QUALITY REQUIREMENTS OF FLAX, LINSEED AND HEMP FIBRE FOR INSULATION MATERIALS

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ABSTRACT

Flax, linseed and hemp fibres can be used for thick and thin insulation mats and loose-fill insulation. Overretted hemp fibre was very absorbant. Unretted hemp and flax/linseed fibre began to mould sooner than the retted hemp and flax/linseed fibre. The unretted fibres reached higher moisture contents before moulding than did the retted fibres. Microbial content did not have a direct correlation with moulding tendency of fibre materials. The following properties should be included in the quality criteria: 1) retting degree, 2) moisture content, 3) shive and dust content, 4) hygienic level of raw materials measured by microbial density and ash, and 5) length of fibre.
Keywords: FIBRE, QUALITY CRITERIA, MICROBES, HUMIDITY, MOISTURE.

1. INTRODUCTION

Flax, linseed and hemp fibres can be used for thick and thin insulation mats and loose-fill insulation. Relatively long fibre is used for mats, and short fibre for loose-fill. The location of the fibres in the plant necessitates the use of special separation techniques. One straw of *Linum* (flax and linseed) contains approximately 20-50 fibre bundles. Each bundle contains 10-30 individual fibre cells. Fibres of hemp are located as in Linum, but two types of fibre bundles can be distinguished in hemp: outer primary and inner secondary bundles. The primary bundles contain 2-20 and the secondary bundles over 40 individual fibres (Haudek and Viti, 1978). Fibre bundles are separated from shive using chemical, biological, and mechanical processing.

There are currently no exact quality definitions for fibre raw materials. Only microbial limits have been set by the government authorities. There is a strong need for definition of fibre quality, and experiments to determine the quality of the different fibres are needed.

The aim of this study was to define the basic properties of flax, linseed and hemp. In addition, their equilibrium moisture content, capillarity properties and microbiological status were examined.

2. MATERIALS AND METHODS

Two plants, flax (*Linum usitatissimum* L.) and fibre hemp (*Cannabis sativa* L.) were investigated. Two types of *Linum* were used; flax (varieties Viola and Viking) and linseed (variety Helmi). Plant samples were picked from various farms in southern Finland. Harvesting was in autumn when the straw was still green, or in spring when the dry-line method (Pasila, 1999) was used. The fibre fraction was obtained by a process consisting of taking samples from the field in autumn or sampling from the bale, cutting as a pretreatment, milling the cut straw with a hammer mill and separating the fibre and shive fractions with a drum separator (Kymäläinen et al., 2001). The hammer mill screen size was ∅ 20 mm, except for short spring-harvested hemp (∅ 8 mm screen). The fibres are described in Table 1 by five basic properties: shive content, length, thickness, bulk density and ash. Detailed methods for these measurements were presented by Kymäläinen et al. (2001) and Kymäläinen (2002). Figure 1 shows the division of retted fibres into thin fibres.

A vertical capillary rise method introduced by Chwastiak (1973) was applied for capillarity determination. Five replicate samples from the capillarity test were taken from each treatment (Kymäläinen et al., 2001).

Equilibrium moisture content (EMC) experiment was conducted with a completely random design. One sample consisted of 1-1.5 g of room-dry fibre. Samples in metal bowls were put into a plastic container in a conditioning room (T = 20 ± 2°C, RH = 65 ± 2 %). The samples were subjected to different conditions to achieve EMC in the order of 15 % (RH of air) -> 76 % -> >97 % (Kymäläinen and Pasila, 2000).

Table 1. Materials and variation ranges of their properties

	Fibre material/sample						
	Green flax	Green linseed	Green hemp	Spring-harvested flax	Spring-harvested linseed	Spring-harvested hemp	Spring-harvested hemp, short
Variety	Viola	Helmi	Felina 34	Viking	Helmi	Kompolti hybrid	Kompolti hybrid
Harvest time	Autumn	Autumn	Autumn	Spring	Spring	Spring	Spring
Stem maturity at harvest time	Stem unripened	Stem unripened	Stem unripened	Overretted	Overretted	Overretted	Overretted
Harvest method and preliminary treatment	Pulling, drying, rippling, cutting roots	Pulling, drying, rippling, cutting roots	Pulling, drying, rippling, cutting roots	Round baling	Small baling, preprocessing	Round baling	Round baling
Shive content (%)	19-39	78-84	37-55	8-11	15-20	14-33	1-2
Fibre length average (mm)	19 ± 0.9[a]	22 ± 0.9	17 ± 0.9	17 ± 0.9	21 ± 1.5	23 ± 1.4	2.0 ± 1.2
Proportion of >29 mm long fibres (%) from all fibres	9	15	8	7	12	27	0
Proportion of thin[b] fibres (%)	28	35	17	80	81	74	98
Bulk density (kg/m^3)	24-27	13-17	28-35	29-33	24-26	23-27	35-38
Ash (%)	3.8	3.8	2.5	3.2	2.9	2.2	2.8

a Error limits for length averages are standard deviations,
b <50 µm (flax/linseed) or <60 µm (hemp).

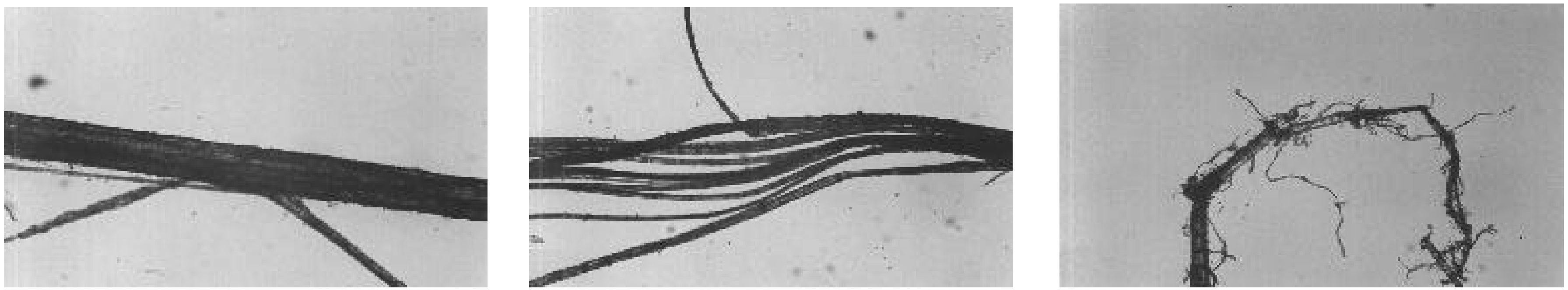

Figure 1. Green flax (left), spring-harvested flax (middle), and short spring-harvested hemp (right) shown by optical microscope (magnific. 50x)

Microbiological quality was investigated by measuring the microbial densities using yeast & fungi count plates (3M petrifilm™) (Kymäläinen, 2002). Microbial growth was investigated in a liquid which was obtained by mixing fibre and NaCl. Liquid samples were prepared by adding 15 ml NaCl (0.9 % solution) to 0.5 g room-dry fibre and mixing with a glass rod for 1 min. Incubation was for 5 d at 25 °C.

3. RESULTS AND DISCUSSION

3.1. Capillarity

Spring-harvested hemp was the most absorbant and linseed the least absorbant of the plant fibres tested. The short hemp fibre, which was of the same origin as the spring-harvested hemp, was clearly more absorbant than the longer fibre (Fig. 2). The absorption rate of hemp was highest during the first few minutes of the test. This method was previously used by Nevander and Elmarsson (1994) for testing of building materials. Method describes well the situation when the insulation material is in contact with free water. This situation is typical in building sites, where insulation materials are not well protected from rain.

The results show that retted hemp fibre has a clearly greater risk of reduced quality due to wetting from free water than has *Linum* fibre. Heino et al. (2000) investigated linseed and hemp fibre in loose-fill insulation, in which hemp fibre was also found to be very hygroscopic.

3.2. Equilibrium moisture content (EMC)

At 15 % and 76 % RH of air, the EMC values of the green and frost-retted fibres were rather similar (Fig. 3).

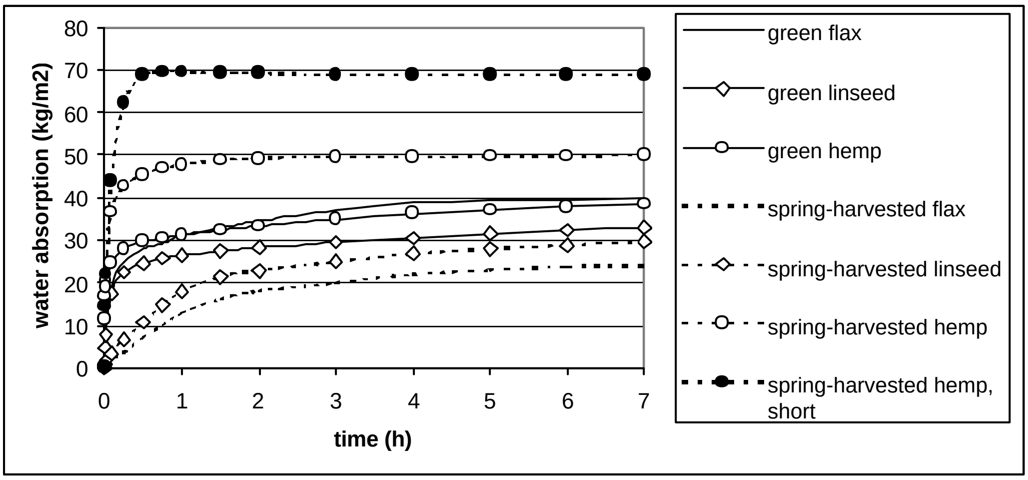

Figure 2. Amount of absorbed water per area as means of five replicates

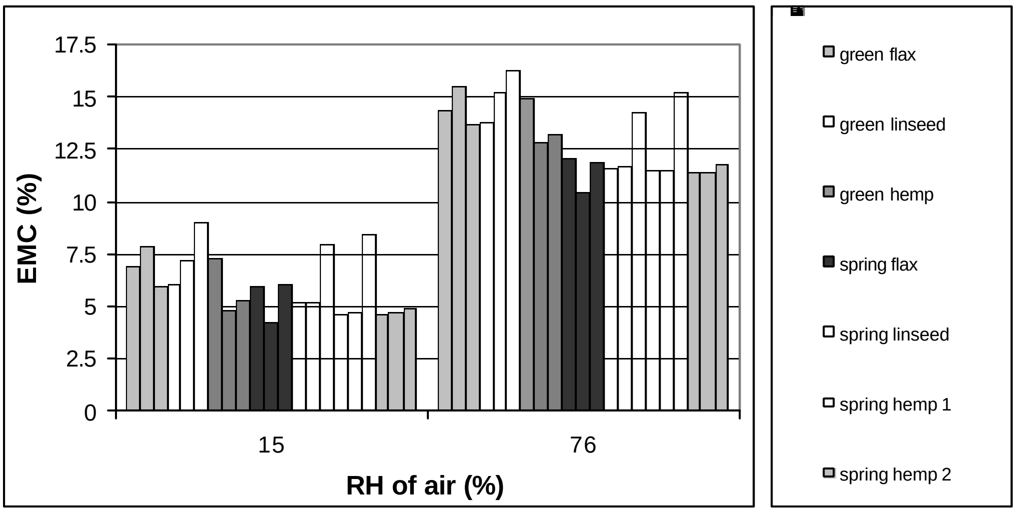

Figure 3. Equilibrium moisture content (EMC) of fibres in 15 and 76 % RH of air. 3 replicates

At higher relative humidities, all fibre samples began to lose weight due to moulding (Table 2), and clear differences were observed between unretted and frost-retted samples. Later investigations (Kymäläinen et al., unpublished report) have shown that weight loss begins even at lower relative humidities of air than >97 %, if the investigation period is long enough. The frost-retted fibres began to lose weight more slowly than green samples at >97 % RH of air, although the deviation within a raw material was considerable. The unretted, green samples attained higher EMCs before losing weight than did the frost-retted samples (Table 2).

Table 2. Time during which samples began to lose weight due to moulding and the highest moisture contents of the samples before losing weight in >97 % RH of air (three replicates)

	time (d)	highest moisture content (% w.b.)
green flax	2 - 3	33.7±1.7
green linseed	2	31.5±1.1
green hemp	3 - 4	32.0±1.4
spring flax	5 - 8	23.5±0.5
spring linseed	4 - 8	24.4±0.9
spring hemp	5 - 8	25.2±0.6
spring hemp, short	7 - 9	29.0±0.6

The amount of pectin decreases in fibre during retting, and thus frost-retted fibres were expected to absorb less water than unretted ones, which was observed in the dampest air as lower moisture contents before moulding. Lignin is less hydrophilic than cellulose or hemicellulose (Parham and Gray, 1984), which may have decreased the hygroscopicity of unretted fibres due to their higher shive content.

3.3. Hygienic level

The microbial density and ash content were used to define the hygienic level of the fibres. Spring-harvested linseed with visually evident moulding had a very high microbial density (Fig. 4). Frost-retted hemp fibre had spots of brown rot on its surface. The microbial densities of all samples were above the lower recommended spore count limit of 10 000 cfu/g for building materials in Finland. The microbial densities of green and frost-retted hemp fibres did not exceed the highest recommended spore count limit of 100 000 cfu/g (Sisäilmaohje, 1997). In this study the processing equipment and layout was preliminary, and no special attention was paid to the hygienic questions. It would be relatively easy to rise the hygiene of the system to a reasonable level. In the future, special attention should be paid on the hygiene aspects in fibre processing, and research should be continued in this field to find the contaminating phases in the production chain.

Fibres began to mould in the EMC test in the highest relative humidities of air. The high spore count of the frost-retted linseed fibre or the brown rot spots on the frost-retted hemp fibre did not increase further moulding of these samples compared to other fibres. It has been suggested that the mould content of the fibre may be regulated by the separation process of fibre from the straw (Kymäläinen, unpublished result).

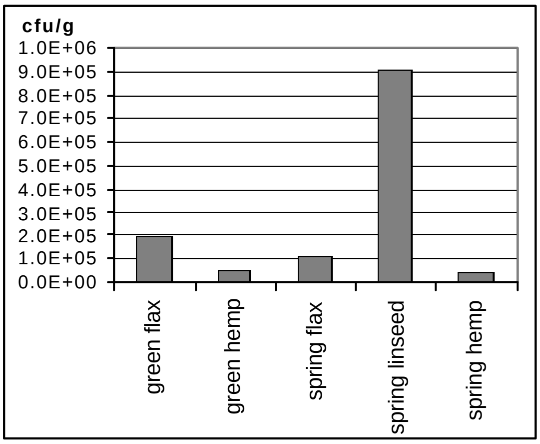

Figure 4. Microbial density of fibres. cfu/g = colony forming units / g of oven dry fibre

The ash content of all fibres in the investigation was rather low (Table 1). In practice, the soil contamination of fibres produced by various production methods has been found to increase the ash level much more than was measured in this work (Kymäläinen, unpublished result).

4. CONCLUSIONS

- Overretted hemp fibre was very absorbant in the capillarity experiment compared to unretted hemp, unretted flax/linseed and overretted flax/linseed fibre. A high absorption level leads to moulding risks if fibres are in contact with free water.
- Retting degree clearly has an effect on fibre moisture intake from air, because it alters the chemical and physical structure of fibres. Unretted hemp and flax/linseed fibre began to mould sooner than the retted hemp and flax/linseed fibre. The unretted fibres reached higher moisture contents before moulding than did the retted fibres. Retting degree affects the capability of the fibre to retain its properties in storage and in use.
- Microbes in insulation materials may be harmful to human health, and therefore the microbial density of raw materials for insulation materials should be below the maximum limit (10 000 – 100 000 cfu/g). Microbial content did not have a direct correlation with moulding tendency of fibre materials. Visible mould on a fibre surface was detected as a high microbial density, but this did not lead to more extensive moulding compared with fibres with a low microbial density.
- In the future, the quality of fibre raw material for insulation materials should be confirmed by quality

systems. The following properties should be included in the quality criteria: 1) retting degree, 2) moisture content, 3) shive and dust content, 4) hygienic level of raw materials measured by microbial density and ash, and 5) length of fibre.

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