补充蛋白质的唯一来源。许多研究已证明，在生长猪的饲料里添加亚麻产品对生产性能不会产生负作用。早期的研究表明，在猪的日粮里可以添加高达饲料的25%亚麻籽粕，而不影响生产性能。最近，Matthews等（2000年）给30千克重的猪喂食添加5%或10%亚麻籽的饲料，而没有影响生产性能。但是，Thacker等（2004）测试了喂食掺入经过挤压加工的亚麻与豌豆各半混合饲料的影响，结果表明在加入量到达30%时，猪的生产性能开始下降，但是在生长猪的饲料中加入22.5%的亚麻与豌豆混合饲料，对猪的生产性能则没有影响。Batterham等（1991年）给20千克至45千克猪喂食含30%预压溶剂萃取过的亚麻籽粕的饲料，观测到了猪的体重减轻。这表明不应给体重在45千克以下的猪喂食这一水平的亚麻量。Batterham等（1991年）得出结论，籽粕中的抗营养因子会对45千克以下的猪产生不良反应。

Numerous studies have demonstrated the use flaxseed in finisher rations without affecting animal performance. Romans et al. (1995a) fed finishing hogs 0, 5, 10, and 15% ground flaxseed to hogs for 25 days prior to slaughter. Inclusion of the flaxseed in the diet had no effect on animal performance. In a follow-up study Romans et al. (1995b) fed 15% flax for 28 days prior to slaughter and once again did not observe any impact on animal performance. Matthews et al. (2000) fed rations with 0, 5 or 10% whole flaxseed and did not observe any impact on animal performance. Thacker et al. (2004) fed a 50/50 blend of peas and flax that had been processed through an extruder and observed equal performance up to 18% inclusion in the diet; however, at 24% they started to observe a depression in weight gain. Solvent-extracted flax meal can also be fed to finishing hogs; however, it is not commonly used due to the low energy content (Table 7) and low lysine content (Table 3).

许多研究已证明，在育成猪的日粮中加入亚麻籽不会影响猪的生产性能。Romans等（1995年a）在屠宰育成猪前，给猪喂食了25天0%、5%、10%和15%磨碎的亚麻籽，发现在饲料中添加亚麻籽

未对猪的生产性能产生影响。在后续的研究中，Romans等（1995年b）在屠宰猪前，给猪喂食了28天15%亚麻，再次观测到对猪的生产性能没有影响。Matthews等（2000年）给猪喂食添加了0%、5%或10%全亚麻籽的日粮，也未观测到对猪的生产性能有任何影响。Thacker等（2004年）给喂18%豌豆与亚麻各参半、经挤压机加工的混合饲料，观测到生产性能与以前相同。但是在24%的水平时，猪的体重增长则开始下降。我们也可以给育成猪喂食预压溶剂萃取过的亚麻籽粕，但是由于其能量低，请见表（七）；及赖氨酸含量低，请见表（三），故不建议使用。

TABLE 7. Energy content of flaxseed and expeller and solvent-extracted meals
表（七） 亚麻籽、压榨过的亚麻籽粕和溶剂萃取过的亚麻籽粕所含的能量

COMPONENT	SEED	EXPELLER MEAL	SOLVENT MEAL	FLAX OIL
DE (kcal/kg) Boland 1990	4253	3340	3060	8380
ME (kcal/kg)	2580	2000	2400	8220
NE (MJ/kg)	13.1	8.4	7.3	29.8

成分	亚麻籽	压榨过的亚麻籽粕	溶剂萃取过的亚麻籽粕	油
消化能（DE）（千卡/千克）Boland，1990年	4253	3340	3060	8380
代谢能（ME）（千卡/千克）	2580	2000	2400	8220
净能（NE）（兆焦尔/千克）	13.1	8.4	7.3	29.8

Enrichment of Pork Products with Omega-3 Fatty Acids
欧米茄-3脂肪酸强化的猪肉产品

Due to the positive impact of including omega-3 fatty acids in human diets, there is significant interest in enriching the omega-3 fatty acid content of meat and lard products produced by swine. Like other monogastric species such as poultry, the fatty acid profile of the meat and fat is directly affected by the source of fat in the diet. Therefore, it is possible to change the fatty acid profile, especially the ratio of omega-6 to omega-3 fatty acids, by feeding flax oil or flaxseed, a rich source of omega-3 fatty acids.

由于在人的膳食中摄入欧米茄-3脂肪酸对人体健康有积极的作用，人们对富含欧米茄-3脂肪酸的猪肉和猪油产品产生了极大的兴趣。像其他单胃动物（如家禽）一样，猪肉和脂肪里的脂肪酸组成直接受到饲料中脂肪来源的影响，因此，我们可以通过喂食亚麻油或亚麻籽等富含欧米茄-3脂肪酸的食物来改变猪肉中脂肪酸组成，尤其是欧米茄-6与欧米茄-3脂肪酸的比例。

Romans et al. (1995a) examined the effect of feeding graded levels of flax to pigs 25 days prior to slaughter. Feed containing 0%, 5%, 10% and 15% ground flax increased the ALA from 10 to 23, 37 and 53 mg/g inner backfat, respectively. EPA increased from 0.09 from control to 0.20, 0.28 and 0.38 mg/g backfat, when fed 5%, 10% and 15% ground flaxseed respectively, clearly indicating the potential to increase the omega-3 content of pork products by feeding flaxseed in the finishing phase. Specht-Overholt (1997) also observed significant improvements in ALA concentrations in the meat of swine fed 15% flaxseed. After 28 days, ALA concentration increased from 1.1% of the fat to 8.8% while those fed 15% flax for 42 days increased from 1.3% to 12%.

在屠宰猪前，Romans等（1995年a）以分级水平给猪喂食亚麻25天，并测试了这样做的效果。在喂食0%、5%、10%和15%磨碎的亚麻籽时，α-亚麻酸含量从每克内背膘含10毫克分别提高到23、37和53毫克，在分别喂食5%、10%和15%磨碎的亚麻籽时，二十碳五烯酸（EPA）含量从对照组的每

克背膘含0.09毫克提高到0.20、0.28和0.38毫克，这清楚地表明在育成阶段，通过喂食亚麻籽来提高猪肉产品欧米茄-3的含量是有可能的。Specht-Overholt（1997年）也观测到，喂食15%亚麻籽时，猪肉中的α-亚麻酸浓度有大幅提高，28天后，α-亚麻酸浓度从占脂肪的1.1%升到8.8%，而那些喂食了42天15%亚麻的猪则从1.3%升到12%。

Romans et al. (1995b) examined the impact of feeding duration on omega-3 enrichment and concluded flax should be fed for a minimum of 21 days prior to slaughter to achieve optimal concentration. Fontanillas et al. (1998) fed 4% flax oil for 60 days and determined omega-3 content by biopsies. They observed an increase in ALA from 1.14% to 4.94, 7.40, and 7.89% after 17, 31, and 60 days feeding, respectively. These data were used to model rates of change in deposition of fatty acids. Fontanillas et al. (1998) concluded that 70% of the maximum ALA enrichment is achieved after only feeding 30 days while 95% is achieved if fed 60 days.

Romans等（1995年b）测试了喂食持续时间对增强欧米茄-3含量的影响，并得出结论，为了达到最理想的浓度，应在屠宰猪前喂食亚麻至少21天。Fontanillas等（1998年）给猪喂食4%亚麻油60天，并通过活组织检查来确定了欧米茄-3的含量。他们观测到在分别喂食17、31和60天后，α-亚麻酸含量从1.14%提高到4.94%、7.40%和7.89%。他们用这些数据建立了脂肪酸沉积变化率模型。Fontanillas等（1998年）得出结论，喂食30天，α-亚麻酸可达到了最高强化量的70%，如果喂食6天，则可达到95%。

Omega-3 enriched pork products, produced through the feeding of flaxseed, are now available commercially in both Canada and the United States. These products are slowly gaining in popularity as they not only deliver omega-3 fatty acids into our diet but are also reported to result in a juicier and tastier meat product.
在加拿大和美国，市面上均有出售通过喂食亚麻籽而製成的富含欧米茄-3 的猪肉产品。由于这些产品不仅帮助我们摄入更多的欧米茄-3 脂肪酸，而且还可使肉产品汁更多、味更美，因此它们正日渐受到人们的欢迎。

Sow Rations
母猪日粮

Flax has often been used for its medicinal properties. Flax is occasionally used at the time of parturition to alleviate constipation but there is growing interest in the effects of the omega-3 fatty acids. These compounds alter the immune and inflammation responses through the modification of eicosanoids which play a major role in the inflammatory process. In addition, flax contains secoisolariciresinol diglycoside (SDG), a phenolic lignan that is converted to mammalian lignans by the micro-organisms in the hindgut. The imunomodulating effects of omega-3 fatty acids combined with the potential hormonal effects of the phytoestrogens may have a positive effect on sow productivity and the health of the piglets. To study the effect of flaxseed on the long term productivity of sows and the performance of the offspring, Lawrence et al. (2004) fed 5% flaxseed to 2400 sows and a control diet to 4800 sows. Performance over three parities was studied. Feeding flaxseed increased the number of pigs weaned per mated sow by 0.5 per year over the control group. They also observed an increase in birth weight, weaning weight in the third parity, improvements in farrowing rate and percentage of sows rebred within seven days. Further research is needed to completely understand the potential impact of feeding flaxseed in the sow ration, but based on the research to date the addition of 5% ground flaxseed may have long term health and production benefits.
亚麻常因其药用性而在母猪日粮中被使用。亚麻偶尔会被用在分娩时缓解便秘。但是人们更感兴趣的是亚麻中欧米茄-3脂肪酸的效果。这些化合物可以通过修改类花生酸，来改变免疫和炎症反应。此外，亚麻含有开环异落叶松树脂酚二葡萄糖苷（英文缩写SDG）。这是一种酚类木脂素，它可以通过后肠里的微生物转化成哺乳动物木脂素。亚麻中欧米茄-3脂肪酸的免疫调节作用结合其植物雌激素的潜在荷尔蒙作用，可能对母猪的繁殖力和小猪健康产生正效应。为了研究亚麻籽对母猪长期的繁殖力和小猪生产性能的影响，Lawrence等（2004年）给2400头猪喂食5%亚麻籽， 4800头猪喂食对照组饲料，并对母猪三胎次的生产性能进行研究。喂食了亚麻籽的一组，每头配母猪生产断

奶猪的头数每年比对照组多0.5。他们还观测到亚麻喂食组的第三胎次小猪出生时体重和断奶时体重都有所增加，母猪七天内再受孕率和产仔率都有上升。不过要完全明白在母猪日粮里添加亚麻籽的潜在影响，有待做进一步的研究，基于至今为止的研究，添加5%磨碎的亚麻籽可对母猪健康和生产有长期的益处。

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SECTION 6 – RUMINANTS
第六节　反刍动物

Flax products are an excellent source of protein and energy for ruminants. The anti-nutritional components that can affect monogastric animals such as mucilage are effectively neutralized in the rumen and may even stimulate rumen function. It appears flax products, especially the by-products of flax processing, have been used effectively in beef and dairy rations since the beginnings of agriculture. Bethke et al. (1928) reported successfully using 10% linseed meal in beef calf diets without affecting animal performance. Weber (1934) studied the relative value of linseed meal and reported enhanced growth and feed conversion. They also reported improved carcass fat content and “glossier coats of hair.” Flax products are still widely believed to be useful in promoting health, skin and hair quality and are often included in rations for show cattle for this reason.

亚麻产品可以为反刍动物提供极佳的蛋白质和能量来源。那些会影响单胃动物的抗营养成分如粘质物可以在瘤胃内被有效地中和，甚至可以帮助刺激提高瘤胃功能。似乎自农业萌芽起，亚麻产品尤其是亚麻加工后的副产品就已被有效地用于肉牛和奶牛的日粮中。Bethke等（1928年）报告说，他们成功地在肉牛小牛饲料里添加10%胡麻籽，而未对牛的生产性能产生影响。Weber（1934年）研究了亚麻籽粕的相对营养价值，并报告说添加亚麻加强了牛的生长和饲料转化。他们还报告说亚麻提高了牛胴体脂肪含量，并使其“皮毛更光滑了”。亚麻产品现在被广泛认为有助于提高牛

的健康和皮毛的质量，因此常被添加进展示牛的日粮里。

Typically the fat content of ruminant diets must be limited to less than 5% of the dry matter of the diet due to the negative effects of free fat on rumen function and reduced feed intake and performance. However, in many cases it is desirable to increase the energy content of rations when feed intake is limited. Flaxseed offers the advantage of packaging the fat in such a way so as not to negatively affect rumen function while promoting feed intake. Therefore, it can be an effective way to increase the energy content of the diet. Recently there has been interest in using whole fat flaxseed for beef or dairy animals. The primary objective is to enhance the omega-3 fatty acid and conjugated linoleic acid content of the meat products but some research has also suggested it enhances disease resistance due to the potential immuno-modulating effects of ALA.

由于游离脂肪对瘤胃功能具有副作用，可使牛采食量减少，生产性能下降，因此通常反刍动物饲料的脂肪含量必须限制在少于饲料干物质的5%。但是在许多情况下，当采食量被限制时，我们需要尽可能提高日粮所含的能量。亚麻籽可以包住其所含的脂肪，避免对瘤胃功能产生不利影响，同时促进采食量。因此，添加亚麻籽是提高饲料能含量的一种有效方式。近来越来越多的人开始对给肉牛或奶牛使用全脂亚麻籽，以增强肉产品的欧米茄-3脂肪酸和共轭亚油酸的含量。另外也有一些研究提示说，亚麻可以增强牛的抗病力，这是缘于α-亚麻酸的潜在免疫调节作用。

Beef Cattle
肉牛

Linseed meal can be used effectively as a protein source for beef cattle at all stages of life. It is very palatable with a high protein and energy content (Table 8) and can be used as the sole protein supplement. Similarly, whole fat flaxseed can be used in beef rations as a source of protein, energy and omega-3 fatty acids.

胡麻籽粕可被有效地用作肉牛一生各个阶段的蛋白质来源，它味美可口，蛋白质和能含量高，请见表（八），并且可以作为独立使用的蛋白质补充剂。同样的，全脂亚麻籽也可作为蛋白质、能量和欧米茄-3脂肪酸的来源添加进肉牛的日粮里。

TABLE 8. Typical fibre ruminant digestible protein and energy composition of flaxseed and expeller and solvent-extracted meals

表（八） 亚麻籽、压榨过的亚麻籽粕和溶剂萃取过的亚麻籽粕的典型反刍动物可消化的蛋白质纤维和能量组成

COMPONENT	SEED	EXPELLER MEAL	SOLVENT MEAL
TDN (%)[1]	115	82	78
CP (%)[1]	25.6	37.9	38.3
Ether Extract (%)[1]	38.3	6.0	1.5
Crude Fibre (%)[1]	6.7	9.6	10.1
NDF (%)	20.2[3]	22.6[2]	25.9[2]
ADF (%)	12.4[3]	12.8[2]	17.3[2]
Potentially degradable Crude Protein (% of CP)[2]	-	75.4	67.2
NEm (Mcal/kg)[1]	3.15	2.00	1.87
NEg (Mcal/kg)[1]	1.63	1.34	1.23
NEI (Mcal/kg)[1]	2.68	1.89	1.78

Ca (%)[1]	0.23	0.45	0.43
P(%)[1]	0.55	0.96	0.89

[1]*Adapted from Feedstuffs 2008 Reference Issue and Buyers Guide.*

[2]*Adapted from Khorasani et al. 1994.*

[3]*Adapted from Gonthier et al. 2004.*

成分	亚麻籽	压榨过的亚麻籽粕	溶剂萃取过的亚麻籽粕
可消化的养分总量（TDN）（%）[1]	115	82	78
粗蛋白质（CP）（%）[1]	25.6	37.9	38.3
粗脂肪（%）[1]	38.3	6.0	1.5
粗□□（%）[1]	6.7	9.6	10.1
中性洗涤□□（NDF ）（%）	20.2[3]	22.6[2]	25.9[2]
酸性洗涤□□（ADF）（%）	12.4[3]	12.8[2]	17.3[2]
潜在可降解的粗饲料			
蛋白质（粗蛋白质%）[2]	-	75.4	67.2
维持净能（NEm）（兆卡/千克）[1]	3.15	2.00	1.87
增重净能（NEg）（兆卡/千克）[1]	1.63	1.34	1.23
摄入净能值（NEI）（兆卡/千克）[1]	2.68	1.89	1.78
钙（%）1	0.23	0.45	0.43
磷（%）1	0.55	0.96	0.89

[1]*改编自《饲料2008特辑与买家指南》（Feedstuffs 2008 Reference Issue and Buyers Guide）。*

[2]*改编自作者：Khorasani等，1994年。*

[3]*改编自作者：DeClercq等，2004年。*

Creep feeds
教槽料

Creep feeding is the practice of providing supplemental feed to nursing calves. The objective is to increase weaning weights and to prepare the calves for grain-based diets. Researchers at the North Dakota State University Central Grasslands Research Extension Center (Maddock et al., 2006) examined the potential to use ground flaxseed in creep feeds. Steer calves were provided a creep feed containing either 12.5 or 25% flax and there was no effects on average daily weight gain or feed intake as compared to the control creep feed. The diets containing 12.5% flax appeared to improve feed intake upon receiving; however, there was a tendency towards reduced performance at the 25% level.

教槽料是给哺乳牛犊提供补充饲料的做法，目的是要增加断奶时的体重，并为牛犊进食以谷物为基础的饲料做准备。北达科他州立大学中部草原研究扩展中心（North Dakota State University Central Grasslands Research Extension Center）的研究人员（Maddock等，2006年）测试检查了在教槽料中添加磨碎亚麻籽的可能性。他们给食用牛犊喂食了含12.5%或25%亚麻的教槽料，与对照组相比，这种喂法对牛日增重或采食量没有影响。在进食含12.5%亚麻的饲料后，牛的采食量似乎提高了；但是在进食25%亚麻水平时，牛的生产性能有降低的趋势。

Feedlot rations
饲养场的日粮

Flaxseed can be effectively used in feedlot rations. Several studies have demonstrated the use of up to 20% flaxseed in the diet without negatively affecting performance. Flaxseed has high levels of energy and protein and promotes feed intake and weight gain and, therefore, is often economical to include in the ration even when the price is three or four times that of corn. Flaxseed has also been shown to offer additional benefits over its nutritional value alone. Drouillard et al. (2002) demonstrated increased feed intake in the critical first few days in the feedlot. The transition into the feedlot can be a stressful experience for newly weaned calves and they are prone to illness as a result. The objective is to transition the animals into the feedlot, minimize stress and disease, and maximize feed intake. Flax is a highly palatable feed ingredient and contains high levels of nutrients. Inclusion in the initial ration seems to promote feed intake and in some instances reduced incidence of disease (bovine respiratory disease) are observed (Drouillard et al., 2002). It is hypothesized that the immune status of the animal is enhanced by the omega-3 fatty acids present in the flax and that they reduce the inflammatory response, therefore, promoting feed intake and the overall well-being of the animals.

亚麻籽可有效地添入饲养场的日粮里。一些研究已证明在饲料中添加多至高达20%亚麻籽，不会对牛的生产性能产生不良影响。亚麻籽有高水平的能量和蛋白质，可提高牛的采食量，增加体重。因此即使亚麻它的价格约是玉米的三四倍，它仍常被添加到日粮里，这是较经济的做法。亚麻籽就其营养值这一项而言，还显示了其额外的好处。Drouillard等（2002年）证明了，亚麻可以帮助牛犊在饲养场关键的头几天里增大采食量。刚断奶的牛犊在被转到饲养场时，通常会感到紧张不适应而容易生病。因此将牛转到饲养场时，要尽可能地帮助牛降低压力，减少疾病，并提高采食量。亚麻是极其可口美味的饲料原料，含有高水平的营养物。Drouillard等（2002年）观测到，在最初的日粮里添加亚麻，似乎可提高牛采食量，并且在某些情况下降低了牛呼吸道疾病的发病率。人们推测亚麻的欧米茄-3脂肪酸增强了牛的免疫力，降低了炎症反应，故提高了牛的采食量和整体的健康。

Feeding flaxseed may also improve carcass quality. Drouillard et al. (2002) have also observed increased marbling and grade scores when the finishing diet was supplemented with ground flaxseed.

喂食亚麻籽还可提高胴体的质量。Drouillard等（2002年）也观察到，当在育成饲料中补充磨碎的亚麻籽时，牛的细脂肪纹路和等级评分提高了。

Impact of flaxseed on fatty acid content of meat products
亚麻籽对肉产品脂肪酸含量的影响

The fatty acid profile of meat products from beef cattle can be altered by feeding flax. Several studies have demonstrated the ability to increase the omega-3 content of meat products by feeding flaxseed. Unlike monogastric species, it is not possible to feed large quantities of oil to the animal as it will negatively affect the function of the rumen, reduce feed intake, and, therefore, the performance of the animal. Therefore, it is necessary to provide the fat in a protected form so it does not significantly affect ruminal function. Flaxseed (ground or rolled) on the other hand, can be added to the diet without affecting performance as the seed provides a degree of protection from solubilization in the rumen.

喂食亚麻可以改变牛肉产品的脂肪酸组成。一些研究已证明了，喂食亚麻籽可提高肉产品欧米茄-3脂肪酸的含量。与单胃动物不同，我们不可能给牛喂食大量的油，因为这会对瘤胃功能产生副作用，降低牛的采食量，并进而影响牛的生产性能。因此为此，我们必须给牛喂食有保护的，不对瘤胃功能产生很大的影响的脂肪。（磨碎或滚压过的）亚麻籽可以被添加进饲料里，而不影响牛生产性能。这正是因为亚麻籽可以保护自身脂肪，使其在瘤胃里不被溶解。

Given the many benefits of increasing the omega-3 content of human diets through modifying the fatty acid composition of meat products, numerous studies have examined the potential to modify the fatty acid profile of beef products by feeding flax. Much of the unsaturated fat fed to beef cattle is hydrogenated in the rumen, making it difficult to make dramatic changes in unsaturated fatty acid composition as is commonly observed when feeding pigs or chickens. In addition, the greater the degree of unsaturation the more likely

the fat will be hydrogenated. Approximately 90% of the ALA in flax oil is hydrogenated and 80% of the LA is hydrogenated. However, in spite of the hydrogenation, feeding flaxseed increases the omega-3 content of both the subcutaneous and intramuscular fat deposits.

通过改变肉产品的脂肪酸组成，来提高人类膳食的欧米茄-3含量，可带来诸多健康好处。鉴于此，许多研究已经测试了通过喂食亚麻，来改变牛肉产品的脂肪酸组成的潜在可能性。给肉牛喂食的不饱和脂肪，其中大多数会在瘤胃里被氢化，因此很难大幅改变肉质中不饱和脂肪酸的组成，这种现象在给猪或鸡喂食时，常被观测到。此外，脂肪酸不饱和的程度越大，脂肪就越有可能被氢化。亚麻油里约90% α-亚麻酸被氢化了，80%亚油酸被氢化了。然而，尽管有氢化作用，喂食亚麻籽仍可使皮下和肌内脂肪沉积的欧米茄-3含量有所提高。

Aharoni et al. (2004) fed 8% flaxseed to bull calves and observed an increase in ALA from 3.2 to 9.3 g/100g of intramuscular fat. Mach et al. (2006) fed bull calves 0, 3.6, 11.2 or 18% flaxseed during finishing and observed an increase in total omega-3 fatty acids of approximately 0.48 to 2.25 g/100g fatty acids when fed the highest level of canola and flaxseed respectively. The majority of the change in omega-3 content is ALA, the predominant fatty acid in flax.

Aharoni等（2004年）给公牛犊喂食了8%亚麻籽，并观测到每100克肌内脂肪内的α-亚麻酸从3.2克升到9.3克。Mach等（2006） 年）在育成期，给公牛犊喂食了0%、3.6%、11.2%或18%亚麻籽，并观测到在分别喂食最高水平的油菜籽和亚麻籽时，每100克脂肪酸的总欧米茄-3脂肪酸上升了约0.48克至2.25克，欧米茄-3含量的主要变化来自α-亚麻酸，这是亚麻中所含的主要脂肪酸。

In long term studies there is also a two to four fold increase in the EPA but there is generally very little change in DHA concentration.

在长期的研究中，二十碳五烯酸（EPA）也显示了两至四倍的增加。但是一般来说，二十二碳六烯酸（DHA）的浓度几乎没有什么变化。

Conjugated linoleic acid (CLA) is a unique fatty acid found in ruminant products that has been shown to reduce tumour growth and, therefore, may have beneficial effects in preventing cancer in humans. CLA is produced by ruminants by partial hydrogenation of ALA or LA in the rumen to trans-vaccenic acid (C18:1*trans*-11) and then converted to (C18:2c9,t11 CLA) or (C18:2c10,t12 CLA) in the intramuscular fat or mammary gland. CLA content of the meat is affected by both forage and fat content of the diet. Many forage products contain LA or ALA which can be converted into CLA; therefore, high forage diets tend to promote enrichment of the meat. Feeding flaxseed also promotes the deposition of CLA in the ruminant animal. Feeding a combination of high forage content and flaxseed tends to result in the greatest enrichment of the meat with CLA.

共轭亚油酸是反刍动物产品中独特的脂肪酸。已有证据显示它可抑制肿瘤生长，因此可能对人类防癌有良好的作用。反刍动物通过在瘤胃里将α-亚麻酸或亚油酸部分氢化成11-反-十八烯酸（C18:1*trans*-11），然后在肌内脂肪或乳腺里转为（C18:2c9,t11 CLA）或（C18:2c10,t12 CLA），生成共轭亚油酸。这种肉的共轭亚油酸含量受饲料中的草料和脂肪含量影响很大。许多草料产品含亚油酸或α-亚麻酸，则可以被转化成共轭亚油酸，因此，含草料高的饲料易于促进增强肉的营养。喂食亚麻籽也可促进共轭亚油酸在反刍动物里沉积，喂食草料含量高，并混合亚麻籽的饲料易于产出最富含共轭亚油酸的肉。

Aharoni et al. (2004) fed 8% flaxseed to bull calves fed a diet containing either 28 or 42% forage on a dry matter basis. The high forage diets were most responsive to feeding flax which increased the CLA content from 4.0 to 6.7 g/100g fatty acids in the longissimus muscle.

Aharoni等（2004）给公牛犊喂食了含8%亚麻籽，以及以干物质为基础含有28%或42%草料的饲料。进食草料含量高的饲料对喂食亚麻产生的效果最有促进，每100克最长肌脂肪酸的共轭亚油酸含量从4.0克升到6.7克。

Dairy Cattle

奶牛

Linseed meal is an excellent protein supplement for use in dairy rations and can be used as the sole protein supplement in the concentrate. It is highly palatable and does not affect dry matter intake. The protein quality for dairy is similar to canola meal and ranks higher than other commonly used protein sources such as soybean meal, brewers dried grains, and feather meal (Arambel and Coon, 1981). Expeller-processed meal contains higher levels of fat and, therefore, energy (Table 8) but has a higher rate of ruminal crude protein degradation. Solvent-extracted meal is often the preferred source for dairy rations as it has a higher level of ruminal by-pass protein due to protein denaturation during desolventization, but it still retains a high level of total tract protein digestibility (Khorasani et al. 1994) and, therefore, supports high levels of milk production, milk fat, and protein content.

胡麻籽粕是奶牛日粮的极佳蛋白质补充剂，可作为独立使用的浓缩蛋白质补充剂，胡麻籽粕非常味美可口，不影响奶牛进食干物质。它供给奶牛所需的蛋白质质量类似于油菜籽粕，它的级别要高于其他常用的蛋白质来源如大豆粕、啤酒糟和羽毛粉（Arambel和Coon，1981年）。压榨加工的亚麻籽粕所含的脂肪水平更高，因此能量也更高，请见表（八），但其粗蛋白质在瘤胃中的降解率也较高。溶剂萃取产出的亚麻籽粕由于在脱溶时的蛋白质变性，因此有较高水平的过瘤胃蛋白质。但它仍保留高水平的全消化道蛋白消化率（Khorasani等，1994年），从而维持高水平的产奶量、乳脂和蛋白质含量，所以溶剂萃取产出的亚麻籽粕常是奶牛日粮首选的原料来源。

Flaxseed in dairy rations
奶牛日粮中的亚麻籽

Omega-3 fatty acids have been shown to improve the reproductive performance of dairy cattle. However, feeding significant quantities of oil (greater than 5%) directly to ruminants is not practical as it will negatively affect rumen function and, therefore, feed intake and milk production. Supplemental fat is often fed as a calcium salt to prevent rumen upset, but these salts are often very expensive and contain very little omega-3 fatty acids. The oil in flaxseed, however, is encapsulated in such a way that it does not interfere with rumen function. Feeding ground flaxseed is a practical and often cost effective way to introduce oil into the diet of high producing dairy animals and thereby supplying the much needed energy for milk production. In addition, flax contains very high levels of the omega-3 fatty acid ALA and this has been shown to have additional benefits for the dairy animal.

已有证据显示欧米茄-3脂肪酸可提高奶牛的繁殖能力。但是直接给反刍动物喂食大量的油（大于5%）会对瘤胃功能产生不良影响，进而影响采食量和产奶量，故这样做并不可行。虽然为了防止瘤胃不适，可以将补充的脂肪以钙盐的形式来给喂。但是这些盐常常很昂贵，并且所含的欧米茄-3脂肪酸量微乎其微。然而亚麻籽里的油是包裹在籽里的，这使得它不会妨碍瘤胃的功能。因此喂食磨碎的亚麻籽是将油添入高产奶牛的饲料里，从而提供产奶所需能量的是一种可行又实惠的做法。此外，亚麻含有非常高水平的欧米茄-3脂肪酸α-亚麻酸，已有证据显示它可为奶牛提供额外的好处。

Petit et al. (2001) was the first to demonstrate that feeding flaxseed to dairy animals not only supports high levels of milk production but also increases reproductive function. Since that time several other studies have also shown that feeding flaxseed reduces the level of embryo deaths, increases follicle size and increases the size of the corpus luteum and the size of the large dominant follicle and, therefore, increases reproductive performance.

Petit等（2001年）首次证明了给奶牛喂食亚麻籽不仅可维持高水平的产奶量，而且可提高繁殖能力。自那时起，很多其他研究也已显示，喂食亚麻籽可降低胚胎死亡水平，增大卵泡、黄体和大优势卵泡的大小，从而提高繁殖能力。

Ground flaxseed can be fed up to 15% of the dry matter of the diet without negatively impacting dry matter feed intake of the cow. Flaxseed can also be used to maintain milk production, milk fat and milk protein yield during the hot summer months when feed intake is often otherwise depressed due to heat stress. It is becoming common practice to include 1 kg of ground flaxseed/day for dairy cows to achieve

increased reproduction and to incorporate energy into the diet.

喂食磨碎亚麻籽的量可多至饲料干物质的15%，而不会对奶牛的干物质采食量产生不良影响。在炎热的夏季，炎炎酷暑会使奶牛采食量下降。在这期间可给奶牛喂食亚麻籽来保持其产奶量、乳脂和乳蛋白产量。为了提高繁殖并在饲料里加入能量，我们可以给奶牛每日喂食1千克磨碎的亚麻籽。这正逐步成为奶牛饲养中的一种常见的做法。

The seed should be ground to increase nutrient availability but due to the potential for oxidation of the polyunsaturated fatty acids the product should not be stored in the ground form for more than two weeks. Heating the seed prior to feeding increases the by-pass value of the protein. Gonthier et al. (2004) examined the effects of heat treating flaxseed prior to feeding. They micronized the seed at 115°C for 90 seconds or extruded the seed at 155°C for 43 seconds. Micronization significantly reduced ruminal protein digestibility and increased post-ruminal protein digestibility. Extrusion cooking, however, did not enhance ruminal protein by-pass values. The extrusion process appears to have increased nutrient disappearance in the rumen due to the effects of shear force and, therefore, counteracted the positive effects of heat treatment.

为了提高营养的有效性，用于喂食的应是磨碎亚麻籽。但是由于多不饱和脂肪酸有可能出现氧化，故不应将这种产品以磨碎的方式储存超过两个星期以上。在喂食前加热亚麻籽可提高过瘤胃蛋白□值。Gonthier等（2004年）测试检查了在喂食前加热亚麻籽的作用，他们以115°C微粉化亚麻籽90秒，或以155°C挤压亚麻籽43秒，发现微粉化大幅降低了瘤胃蛋白质消化率，并提高了过瘤胃蛋白质消化率，然而挤压煮制并未增强过瘤胃蛋白□值。这是因为，在挤压过程，由于剪切力的作用，似乎加大了瘤胃里的养分消失，从而抵消了热处理的正效应。

TABLE 9. Effect of feeding whole flaxseed (10.4 and 10.8% of dry matter) on embryo mortality and corpus luteum size in dairy cows

表（九） 给喂全亚麻籽（干物质的10.4%和10.8%）对奶牛的胚胎死亡率和黄体大小的影响

	FLAXSEED	MEGALAC	MICRONIZED SOYBEANS
Total Embryo Mortality	0	15.4	8.0
Corpus Luteum Size (mm)	19.1	18.3	16.3

Adapted from Petit and Twagiramungu (2006).

	亚麻籽	皂钙	微粉化的大豆
总胚胎死亡率	0	15.4	8.0
黄体大小（毫米）	19.1	18.3	16.3

改编自作者Petit和Twagiramungu（2006年）。

TABLE 10. Effect of feeding whole flaxseed (10.4 and 10.8% of dry matter) on milk production and milk composition between calving and 16 weeks of lactation

表（十） 给喂全亚麻籽（干物质的10.4%和10.8%）对在生小牛至16周哺乳期期间产奶量和乳成分的影响

FLAXSEED	MEGALAC	MICRONIZED SOYBEANS	
Dry Matter Intake (kg/d)	19.4	18.3	18.7
Peak Milk yield (kg/d)	40.1	37.5	38.8
Millk Production (kg/d)	35.7	33.5	34.4
Milk Fat (%)	3.81	4.14	3.70
Milk Protein (%)	2.98	2.86	2.87

Milk Lactose	4.71	4.57	4.70
4% FCM (kg/d)	34.5	33.7	32.9

Adapted from Petit (2002).

	亚麻籽	皂钙	微粉化的大豆
干物质采食量（千克/日）	19.4	18.3	18.7
产奶量峰值（千克/日）	40.1	37.5	38.8
产奶量（千克/日）	35.7	33.5	34.4
乳脂（%）	3.81	4.14	3.70
乳蛋白质（%）	2.98	2.86	2.87
乳糖	4.71	4.57	4.70
4%乳脂校正乳（千克/日）	34.5	33.7	32.9

改编自作者Petit（2002年）。

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SECTION 7– HORSES

第七节　马

Flax products are commonly used in horse rations and are often the preferred source of protein. Flax can be used as the sole protein supplement comprising as much as 15% of the dry matter in the diet. The lysine content of the meal is too low, however, for young developing horses (Hintz et al., 1971) and will need to be supplemented into the diet to maximize growth and development.

亚麻产品通常被用于马的日粮里，并且常常是首选的蛋白质来源。亚麻可作为独立使用的蛋白质补充剂，它在饲料里可达干物质的15%。然而对于正在发育的马驹，亚麻籽粕的赖氨酸含量太低

（Hintz等，1971年），为了最大化地促进马驹的生长和发育，需要在饲料里添加补充剂。

Ground flaxseed or expeller-processed meal are thought to impart a glossy coat to the animal due to the oil content. Linseed meal is highly palatable and the mucilage also acts as a mild laxative and helps prevent digestive upset such as colic. Flax oil, ground flaxseed or expeller-processed meal can also be used as a source of essential fatty acids in the diet.

通常认为，磨碎的亚麻籽或压榨加工生产的亚麻籽粕因其所含的油脂，可使动物拥有一身光滑的皮毛。胡麻籽粕非常美味可口，它的粘质物还可充当一种温和的泻药，并有助于防止消化不良如急腹痛。亚麻油、磨碎的亚麻籽或压榨过的亚麻籽粕还可用作饲料里必需脂肪酸的来源。

TABLE 11. Nutritional value of linseed meal for horses (dry matter basis)
表（十一） 给马喂食胡麻籽粕（干物质为基础）的营养价值

	DE (Mcal/kg)	TDN%	Crude Protein (%)	Digestible Protein(%)	Lysine (%)	Crude Fibre (%)
Solvent-extracted meal	3.04	69	38.9	27.6	1.34	10

Adapted from Nutrient Requirements of Horses, 1978. National Academy Press, Washington, DC.

	消化能（DE）（兆卡/千克)（TDN）	可消化的养分总量（TDN）	粗蛋白质（%）	可消化蛋白质	赖氨酸（%）	粗纤维（%）
溶剂萃取过的亚麻籽粕	3.04	69	38.9	27.6	1.34	10

Adapted from Nutrient Requirements of Horses, 1978. National Academy Press, Washington, DC.

改编自《马的营养需求》，1978年。国家学术出版社（National Academy Press），美国华盛顿哥伦比亚特区。

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SECTION 8 – AQUACULTURE
第八节 水产养殖

Fish are an important source of omega-3 fatty acids in human diets but the volume of fish caught in the wild is not keeping pace with the ever increasing demands for fish products. As a result, aquaculture has become a very important source of fish for human consumption but highly valued species such as salmon require large amounts of protein and oil in their diet. Traditionally the primary source has been fish meal and oil from rendered fish caught in the wild but the supply of fish meal and oil is not adequate to meet demands for this growing industry. Numerous studies have shown that vegetable oil, including flax oil, can be used in fish diets to replace fish oil without affecting growth performance (Chen et al. 2006). The fat composition of fish is a direct reflection of the oil used. Unlike feeding a diet high in saturated fats or omega-6 fats, feeding a diet high in flax oil will result in a meat product that is desirable to consumers. Flax oil can be fed to fish and completely replace the fish oil in the diet. Since the oil is high in omega-3 fatty acids, the fish will retain a desirable fatty acid profile (Drobna et al., 2006; Menoyo et al., 2005). The oil is prone to oxidation so an anti-oxidant should be added to the oil to prevent rancidity.
虽然鱼是人类膳食中欧米茄-3脂肪酸的重要来源，但是野生捕捞的鱼量难以满足人们对鱼类产品日益增加的需求。因此水产养殖已成为市场上食用鱼类的极其重要来源。但是高价值的品种如三

文鱼需要在其饲料中加入大量的蛋白质和油脂。在传统上这些营养素的主要来源是鱼粉，还有用野生捕捞到的鱼熬出的油。但是由于鱼粉和油供不应求，已不能满足这个正在迅速发展的行业的需求。许多研究已显示，植物油包括亚麻油可取代鱼油，用于鱼饲料中而不影响其生长性能（Chen等，2006年）。鱼的脂肪组成直接反应饲料中所用的油。与含高饱和脂肪或欧米茄-6脂肪的饲料不同，含高亚麻油的饲料更会产出消费者想要的鱼肉产品。亚麻油可以喂给鱼吃，并且可以完全取代饲料中鱼油，由于这种油的欧米茄-3脂肪酸的含量高，用它喂养的鱼会保持一个令人满意的脂肪酸组成（Drobna等，2006年；Menoyo等，2005年）。但是这种油容易氧化，因此为了防止油产生异味，应在油里添加抗氧化剂。

The oil in flaxseed is naturally protected from oxidation so it would seem wise to feed the seed directly to fish; however, the mucilage and fibre negatively affect nutrient absorption in most fish species making it impractical to feed. Researchers at the University of Saskatchewan have studied the potential to use processed flaxseed in the diets of rainbow trout. Drew et al. (2007) reported significant improvements in performance when the mucilage was removed by hot water extraction; however, this technology is not yet being applied commercially.

亚麻籽里的油受到种皮的天然保护而免于被氧化，所以直接给鱼喂食亚麻籽似乎是聪明的做法。但是亚麻籽的粘质物和纤维对大多数鱼种的养分吸收会产生不利的影响。这使得直接喂亚麻籽的做法变得不切实可行。萨斯喀彻温大学（University of Saskatchewan）的研究人员已经研究了将加工过的亚麻籽添入虹鳟鱼饲料的可能性。Drew等（2007年）报告说，用热水脱除粘质物后，鱼的生产性能有了大幅提高。然而这种技术还未在商业中得到应用。

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