

PROPERTIES AND THERAPEUTIC APPLICATION OF FLAX SEED FIBER IN MEDICAL TEXTILES

JANARTHANAN.M

Assistant Professor, Department of Fashion Technology, Angel College of Engineering and Technology,
Tirupur, Tamilnadu, India

ABSTRACT

Flax (*Linum usitatissimum* L.) is an annual plant, 18 -36 inches tall, with small and thin leaves and blue flowers. Flax seed is brown but modern varieties with golden seeds are also available. Flaxseeds are an excellent source of omega-3 essential fatty acids. They are a very good source of dietary fiber and manganese. They are also a good source of folate and vitamin B₆ as well as the minerals such as magnesium, phosphorus, and copper. In addition, flax seeds are concentrated in lignan phytonutrients. Lignans, which are antioxidants, are also associated with lower serum cholesterol and may help reduce oxidative damage to cells and cellular molecules from free radicals. Flax seed may also helps for lower blood glucose and improve insulin tolerance. Flax seed may also reduce serum total cholesterol and low-density lipoprotein cholesterol, some markers of inflammation, and raise serum levels of the omega-3 fatty acids, ALA. With the burgeoning interest in natural fibers for a variety of industrial uses, flax fibers provide the potential to supply these applications from diverse, nontraditional linen sources. Flax fiber is used in the textile industry for linen cloth. The flax fiber cloth used in medical purpose like cancer and wound healing etc.

KEYWORDS: Omega-3-Fatty Acids, Anti-Cancer, Diabetes, Reduce Cholesterol, Anti Oxidant Activity

INTRODUCTION

Flax or linseed is among the oldest crop plants cultivated for the purpose of oil and fiber. It belongs to the genus *Linum* and family *Linaceae*. It is an annual herbaceous plant with shallow root system. The common names flax and linseed are used in North America and Asia, respectively, for *Linum usitatissimum*. Oilseed varieties and fiber varieties are specialized development of this species. (1)

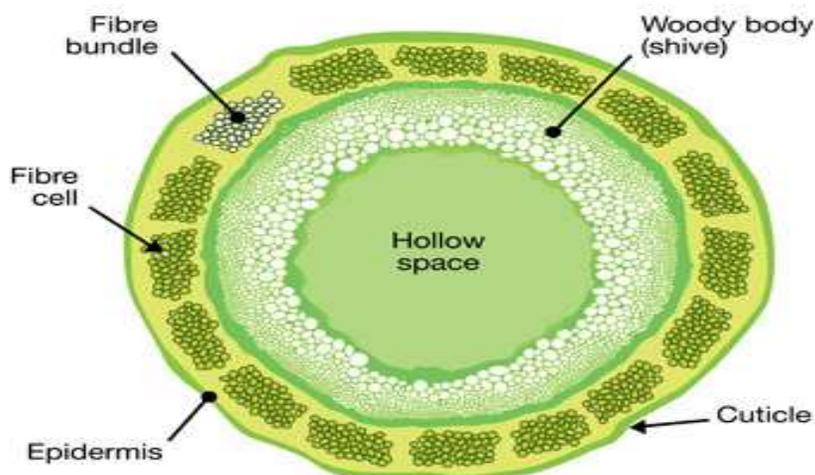
The cultivars grown primarily for seed/oil purpose are relatively short in height and possess more secondary branches and seed bolls (seed capsule). The cultivars grown for fiber purpose are tall growing with straight culms and have fewer secondary branches. The Mediterranean and Southwest Asia have both been proposed as the center of origin; however the exact location is uncertain. The initial use of flax has also been debated. Based on archeological evidence, it was proposed that flax was used first for fiber (2)

Flax, while a minor crop, is grown in a wide range of countries, climates and for many different products. Because of its adaptability and product diversity, it is being considered as a platform for the development of novel bio products. Research on use of flax for byproduct production is being conducted in Australia, North America, Europe and Asia. (2)

Flax (*Linum usitatissimum* L.) is an annual plant, 18 -36 inches tall, with small and thin leaves and blue flowers. Flax seed is brown but modern varieties with golden seeds are also available. It is an ancient plant with a variety of uses. Flax stem is used as a source of fiber for textile fabric (linen), and its oil is an ingredient in paint and varnish. Besides, flaxseed meal is used as animal feed. Whole flaxseed, as ground (meal), powder, and intact seed, and oil capsule, is a source of essential fatty acids and fiber for human diet. There is growing evidence that flax seed is good for improving general health or preventing disease (1)

Flax is naturally high in polyunsaturated fatty acids (PUFA), more specifically in omega-3 fatty acids; and hence flax seed as a component of poultry meal, can provide omega-3 enriched eggs. Rapid drying linseed oil is used for several purposes in industry, including paint and flooring (linoleum) industries. Because of its novel oil profile, flax may also be a suitable platform crop for synthesis of specialized industrial and nutraceutical products (3)

Flax fiber is used in the textile industry for linen cloth. The residues remaining after the oil extraction from linseed contains about 35-40% protein and 3-4% oil, a rich source of feed to livestock like cattle and buffalo (22)



NUTRIENT ANALYSIS OF FLAX SEED

Flax Seed Nutrition

Flaxseeds are an excellent source of omega-3 essential fatty acids. They are a very good source of dietary fiber and manganese. They are also a good source of folate and vitamin B₆ as well as the minerals magnesium, phosphorus, and copper. In addition, flax seeds are concentrated in lignan phytonutrients. (3)

Flax Seed is Rich in Omega-3 Fatty Acids

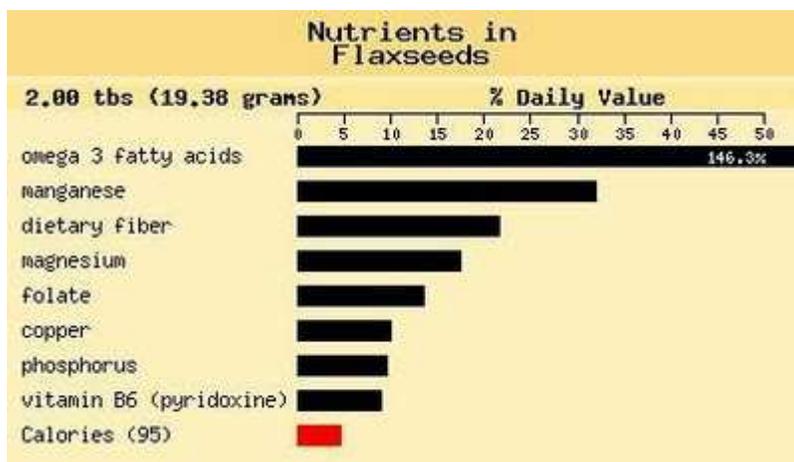
Omega-3 fatty acids are a key force against inflammation in our bodies. Mounting evidence shows that inflammation plays a part in many chronic diseases including heart disease, arthritis, asthma, diabetes, and even some cancers. This inflammation is enhanced by having too little Omega-3 intake (such as in fish, flax, and walnuts), especially in relation to Omega-6 fatty acid intake (in oils such as soy and corn oil. Most of the oil in flax seeds is alpha linolenic acid (ALA). ALA is an Omega-3 that is a precursor to the fatty acids found in salmon and other fatty cold-water fish (called EPA and DHA). Because not everyone is able to easily convert ALA into EPA and (especially) DHA, it is best not to rely solely on flax for your Omega-3 intake. However, ALA also has good effects of its own, and definitely helps in the Omega 3/6 balance. (4)

Flax Seed is high in Fiber

You'd be hard-pressed to find a food higher in fiber, both soluble and insoluble than flax. This fiber is probably mainly responsible for the cholesterol-lowering effects of flax. Fiber in the diet also helps stabilize blood sugar, and, of course, promotes proper functioning of the intestines. (5)

Flax Seed is high in Phytochemicals

Flax seed is high in phytochemicals, including many antioxidants. It is perhaps our best source of lignans, which convert in our intestines to substances that tend to balance female hormones. There is evidence that lignans may promote fertility, reduce peri-menopausal symptoms, and possibly help prevent breast cancer. In addition, lignans may help prevent Type 2 diabetes. (6)



FLAX FIBERS

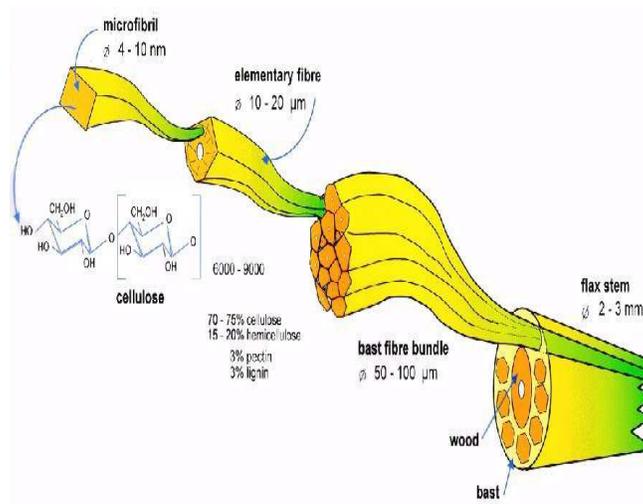
Flax is a versatile crop that is grown throughout the world and in a variety of climates. The translation of its scientific name, 'linen most useful', aptly describes its versatility. Linen, which is used for apparel and interior textiles, comes from the long, strong bast fibers that form in the outer portions of the flax stem. Flax fibers also are used in industrial applications, E.g., composites, geo-textiles, insulation, and specialty papers. Flax seeds are the source of linseed oil, which has been widely used in paints, varnishes, cosmetics, and linoleum. More recently, flax seeds are being recognized as a health food, with nutritional benefits from lignans and omega-3 fatty acids. Even the woody core tissue (shive), which is removed during cleaning of fiber, is used for particleboards and animal bedding. Linen, which is valued for comfort and its distinctive appearance, remains a favorite in the textile industry. With the burgeoning interest in natural fibers for a variety of industrial uses, flax fibers provide the potential to supply these applications from diverse, nontraditional linen sources. (18)

Linen is a bast fiber. Flax fibers vary in length from about 25 to 150 cm (18 to 55 in) and average 12-16 micrometers in diameter. There are two varieties: shorter tow fibers used for coarser fabrics and longer line fibers used for finer fabrics. Flax fibers can usually be identified by their "nodes" which add to the flexibility and texture of the fabric. The cross-section of the linen fiber is made up of irregular polygonal shapes which contribute to the coarse texture of the fabric. (18)



Structure and Chemistry of Flax

Bast fibers are produced in the outer regions of the stem between the outermost cuticle–epidermis layer and the innermost, woody tissues. Separated fibers and fiber bundles appear stiff and brittle in longitudinal views under the microscope. The structure of the stem is important in retting, which is the process of separating fiber and non-fiber fractions. Fibers vary in length with position on the stem. Oval-shaped bundles indicate high quality fiber, while irregularly shaped bundles indicate poor quality. A thin cambium layer separates fibers and core tissues. These core tissues are comprised of lignified woody cells, which constitute the ‘shive’ fraction produced during fiber cleaning. (19)



The stem cuticle of flax contains waxes, cutin, and aromatics. This structure serves as a barrier to protect plants from invading organisms and water loss. The cuticle closely covers the epidermis, and this relationship constitutes a rigid and formidable structure that influences the ease of retting. During retting, microorganisms enter the stems through cracks and disruptions in the cuticle, partially degrade tissues, and

thereby separate the cuticle/epidermal barrier from the fibers. Incomplete degradation, i.e., poor retting, leaves this protective barrier and fibers still attached and contributes to reduced fiber and yarn quality.⁽¹⁹⁾

Flax fibers are primarily comprised of cellulose, but pectins, hemicellulose, and phenolic compounds also are present. Compared with cotton fibers, which typically contain ~ 95% cellulose, flax has a lower percentage of cellulose and more pectin and hemicellulose. For example, in retted “Ariane” flax glucose was the predominant sugar (650 mg/g dry wt.) followed by mannose (39.2 mg/g) and galactose (35.0 mg/g); rhamnose, xylose, arabinose, and uronic acids were also present. In contrast to cotton, flax fibers stained with Oil Red, which indicates the presence of wax. ⁽²⁰⁾

PROPERTIES

Highly absorbent and a good conductor of heat, linen fabric feels cool to the touch. Linen is among the strongest of the vegetable fibers, with 2 to 3 times the strength of cotton. It is smooth, making the finished fabric lint free, and gets softer the more it is washed. However, constant creasing in the same place in sharp folds will tend to break the linen threads. This wear can show up in collars, hems, and any area that is iron creased during laundering. Linen has poor elasticity and does not spring back readily, explaining why it wrinkles so easily.

Linen fabrics have a high natural luster; their natural color ranges between shades of ivory, ecru, tan, or grey. Pure white linen is created by heavy bleaching. Linen typically has a thick and thin character with a crisp and textured feel to it, but it can range from stiff and rough, to soft and smooth. When properly prepared, linen fabric has the ability to absorb and lose water rapidly. It can gain up to 20% moisture without feeling damp.

When freed from impurities, linen is highly absorbent and will quickly remove perspiration from the skin. Linen is a stiff fabric and is less likely to cling to the skin; when it billows away, it tends to dry out and become cool so that the skin is being continually touched by a cool surface. It is a very durable, strong fabric, and one of the few that are stronger wet than dry. The fibers do not stretch and are resistant to damage from abrasion. However, because linen fibers have a very low elasticity, the fabric will eventually break if it is folded and ironed at the same place repeatedly.

Mildew, perspiration, and bleach can also damage the fabric, but it is resistant to moths and carpet beetles. Linen is relatively easy to take care of, since it resists dirt and stains, has no lint or pilling tendency, and can be dry cleaned, machine washed or steamed. It can withstand high temperatures, and has only moderate initial shrinkage. ⁽¹⁹⁾

Linen should not be dried too much by tumble drying: it is much easier to iron when damp. Linen wrinkles very easily, and so some more formal linen garments require ironing often, in order to maintain perfect smoothness. Nevertheless the tendency to wrinkle is often considered part of the fabric's particular

"charm", and a lot of modern linen garments are designed to be air dried on a good hanger and worn without the necessity of ironing. A characteristic often associated with contemporary linen yarn is the presence of "slubs", or small knots which occur randomly along its length. However, these slubs are actually defects associated with low quality. The finest linen has very consistent diameter threads, with no slubs. (20)

Flax Fiber Production

Flax can be grown for fiber or linseed. Flax is a temperate weather crop, generally cultivated in areas where the daily temperature remains $<30^{\circ}$. Production of flax is environmentally friendly in that few chemicals are required for crop production. In traditional production of linen such as that practiced in Europe, flax plants are pulled from the soil, manually in early times and now with specialized equipment. Plants can be harvested by mowing when short flax fiber, rather than long line for linen, is the objective. (21)

Retting

Retting, which is the separation or loosening of fiber bundles from non-fibrous tissues, is a major problem in processing flax. In retting, fiber bundles are separated from the cuticularized epidermis and the woody core cells and subdivided to smaller bundles and ultimate fibers. Under-retted flax results in coarser fibers heavily contaminated with shive and cuticular fragments, while over retting can reduce fiber strength due to excessive thinning of bundles or microbial attack on fiber cellulose. Two primary methods for retting, namely water-retting and dew-retting, have been used traditionally over millennia to separate fibers for textile and other commercial applications. (21)

Mechanical Cleaning

In traditional linen production, mechanical cleaning follows retting to remove shive and cuticularized epidermis from the fiber. The first phase of cleaning breaks the stems by passage through fluted rollers and then the scutching process beats and strokes the fiber to remove shive. Scutching mills clean long fiber by gripping the broken stems and beating first the top portion and then the lower portion with paddles or blades. As the long line flax is beaten, a short fiber fraction, called tow, is removed along with contaminants and cleaned separately (22). Prior to breaking the stems, modern mills may align and carry out other processes to improve the efficiency of scutching. Maintenance of the integrity of the long fibers, which are to be spun into linen yarn, is maintained during the mechanical cleaning processes. Scutched flax is then cleaned using a combing action called hackling, which removes smaller contaminants, disentangles and aligns the long fibers, and separates the bundles without destroying length. (23)

APPLICATION OF FLAX FIBRES

Flax Fiber for Textile

Linen uses range from bed and bath fabrics (tablecloths, dish towels, bed sheets, etc.), home and commercial furnishing items (wallpaper/wall coverings, upholstery, window treatments, etc.), apparel items

(suits, dresses, skirts, shirts, etc.), to industrial products (luggage, canvases, sewing thread, etc.).(23) It was once the preferred yarn for hand sewing the uppers of moccasin-style shoes (loafers), but its use has been replaced by synthetics.(26) A linen handkerchief, pressed and folded to display the corners, was a standard decoration of a well-dressed man's suit during most of the first part of the 20th century. Currently researchers are working on a cotton/flax blend to create new yarns which will improve the feel of denim during hot and humid weather. (22)

FLAXSEED OIL		
Serving Size 1 Softgel Servings Per Container 100		
Amount Per Serving	% Daily Value	
Calories	10	
Calories from Fat	10	
Total Fat	1 g	2%*
Polyunsaturated Fat	0.5 g	†
Flaxseed Oil	1,000 mg	†
Alpha-Linolenic Acid	500 mg	†
Linoleic Acid	200 mg	†
Oleic Acid	200 mg	†
Palmitic Acid	60 mg	†
Stearic Acid	40 mg	†

* Percent Daily Values are based on a 2,000 calorie diet.
† Daily Value not established.

OTHER INGREDIENTS: Gelatin, Glycerin, St. John's Bread Extract.

SUGGESTED USE: As a dietary supplement, take 1-3 softgels daily with meals.

Health benefits of flax seed

Flaxseeds are rich in alpha linolenic acid (ALA), an omega-3 fat that is a precursor to the form of omega-3 found in fish oils called eicosapentaenoic acid or EPA. Since the fats are found in their isolated form in flaxseed oil, it is a more concentrated source of ALA than the seeds themselves (although it doesn't have the other nutrients that the seeds do). ALA, in addition to providing several beneficial effects of its own, can be converted in the body to EPA, thus providing EPA's beneficial effects. For this conversion to readily take place, however, depends on the presence and activity of an enzyme called delta-6-desaturase, which, in some individuals, is less available or less active than in others. In addition, delta-6-desaturase function is inhibited in diabetes and by the consumption of saturated fat and alcohol. For these reasons, higher amounts of ALA-rich flaxseeds or its oil must be consumed to provide the same benefits as the omega-3 fats found in the oil of cold-water fish. (3)

Flax Fights Cholesterol

The consumption of flaxseed is associated with a reduction in total cholesterol, including the LDL (bad) cholesterol and triglycerides. Study after study has shown a positive response to eating ground flax seed

daily. Eating low fat foods, increasing your exercise, limiting the salt, sugar and eating flax seed daily are a few ways that you can win the battle against high cholesterol.(7)

Flax Fights Diabetes

Nutritionists are instructing their diabetic patients to eat flax daily. It has been discovered that the omega-3 fat and high fiber in flax may play a role in the fight against diabetes. In a study conducted by the University of Toronto, participants who ate flaxseed bread had blood sugar levels 28% lower an hour after eating than their counterparts who ate bread made with wheat flour! (8)

Flax Fights Cancer

Flaxseed is high in lignans, up to 800 times the amount as in any tested plant food. Lignans (a phytoestrogen) have been called by H. Adlercreutz (in his article “Phytoestrogens: Epidemiology and a Possible Role in Cancer Protection”), natural cancer-protective compounds. Flax seed is also high in alpha linolenic acid (ALA) which has been found to be promising as a cancer fighting agent. The American National Cancer Institute has singled out flaxseed as one of six foods that deserve special study. Flax seed's high fiber aspect is also beneficial in the fight against colon cancer. Epidemiological studies note that diet plays a major role in the incidence of colon cancer. Research has shown that increasing the amount of fiber in your diet reduces your colon-cancer risk. Flax seed, high in fiber, lignans, alpha linolenic acid, is a key player in the fight against cancer, particularly breast and colon cancer. (9)

flax fights constipation

Flax is high in both soluble and insoluble fiber. One ounce of flax provides 32% of the USDA's reference daily intake of fiber. Flax promotes regular bowel movements because it is high in insoluble fiber. Flaxseed's all natural fiber helps to absorb water, thereby softening the stool and allowing it to pass through the colon quickly. When adding fiber to your diet, it is important to make sure that you are drinking at least eight glasses of water daily. Without enough liquids, fiber can actually cause constipation! In the fight against constipation exercise, eat fruits and vegetables, drink eight glasses of water daily and add two to four tablespoons of flax to your daily regime. (10)

Flax Fights Inflammation

Flax is high in Omega 3 essential fatty acids. That's good news for people who suffer from inflammatory disorders, including rheumatoid arthritis. Health experts, recommend eating foods high in Omega 3's for people suffering from rheumatoid arthritis. It is the inflammation within the joints that cause so much of the pain associated with arthritis. The January 1996 issue of the American Journal of Clinical Nutrition reported

that the participants in a study that took flax oil daily reduced inflammatory responses by as much as 30%. (11)

Flax Fights Menopausal Symptoms

Flax is the richest known plant source of phytoestrogen. Phytoestrogens act as a natural hormone therapy and help to stabilize hormonal levels. This stabilization of hormonal levels helps to lessen the symptoms of menopause. (12)

Flax fights Heart Disease

Flax has been found to help reduce total cholesterol, LDL levels (the bad cholesterol), triglycerides. Flax helps to reduce clotting time and thereby reduces the chance for heart attacks and strokes. Regular intake of flax protects against arrhythmias and helps keep the arteries clear and pliable. (13)

Flax and the Immune System

Research has found that eating flax daily favorably affects immunity, the body's ability to defend itself successfully against bacteria and viruses. Two components of flax, lignans and ALA (alpha-linolenic acid), have been found to affect immune cells and compounds that control immune reaction. (14)

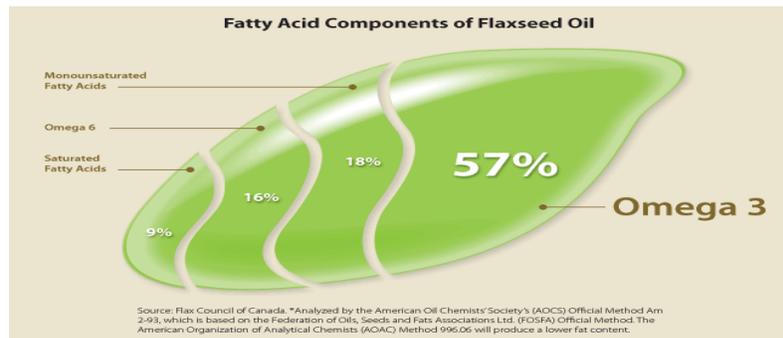
Flax fights "The Blues"

Flax has a mood boosting ingredient: docosahexaenoic acid (DHA) that is essential for the proper function of brain cells, yet up to 85% of women isn't getting enough of it. Early research conducted by Dr. Martha Clare Morris of Chicago's Rush-Presbyterian-St. Luke's Medical Center notes that a diet rich in omega-3 fatty acids is believed to be important for brain development. More research is needed in the area of flax and its relation to depression and brain function; however preliminary research is very promising. (15)

Anti-Inflammatory Benefits

Omega-3 fats are used by the body to produce Series 1 and 3 prostaglandins, which are anti-inflammatory hormone-like molecules, in contrast to the Series 2 prostaglandins, which are pro-inflammatory molecules produced from other fats, notably the omega-6 fats, which are found in high amounts in animal fats, margarine, and many vegetable oils including corn, safflower, sunflower, palm, and peanut oils. Omega-3 fats can help reduce the inflammation that is a significant factor in conditions such as asthma, osteoarthritis, rheumatoid arthritis, migraine headaches, and osteoporosis. (15, 17)

Omega-3-rich Flaxseeds Protect Bone Health



Alpha linolenic acid, the omega-3 fat found in flaxseed and walnuts, promotes bone health by helping to prevent excessive bone turnover, when consumption of foods rich in this omega-3 fat results in a lower ratio of omega-6 to omega-3 fats in the diet (16)

FUTURE OUTLOOK

Linen has about a 2–3% share of the consumer textile market, compared with cotton at ~65%. Comfort, drape, and distinctive appearance, however, continue to command market share for linen. Emphases in the fashion industry will likely continue to dictate a periodicity in use and value of linen and flax fibers for textiles. Cotton and flax blends, both as intimate blends and with flax used as weft yarns, continue to be popular in the United States, which is a major importer. The greatest total value of flax fiber in the future likely will be as cottonized fibers for distinctive textiles and as industrial fibers for nonwoven materials and composites. In textiles, the cottonized flax fibers are blended with cotton or other fibers and spun into yarns on advanced and efficient, short staple spinning equipment. Cottonization of flax demands different methods of processing from traditional long-line flax, and any new retting procedure should take advantage of this opportunity. Flax and other natural fibers are in demand for reinforced composites, and the replacement of glass fiber with flax allows large savings in energy costs, provides advantages in the environment through biodegradability, and offers opportunities for new, value-added crops in agriculture. Commercially viable chemical- or enzyme-retting methods to improve the quality and consistency of flax fiber are needed to expand applications for flax fiber. Such methods, if made cost efficient, could expand production beyond regions where weather now limits dew-retting.

Important as well is the opportunity to employ enzymes to tailor properties for specific applications. Improved retting could take advantage of the vast amounts of seed flax straw as a by-product of the linseed industry available in Europe and North America. Linseed straw, which is becoming an increasing environmental problem for disposal, likely would not surface for traditional long-line flax but could provide a value-added resource at the farm level for use in a wide range of composites and nonwoven materials.

CONCLUSIONS

Linen is a bast fiber. Flax fibers vary in length from about 25 to 150 cm (18 to 55 in) and average 12-16 micrometers in diameter. Flax fibers can usually be identified by their “nodes” which add to the flexibility and texture of the fabric. An oil seed fiber crop like flax (*Linum usitatissimum* L.) has been used by humans from more than 6000 years and it is among the first plants domesticated. The utilization of flax for various purposes including industry, nutraceutical, bio- pharmaceutical, fiber, animal feed and human food is continuing to develop. Increasing cost of artificial fibers and the advantages of natural flax fiber, new technology and equipments for growing, harvesting of flax is useful to make flax a model plant species. New improved methods of retting flax, more efficient processes at each stage of linen manufacture point towards a possible upturn of the utilization of flax fiber than its current limited use, especially in India. There are also opportunities for production of sustainable bio-products and green building materials. The molecular and gene expression experiments are not widely studied in flax, which may also expand the applications and uses of flax in future. Several constrains must be overcome to facilitate the further development of flax and flax bioproducts. Currently, a lack of basic knowledge of flax genomics, and a concerted effort in flax breeding limits rapid development of flax for byproducts. Flax fiber is used in medical textile industry it prevent several disease condition. In such way flax seed powder is coated in fabric by using micro encapsulation method, it helps to enhance the quality of cloth.

REFERENCES

1. Alister D. Muir, Neil D. Westcott, Flax: The Genus *Linum*.
<http://books.google.com/books?id=j0zDO165tHcC&pg.>, page 3 (August 1, 2003).
2. Cleland LG, James MJ. Rheumatoid arthritis and the balance of dietary N-6 and N-3
Essential fatty acids. *Br J Rheumatol* 1997 May; 36(5):513-4 1997
3. Eastwood, GL. Pharmacologic prevention of colonic neoplasms. “Effects of calcium,
Vitamins, omega fatty acids, and nonsteroidal anti-inflammatory drugs. “Cancer
Causes Control” 1997; 8:786-802 1997.
4. Del Toma E, Lintas C, et al. “Soluble and insoluble dietary fibre in diabetic diets”. *Eur*

- J Clin Nutr 1988 Apr; 42(4):313-9 1988.
5. Mayo Clinic (2006-05-01). "Drugs and supplements: flaxseed and flaxseed oil"
<http://www.mayoclinic.com/health/flaxseed/NS-patient-flaxseed>. Retrieved 2007-07.
 6. "Flaxseed Stunts The Growth Of Prostate Tumors". Science daily. 2007-06-04.
<http://www.sciencedaily.com/releases/2007/06/070603215443.htm>. Retrieved 2007-23.
 7. "Meta-analysis of the effects of flaxseed interventions on blood lipids," Pan A, Yu D, Demark-Wahnefried W, Franco OH, Lin X, Am J Clin Nutr. 2009 Aug; 90(2): 288-97.
 8. Dahl, WJ; Lockert EA Cammer AL Whiting SJ (December 2005). "'Effects of Flax Fiber on Laxation and Glycemic Response in Healthy Volunteers". Journal of Medicinal Food 8 (4): 508–511.
doi:10.1089/jmf.2005.8.508.PMID 16379563. <http://www.liebertonline.com/doi/abs/10.1089/jmf.2005.8.508>. Retrieved 2007-05-14.
 9. "Flaxseed and Flaxseed Oil". National Center for Complementary and Alternative Medicine. <http://nccam.nih.gov/health/flaxseed/>. Retrieved 2008-01-03.
 10. Brooks JD, Ward WE, Lewis JE, Hilditch J, Nickell L, Wong E, Thompson LU. Supplementation with flaxseed alters estrogen metabolism in postmenopausal women to a greater extent than does supplementation with an equal amount of soy. Am J Clin Nutr. 2004 Feb;79(2):318-25. 2004. PMID:14749240
 11. Mandasescu S, Mocanu V, Dascalita AM, Haliga R, Nestian I, Stitt PA, Luca V. Flax seed supplementation in hyper lipidemic patients. Rev Med Chir Soc Med Nat Iasi. 2005 Jul-Sep; 109(3):502-6. 2005. PMID: 16607740.
 12. Buchanan HM, Preston SJ, et al. Is diet important in rheumatoid arthritis. Br J Rheumatol 1991 Apr; 30(2):125-34 1991.
 13. Cleland LG, James MJ. Rheumatoid arthritis and the balance of dietary N-6 and N-3 Essential fatty acids. Br J Rheumatol 1997 May; 36(5):513-4 1997.
 14. Cunnane SC, Hamadeh MJ, Liede AC, et al. Nutritional attributes of traditional Flaxseed in healthy young adults. Am J Clin Nutr 1995 Jan; 61(1):62-8 1995. PMID: 18200.

15. Fennema OR (Ed.). Food chemistry. Second edition. Marcel Dekker, New York, 1985
16. Nesbitt PD, Thompson LU. Lignans in homemade and commercial products containing Flaxseed. *Nutr Cancer* 1997; 29(3):222-7 1997. PMID: 18160.
17. Balter M. (2009). Clothes make the (Hu) Man. *Science*, 325 (5946) :1329 .
<http://www.yarn-methods.com/flax-fiber.html>
18. Kvavadze E, Bar-Yosef O, Belfer-Cohen A, Boaretto E, Jakeli N, Matskevich Z, Meshveliani T. (2009). 30,000-Year-Old Wild Flax Fibers. *Science*, 325(5946):1359.
19. Wardey, A. J. (1967). *The Linen Trade: Ancient and Modern*. Routledge. p. 752.
ISBN 071461114X.
20. "FlaxUnshackled". *TextileWorld*.
http://www.textileworld.com/Articles/2011/May/May_June_issue/Departments/Quality_Fabric_Of_The_Month.html. Retrieved 2011-07-04.
21. Laux, Marsha (2009-09). "Flax Profile". Agricultural Marketing Resource Center.
http://www.agmrc.org/commoditiesproducts/grainsoilseeds/flax_profile.cfm. Retrieved 2010-11-07.
22. "These Vintage Threads Are 30,000 Years Old". NPR.
<http://www.npr.org/templates/story/story.php?storyId=112726804&>
Retrieved 2010-11-13.
23. Wardey, A. J. (1967). *The Linen Trade: Ancient and Modern*. Routledge. p. 752.
ISBN 071461114X