Plant Archives Vol. 15 No. 2, 2015 pp. 711-716 ***ISSN 0972-5210***

EXTRACTION METHOD OF FLAX FIBRE AND ITS USES

Namrata Dhirhi*, Rajshree Shukla, Nirmala Bharti Patel, Hemant Sahu and Nandan Mehta

Department of Genetics and Plant Breeding, I.G.K.V., Raipur - 492 012 (C. G.), India.

Abstract

Flax (*Linum usitatissimum*) is a bast fibre plant cultivated for the production of fibres, for use in a wide range of woven and non-woven end uses. Bast fibres are also known as 'soft' fibres or skin fibres and are characterised by their fineness, strength and flexibility, which distinguishes them from the coarser and less flexible fibres of the leaf, or "hard," fibre. Flax is a renewable resource and has the potential to be much more eco-friendly than cotton. Linen fibres are obtained from the inner bark (or skin) of a plant. Flaxseed fibre is a high quality, organic, natural, unrefined whole food product that is naturally gluten free with a shelf life of two years, as reported by the manufacturers. The fibres support the conductive cells of the phloem and provide strength to the stem. Traditionally, the production of fibre from flax has focused on long fibres for use in the manufacture of linen yarns. However, short-fibre flax can also be produced and processed to be a 'cottonised' fibre for the production of textile yarns on cotton processing equipment. the production of a cotton compatible fibre from flax crops. Flax fiber is a raw material used in the high-quality paper industry for the use of printed bank notes and rolling paper for cigarettes and tea bags.

Key words : Flax, fiber, linen, retting, scutching, heckling.

Introduction

Flax (also known as common flax or linseed), with the binomial name *Linum usitatissimum* is a member of the genus *Linum* in the family Linaceae, which has been grown throughout the world for millennia is the source of products for existing, high-value markets in the textile, composites, paper/pulp and industrial/nutritional oil sectors (Hamilton, 1986; Sharma and Sumere, 1992). It is a food and fiber crop that is grown in cooler regions of the world. Originally cultivated in Mesopotamia, the use of flax has been documented as far back as 3000 BC (Cunnane and Thompson, 1995). In addition to referring to the plant itself, the word "flax" may refer to the unspun fibers of the flax plant. Flax fiber is extracted from the bast or skin of the stem of the flax plant. Flax fiber is soft, lustrous and flexible, bundles of fiber have the appearance of blonde hair, hence the description "flaxen". It is stronger than cotton fiber but less elastic. Flax is the source of industrial fibers and as currently processed, results in long-line and short fibers (Van Sumere, 1992). Long line fiber is used in manufacturing high value linen apparel, while short staple fiber has historically been the waste from long line fiber and used for lower value products. The best grades are used for linen fabrics such as damasks, lace and sheeting. Coarser grades are used for the manufacturing of twine and rope and historically for canvas and webbing equipment. Flax fiber is a raw material used in the high-quality paper industry for the use of printed bank note sand rolling paper for cigarettes and tea bags. Flax mills for spinning flaxen yarn were invented by John Kendrew and Thomas Port house of Darlington in 1787. New methods of processing flax and the rising price of cotton have led to renewed interest in the use of flax as an industrial fiber.

***Author for correspondence :** E-mail: namrata123igkv@gmail.com

Biology

Cultivated flax (*Linum usitatissimum*) is an annual of temprate climates, especially of northern Europe. This plant grows to a height up to 60 cm, with slender and very fibrous stems, lanceolate leaves having three veins, up to 4 cm long and 4 mm wide, and its bright blue flowers are up to 3 cm in diameter. The fruit contains a seed known as flaxseed or linseed (Pradhan *et al*., 2010). Separate varities are grown either for the fibre or for the seeds that are used in linseed oil production after flowering, the whole plant is pulled to obtain the maximum length of fibre.

Types of flax

To date, no method of flax cultivation has been discovered that maximizes both quality and yield of both seed and fibers. To obtain the highest quality flax fibers, one must harvest before the plant fully matures, which results in poorer-quality oil. Conversely, if harvest is undertaken after maturation to obtain the best oil, the fiber quality deteriorates. Thus, two distinct types of flax plants are cultivated.

- The linseed type is grown primarily to extract the seed's highly nutritious oil. This type is fairly short and produces many secondary branches, which increases seed yield.
- The flax type tends to grow taller, more slender, and with less branches. It is cultivated in order to extract the very long fibers from inside the wooden stem of the plant, which are then spun and woven into linen fabric. The taller the flax plant, the longer the fiber.

What is flaxseed fiber

Harvested deseeded stalks (up to first branching) are completely dried and subjected to wet retting for 2-3 weeks. Fibres are then separated from the vetted stock by scotching and drying (Chouhan *et al.,* 2009). Long line fiber is used in manufacturing high value linen apparel, while short staple fiber has historically been the waste from long line fiber and used for lower value products. Retting, which is the separation of bast fibers from the core tissues, is preeminent in flax fiber processing, as it affects quality and yield (Pallesen, 1996). Flaxseed flake is the product that remains after the cold extraction of the oil from flaxseed and is sometimes referred to as de-fatted flaxseed. With the appearance of bran flakes, flaxseed flake can be milled to various degrees of coarseness, from a coarse meal to fine flour. Flaxseed fibre is a high quality, organic, natural, unrefined whole food product that is naturally gluten free with a shelf life of two years, as reported by the manufacturers. High temperature screw press extraction of flaxseed on a large scale results in oil that is inedible and is used in paints and varnishes. The residual meal suffers from degradation of the proteins and oil. Low temperature gentle extraction produces good quality polyunsaturated oil (rich in the omega-3 alpha-linolenic acid) with a residual meal that contains high quality protein and un-oxidized oil which should be a significantly more stable food ingredient than whole flaxseed meal.

Cultivation

The soils most suitable for flax, besides the alluvial kind, are deep loams, and containing a large proportion of organic matter. Flax is often found growing just above the waterline in cranberry bogs. Heavy clays are unsuitable, as are soils of a gravelly or dry sandy nature. Farming flax requires few fertilizers or pesticides. Within eight weeks of sowing, the plant will reach 10–15 cm (3.9–5.9 in) in height and will grow several centimeters per day under its optimal growth conditions, reaching 70–80 cm (28–31 in) within fifteen days. Flax is ready to be harvested for its fibers when the stem begins to turn yellow and the seeds turn brown. On some farms however, the plant is harvested prior to seed germination. This yields exceptionally fine fibers, but leaves the grower without any seeds for the next planting and subsequently dependent upon foreign imports. The stems of the flax plant are preferably pulled up with the root system somewhat intact, rather than cut at the base. This maximizes the quality of the fiber in several ways. First, the valuable fibers run the length of the stalk all the way into the roots, so pulling up the plant by the root increases the length of the fiber produced. This practice also prevents the plant sap from leaking out of the cut stalk, a process, which dries out the fibers and ultimately results in poorer-quality fabric. Although the agricultural industry has made great strides in mechanized farming, machine harvesting of flax is still unable to preserve the root system during harvest. For this reason, despite the extremely laborious process of manual harvesting, the highest quality linens are still made from flax plants that were pulled out of the earth by hand. Fabric made from hand-harvested flax is finer, more supple, and more highly prized than fabric made from flax that is machine-harvested.

Harvesting

Flax is harvested for fiber production after approximately 100 days, or a month after the plant flowers and two weeks after the seed capsules form. The base of the plant will begin to turn yellow. If the plant is still green, the seed will not be useful and the fiber will be underdeveloped. The fiber degrades once the plant is brown. Traditional methods for harvesting flax require specially made, sole-purpose and expensive equipment manufactured only overseas to pull and turn flax (Sultana, 1992).

Methods

There are two ways to harvest flax, one involving mechanized equipment (combines) and a second method, more manual and targeted towards maximizing the fiber length.

Mechanical

The mature plant is cut with mowing equipment, similar to hay harvesting and raked into windrows. When dried sufficiently, a combine then harvests the seeds similar to wheat or oat harvesting. The amount of weeds in the straw affects its marketability and this coupled with market prices determined whether the farmer chose to harvest the flax straw. If the flax was not harvested, it was typically burned, since the straw stalk is quite tough and decomposes slowly (*i.e.*, not in a single season) and still being somewhat in a windrow from the harvesting process, the straw would often clog up tillage and planting equipment. It was common, in the flax growing regions of western Minnesota, to see the harvested flax straw (square) bale stacks start appearing every July, the size of some stacks being estimated at 10-15 yards wide by 50 or more yards long and as tall as a two-story house.

Manual

The mature plant is pulled up with the roots (not cut), so as to maximize the fiber length. After this, the flax is allowed to dry, the seeds are removed, and is then retted. Dependent upon climatic conditions, characteristics of the sown flax and fields, the flax remains on the ground between two weeks and two months for retting. As a result of alternating rain and the sun, an enzymatic action degrades the pectins which bind fibers to the straw. The farmers turn over the straw during retting to evenly rett the stalks. When the straw is retted and sufficiently dry, it is rolled up. It will then be stored by farmers before scutching to extract fibers. Flax grown for seed is allowed to mature until the seed capsules are yellow and just starting to split; it is then harvested by combine harvester and dried to extract the seed.

Threshing flax

Threshing is the process of removing the seeds from the rest of the plant. As noted above in the Mechanical section, the threshing could be done in the field by a machine, or in another process, a description of which follows:

The process is divided into two parts:

- The first part is intended for the farmer, or flax-grower, to bring the flax into a fit state for general or common purposes. This is performed by three machines: one for threshing out the seed, one for breaking and separating the straw (stem) from the fiber, and one for further separating the broken straw and matter from the fiber. In some cases the farmers thrash out the seed in their own mill and therefore, in such cases, the first machine will be unnecessary.
- The second part of the process is intended for the manufacturer to bring the flax into a state for the very finest purposes, such as lace, cambric, damask, and very fine linen. This second part is performed by the refining machine only.

The threshing process would be conducted as follows:

- Take the flax in small bundles, as it comes from the field or stack, and holding it in the left hand, put the seed end between the threshing machine and the bed or block against which the machine is to strike; then take the handle of the machine in the right hand, and move the machine backward and forward, to strike on the flax, until the seed is all threshed out.
- Take the flax in small handfuls in the left hand, spread it flat between the third and little finger, with the seed end downwards, and the root-end above, as near the hand as possible.
- Put the handful between the beater of the breaking machine and beat it gently till the three or four inches, which have been under the operation of the machine, appear to be soft.
- Remove the flax a little higher in the hand, so as to let the soft part of the flax rest upon the little finger, and continue to beat it till all is soft, and the wood is separated from the fiber, keeping the left hand close to the block and the flax as flat upon the block as possible.
- The other end of the flax is then to be turned, and the end which has been beaten is to be wrapped round the little finger, the root end flat, and beaten in the machine till the wood is separated, exactly in the same way as the other end was beaten.

Preparation for spinning

Before the flax fibers can be spun into linen, they must be separated from the rest of the stalk. The first step in this process is called retting. Retting is the process of rotting away the inner stalk, leaving the outer fibers intact. At this point there is still straw, or coarse fibers, remaining. To remove these the flax is “broken,” the straw is broken up into small, short bits, while the actual fiber is left unharmed, then “scutched,” where the straw is scraped away from the fiber, and then pulled through “hackles,” which act like combs to comb the straw out of the fiber. In Ireland ‘hackling’ was the term used for the final process in preparing flax for spinning into linen. A hackler, strictly speaking, is a person involved in the process of refining flax, which used to be grown in abundance in County Cavan, Ireland. Prior to the industry becoming mechanised and moving to East Ulster, it was a rural based cottage industry with Coote hill as Ulster’s largest market. The Hackler from Grouse Hall is an Irish song written in the late 1880s by a local man, Peter Smith, from Stravicnabo, Lavey. It has been sung by Christy

Moore, Planxty and Damien Dempsey. In the 1990s a product known as The Hackler, an Irish poitin, was developed by Cooley Distillery. So popular was this song that the promotional literature originally referred incorrectly to a hackler as a maker of poitin.

Retting flax

Retting, which is the separation of bast fibers from the core tissues is preeminent in flax fiber processing, as it affects quality and yield. There are several methods of retting flax. It can be retted in a pond, stream, field or tank. When the retting is complete, the bundles of flax feel soft and slimy and quite a few fibers are standing out from the stalks. When wrapped around a finger the inner woody part springs away from the fibers. Pond retting is the fastest. It consists of placing the flax in a pool of water which will not evaporate. It generally takes place in a shallow pool which will warm up dramatically in the sun, the process may take from a couple of days to a few weeks. Pond retted flax is traditionally considered of lower quality, possibly because the product can become dirty, and is easily over-retted, damaging the fiber. This form of retting also produces quite an odor. Dew-retting is an art that depends upon the removal of matrix materials from the cellulosic fibers before cellulolysis, and therefore weakening of the fibers occurs. This process is dependent mostly upon plant cell-wall degrading enzymes produced by indigenous, aerobic fungal consortia (Fila *et al*., 2001). In dew-retting, flax plants are pulled from the soil and laid out in fields for selective attack by the fungi over several weeks. Disadvantages of dew-retting are its dependence on particular geographical regions that have the appropriate moisture and temperature ranges for retting, coarser and lower quality fiber than water retting, Stream retting is similar to pool retting, but the flax is submerged in bundles in a stream or river. This generally takes two or three weeks longer than pond retting, but the end product is less likely to be dirty, does not smell as bad and, because the water is cooler, is less likely to be over-retted. Both pond and stream retting were traditionally used less because they pollute the waters used for the process. Because of problems with both water- and dew-retting, a long-term objective for improving the flax fiber industry has been development of enzyme-retting (Schunke *et al*., 1995). The strategy of this research was to replace the anaerobic bacteria with enzyme mixtures in controlled tanks, thereby producing flax of water-retted quality, but without the negative aspects of stench and pollution. In field retting, the flax is laid out in a large field and dew is allowed to collect on it. This process normally takes a month or more but is generally considered to provide the highest quality flax fibers and it produces the least pollution. Retting can also be done in a plastic trash can or any type of water-tight container of wood, concrete, earthenware or plastic. Metal containers will not work, as an acid is produced when retting, and it would corrode the metal. If the water temperature is kept at 80°F (27°C), the retting process under these conditions takes 4 or 5 days. If the water is any colder, it takes longer. Scum will collect at the top, and an odor is given off the same as in pond retting. 'Enzymatic' retting of flax has been researched as a retting technique to engineer fibers with specific properties. the retting and mechanical processing steps work together to produce fibers, which are more precisely fiber bundles, of a particular fineness distribution. Variations in enzyme formulations used in retting can modify fiber properties, *e.g*., color, strength, and fineness (Akin *et al*., 2001, 2002) and information is needed on the specific fiber properties resulting from enzyme modifications, particularly related to subsequent cleaning.

Dressing the flax

Dressing the flax is the process of removing the straw from the fibers. Dressing consists of three steps: breaking, scutching, and heckling. The breaking breaks up the straw. Some of the straw is scraped from the fibers in the scutching process, and finally the fiber is pulled through heckles to remove the last bits of straw.

The dressing is done as follows

Breaking : The process of breaking breaks up the straw into short segments. To do it, take the bundles of flax and untie them. Next, in small handfuls, put it between the beater of the breaking machine (a set of wooden blades that mesh together when the upper jaw is lowered, which look like a paper cutter but instead of having a big knife it has a blunt arm) and beat it till the three or four inches that have been beaten appear to be soft. Move the flax a little higher and continue to beat it till all is soft, and the wood is separated from the fiber. When half of the flax is broken, hold the beaten end and beat the rest in the same way as the other end was beaten, till the wood is separated.

Scutching : In order to remove some of the straw from the fiber, it helps to swing a wooden scutching knife down the fibers while they hang vertically, thus scraping the edge of the knife along the fibers and pull away pieces of the stalk. Some of the fiber will also be scutched away; this cannot be helped and is a normal part of the process.

Heckling : In this process, the fiber is pulled through various different sized heckling combs or heckles. A heckle is a bed of “nails” sharp, long-tapered, tempered, polished steel pins driven into wooden blocks at regular spacing. A good progression is from 4 pins per square inch to 12, to 25 to 48 to 80. The first three will remove the straw, and the last two will split and polish the fibers. Some of the finer stuff that comes off in the last hackles is called “tow” and can be carded like wool and spun. It will produce a coarser yarn than the fibers pulled through the heckles because it will still have some straw in it.

Weaving : Linen yarn is generally woven into sheets – a process wherein multiple threads are interlaced both horizontally and vertically on a loom. Occasionally, linen yarn is also knit, or formed into fabric by creating consecutive rows of loops that intertwine with one another. By virtue of these loops, knit fabrics have a degree of stretch inherent in them, and because linen yarn has no elasticity, it is quite difficult to knit and so more frequently woven.

The Rise of the Machines

This preindustrial method of linen production hasn’t changed in centuries. Though, over the last few hundred years we’ve developed machines that complete the tasks of harvesting, retting and dressing flax, these processes damage the delicate fibers such that finest linens are still manufactured almost entirely by hand. Because the process is still so laborious, even mechanized flax production actually requires a great deal more handwork than other mass industrially-produced textiles like cotton and rayon.

Fiber to Fabric : Linen

The flax plant supplies both industrial oil (*i.e.*, linseed oil) and bast fiber used to produce textiles, composites, and paper/pulp. Linen has occupied a prominent place in textiles for centuries. Flax can be grown in many locations and is environmentally friendly (Foulk *et al.*, 2002). Flax is a filament fiber harvested from flax plants that when made into fabric, is called linen, it is still widely used today, though it is less prevalent than it once was due to the ease of obtaining fabrics made of other fibers, such as cotton. Because flax is difficult to harvest it has become more costly to produce linen. Flax plants are used for many purposes, but the fiber itself comes from the stem and root of the flax plant, requiring careful harvesting, often done by hand. After the initial harvest, flax must be dried, soaked, crushed, combed and spun, creating a lengthy process that increases cost for consumers.

Uses

Over the past 30 years the end use for linen has changed dramatically. Approximately 70% of linen production in the 1990s was for apparel textiles, whereas in the 1970s only about 5% was used for fashion fabrics. 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.). It was once the preferred yarn for hand sewing the uppers of moccasin-style shoes (loafers), but its use has been replaced by synthetics. 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. Linen fabric is one of the preferred traditional supports for oil painting. In the United States cotton is popularly used instead as linen is many times more expensive there, restricting its use to professional painters. In Europe however, linen is usually the only fabric support available in art shops, in the UK both are freely available with cotton being cheaper. Linen is preferred to cotton for its strength, durability and archival integrity. Linen is also used extensively by artisan bakers. Known as a couche, the flax cloth is used to hold the dough into shape while in the final rise, just before baking. The couche is heavily dusted with flour which is rubbed into the pores of the fabric. Then the shaped dough is placed on the couche. The floured couche makes a “non stick” surface to hold the dough. Then ridges are formed in the couche to keep the dough from spreading. In the past, linen was also used for books (the only surviving example of which is the Liber Linteus). Due to its strength, in the Middle Ages linen was used for shields and gambeson, much as in classical antiquity it was used to make a type of body armour, referred to as a linothorax. Also because of its strength when wet, Irish linen is a very popular wrap of pool/billiard cues, due to its absorption of sweat from hands.

Advantages of linen fabric

• Excellent strength, gains strength when wet • Hydrophilic: absorbs water and dries quickly • Cool in warm weather • Washable • Withstands very high temperatures when washing and ironing • No static, pilling, or lint problems • Unique texture from the thick-and-thin pattern of the fibers.

Disadvantages of linen fabric

• Wrinkles very easily • Fair abrasion, low durability • Poor drape and elasticity • Expensive.

Conclusion

Flax is a renewable resource and has the potential to be much more ecofriendly than cotton. It requires far less use of pesticides and artificial fertilizers. It grows best under traditional farming methods where the crops are rotated and fields are allowed to lay fallow. it also benefits from a longer lifespan. The environmental impacts associated with water consumption, pollution and build-up of salts in soil are generally limited or avoided. Linen, like other Bast fibres can thrive well on land unsuitable for food production and may even assist the recultivation of soils previously polluted with contaminants such as heavy metals. An additional benefit is the longevity of the fibre, linen is up to twelve times stronger than the equivalent cotton product, which dramatically increases its life span and therefore does not need to be replaced so often. Linen absorbs dye well, especially natural dyes, and does not require chemical treatments. Natural flax colours range from shades of ivory, tan and grey. White or pure white is only achieved through various bleaching processes, but it can be sun bleached to avoid the use of artificial agents. Flax processing is, however labour intensive, and requires skilled workers. But it produces minimum wastage, as there are several by-products, these include linseed oil for linoleum, soap, fuel and cattle feed. Almost every part of its plant is commercially utilized either directly or after processing.

References

Akin, D., J. Foulk, R. Dodd and D. McAlister (2001). Enzyme-retting of flax and characteristics of processed fibers. *J. Biotechnol.,* **89** : 193-203.

Akin, D., J. Foulk, and R. Dodd (2002). Influence on flax fiber of components in enzyme-retting formulations. *Textile Res. J.,* **72** : 510-514.

Allaby, R., G. Peterson, D. Merriwether and Y.B. Fu (2005). Evidence of the domestication history of flax (*Linum usitatissimum* L.) from genetic diversity of the sad2 locus. *Theor. and Applied Gene.,* **112(1)** : 58-65.

Balter, M. (2009). Clothes Make the (Hu) Man. *Science*, **325** : 1329.

Buchanan, R. (2012). A Weaver's Garden: Growing Plants for Natural Dyes and Fibers . Courier Dover Publications, p. 22.

Chauhan, M.P., Singh, S. and Singh, A. K. 2009. *J Hum Ecol*., **28(3)** : 217-219.

Cunnane, S. and L. Thompson (1995). Flaxseed in human nutrition. Champaign, IL: AOCS Press.

Dodd, F. A. (2008). Pectinolytic enzymes and retting. *Bio Resources,* **3(1)** : 155-169.

Foulk, J. A., D. E. Akin, R. B. Dodd and D. D. McAlister III (2002). Flax fiber : Potential for a new crop in the Southeast. p. 361-370.

Fila, G., L. Manici and F. Caputo (2001). *In vitro* evaluation of dew-retting of flax by fungi from southern Europe. *Ann. Appl. Biol.,* **138** : 343–351.

Fu,Y. B. (2011). Genetic evidence for early flax domestication with capsular dehiscence. **58(8)** : 1119-1128.

Hamilton, I. (1986). Linen. *Textiles*, **15** : 30–34.

Holbery, J. and D. Houston (2006). Natural-fiber-reinforced polymer composites in automotive applications. *J. Min. Met. Mater. Soc.*, **58** : 80-86.

Pallesen, B. (1996). The quality of combine-harvested fibre flax for industrials purposes depends on the degree of retting. *Ind. Crops Prod.,* **5** : 65–78.

Pradhan, R., V. Meda, P. Rout, S. Naik and A. Dalai (2010). Supercritical CO_2 extraction of fatty oil from flaxseed and comparison with screw press expression and solvent extraction processes. *J. Food Eng.,* **98(4) :** 393-397.

Schunke, H., C. Sanio, H. Pape, U. Schunke and C. Matz (1995). Reduction of time required for dew retting of flax : Influence of agricultural, mechanical and microbiological techniques on fibre processing. *Melliand,* **76** : 101-104.

Sekhri, S. (2011). *Textbook of Fabric Science: Fundamentals to Finishing*. PHI Learning Private Limited, New Delhi, p. 76.

Sharma, H. and C. Van Sumere (1992). Enzyme treatment of flax. *Genet. Eng. Biotechnol*., **12** : 19–23.

Sultana, C. (1992). *Growing and harvesting flax*. p. 83–109.

Symington, M. C., W. M. Banks, O. D. West and R. A. Pethrick (2009). Tensile testing of cellulose based natural fibers for structural composite applications. *J. Comp. Mater*, **43** : 1083-1108.

Van Sumere, C. (1992). *Retting of flax with special reference to enzyme-retting*. p. 157–198.

Yu, L., K. Dean and L. Li (2006). Polymer blends and composites from renewable resources. *Prog. Polym. Sci*., **31** : 576-602.

Wang, B., L. Tabil and S. Panigrahi (2008). Effects of chemical treatments on mechanical and physical properties of flax fiber-reinforced composites. *Sci. Eng. Compo. Mater*, **15** : 43-5.