Researching Fungus through Design for Innovation

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Abstract: This paper describes a development process of Fusart®-method that can be used for degumming, smoothening and cottonizing flax fibres and removal of lignin of plant origin. In practise it means that lustrous and soft fibres can be produced cost-efficiently and environmentally-consciously for textiles and technical applications. The objective of the study was to explore the suitability of flax elementary fibres in new textile and creating prerequisites for product design and productization. In this product-development-oriented design research was combined natural sciences with product design-specific ways of working. The study was divided in three parts. In the first phase was investigated the fungus Fusarium starting from finding of the microbe following the isolation, the cultivation of fungus and the determination of treatment conditions. In the second part a production model was designed based on "total fibre" lines, which included phases: linseed harvesting, refining processes, cottonizing with Fusart®-method and rotor spinning. The third part includes free experimental processes aimed to explore the handle and tactility of the materials. Knowledge of the differences and nuances of the bast fibres were embodied in artefacts. Artefacts worked also as tool for concretise the ideas that have their basic in intuition and tacit knowledge.

However, this case also shows that a designer can learn to do laboratory science, and can solve problems that have their origins in aesthetic perception and as a result novel materials for productization was created.

Keywords: design research, material research, fungus, textile design

1. Introduction

This paper reports a study that begun in a hemp field in 2001 when a textile designer was on a walk with a plant pathologist. The designer noted something she found interesting: the bark of some hemp stalks contaminated by mould. The stalks were reddish, but fibres underneath were almost white and cottonized. An interesting difference of opinion concerning the mould developed between the plant pathologist and the designer. For the former, it was a disease to be cured. For the latter, it was an opportunity for something new. The designer's aesthetic observation led to a study of the fungus responsible for the change of fibre handle and visual appearance.

In this paper, we report how this study was carried out. It had three main aims. The first aim was to develop a microbiological method for processing bast fibres, which led design researchers into cooperation with microbiologists. The second aim was to develop an industrially applicable, sustainable method for generating fibre material for the process while minimizing the environmental impact of production. The third aim was to demonstrate the design qualities of the fibres thus generated with a series of explorative textile designs. In broader perspective, this paper shows how design researchers can do meaningful work with the life sciences.

2. Ecological aspects of fibre materials

Ecological concerns have increased the research of textile materials that are renewable, recyclable and environmentally safety. In the future there will be an increasing need for alternative fibres, which are compatible with existing, cotton-based textile manufacturing technologies and are competitive on price and quality. Bast fibres, especially flax and hemp have high utilitarian and ecological values, because they are absorbent, hygroscopic, and protective against UV radiation. Their thermal and electrostatic properties are good for apparels. [1.] Also flax is being considered as an environmentally oriented alternative to synthetics fibres in fibre-reinforced polymer composites.

Generally, only fibre flax varieties have been cultivated for textile applications. Traditional long-line linen processing technologies are based on long fibre bundles that have to be moved from woody stem. Processing is very labour-intensive and expensive. With these methods, fibres are suitable in a rather small number of different end uses. Actually, the products have remained surprisingly similar for centuries probably due the processing methods: mainly conventional woven fabrics with plain or damask weaves and dyed as a yarn or fabric. For example 100 % flax yarns are relative rigid and therefore do not bend well enough around knitting needles. [2.] There are good reasons to assume that in ancient Egypt (1. dynasty, 3050–2890 BC) the finest linen was spun from ultimate fibres, i.e. cottonized flax[1]. The “royal linen” was a state monopoly of the Pharaoh himself, and the finest gauze had 80 threads to the cm. In comparison, the finest linen fabrics today are coarse with only app. 40 threads/cm [3, 4]. In recent decades, there have been lots of studies of how to use various enzymatic agents for cottonization. Enzyme retting has been shown to produce good quality fibres, but currently costs are high and enzymatic retting has not replaced dew retting commercially on a scale for industrial operation [5].

To get novel product applications of flax, alternative methods are needed to replace current production practices. In textile applications fibres should be modified close to cotton and the chemical composition should be without non-cellulosic substances and without damage the fibre cellulose. That means that the lignin and the pectin content should be as low as possible. In cottonization fibres are modified that they could be spun on the more productive cotton system, like rotor spinning. Yarns produced with cottonized (affined) flax are usually blended with cotton or polyester with percentage of flax max. 50 % [1, 6, 7]. In processing short-fibre methods are used straw as a one fibre fraction.

[1] Cottonization means multistage mechanical and chemical processing where the pectinous glues between the bundles are removed.

In textile applications garment has to be comfortable in aesthetic and physiological sense. The comfort of textile is composed mainly of the handle, thermal insulation and moisture absorbance of the raw material. So called “fabric hand” is a commonly used method for assessing fabric/material quality and prospective performance in end use in particular: this notion refers to the total sensations experienced when fabric/material is touched in the fingers and it is often the fundamental aspect that determines the success or failure of a textile product. By sensory evaluation, one gets to know properties of the material, such as flexibility, compressibility, elasticity, resilience, density, surface contour (roughness, smoothness), surface friction and thermal characters. [8]

In material based design research, the ultimate objective is the innovative usage of materials and productization. The main aims were to find new application areas with different technologies and supply of high quality linseed fibres that meet the demands of industry. The variation of the material should be small or tailor made by specification. The objective of this study was to explore the suitability of flax elementary fibres in new textile and technical applications, and to create prerequisites for product design and productization. In the development of concrete product applications of bast fibres, the importance of practical applications grows along with the theoretical approaches.

3. Study 1: The Fusarium study

The first study developed a Fusart® method. The aim was to develop a cottonization method based on a microbiological system using the fungus Fusarium. Optimal treatment conditions were tested with different circumstances including amount of fungal supernatant, temperature, time, needs of additives of the liquid, prior- and after-treatments of the fibres. In treatments were used both mechanical stirring and static retting. Also the possible effects of pH to the treatment were estimated. Parallel experiments were carried out to compare closely related species of fungus.

In spring 2001, samples of fungus from contaminated straw were collected from a fibre hemp field in a research farm of the University of Helsinki. The designer isolated the fungus with the help of microbiologist and identification was done in Utrecht, the Netherlands. Sample of fungus was deposited to the German microbe collection according to the treaty of international Budapest treatment. In the beginning all the cultivations and treatments were done at home (fellow scientists did not believe that a designer could find, isolate and cultivate fungi without microbiological education). As a raw material, linseed fibre was used. After first accepted patent application it was easier to find co-operators, and the fungus was cultivated in the laboratory with standard methods.

The effects of treatments to the elementary fibre characters were measured with standardized methods for natural fibres. The main technical properties of the elementary fibres are fineness, fibre length and its distribution, elongation of break and tenacity. The lignin content was measured with standard methods. As a comparison also raw fibre and washed fibres were measured. Here, the design researcher closely cooperated with microbiologist and fibre technologist.

Finally, sensory evaluation was also used. The comfort sensation of a raw material was analysed subjectively using five textile design expert judges. The assessment was done by sensory evaluation with touch and sight together. Seven samples were to be put in order according to opposite characteristics: soft-hard; smooth-coarse; glossy-dull; light-dark and general impression of the best sample. All these evaluations were done verbally.

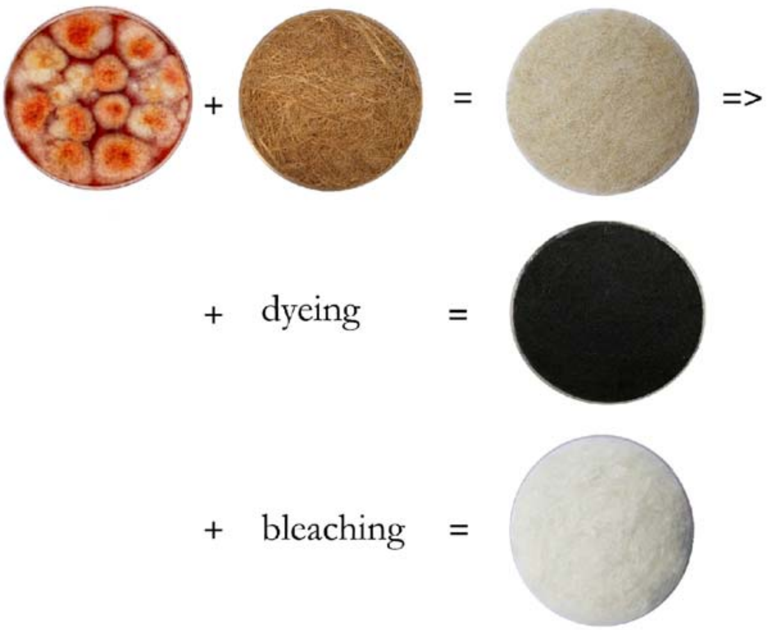

Figure 1. The principle of Fusart®-method

Fungus Fusarium can be used in for retting, smoothening and cottonizing linseed fibres and for removal of lignin. Cleaned and carded fibre will be degraded to elementary fibres with the method and thus washing, cottonization, bleaching and dyeing of fibres can all be done in the same wet-process (Figure 1).

The linseed fibres treated with fungus Fusarium were close to cotton in respect of fineness, length and tenacity. Addition of culture liquid to the treatment can reduce the lignin content of the fibre almost 50 % compared to unwashed reference fibre and almost 20 % compared to the washed fibre (Table 1). [10.]

Table 1. Effects of Fusart®-treatments on the linear density, breaking tenacity, elongation at break and lignin content.

Linseed flax, cultivar Laser								
Sample	Treatment/ Amount of fungus	Linear density [dtex]		Breaking tenacity [cN/tex]		Elongation at break [%]		Lignin content [%]
		Average	Variation	Average	Variation	Average	Variation	
1	Raw fibre	4,57	3,08 – 6,44 (3,36)	52,9	17,6 – 83,2 (65,6)	2,5	2,1 – 3,4 (1,3)	6,48
2	Washed	4,35	2,59 – 7,33 (4,74)	40,9	19,7 – 58,1 (38,4)	2,1	1,4 – 3,0 (1,6)	4,17
Mechanical stirring								
3	2 h, 57 °C/ 14 ml/gram fibre	3,74	2,59 – 4,73 (2,14)	42,3	22,7 – 54,6 (31,9)	2,6	1,8 – 3,2 (1,4)	2,89
4	4 h, 57 °C/ 14 ml/gram fibre	-	-	-	-	-	-	5,13
5	3 x 2,15 h, 40 ºC/ 3 x 1 ml/g	3,47	2,69 – 4,28 (1,59)	21,2	14,2 – 26,8 (12,6)	*	*	-
6	3 x 2,15 h, 40 ºC/ 3 x 3 ml/g	4,25	2,76 – 5,82 (3,06)	34,3	18,5 – 56,3 (37,8)	2,1	1,6 – 3,1 (1,5)	-
Static retting								
7	2 x 6 h, 20 ºC/ 2 x 0,5 ml/g	-	-	-	-	-	-	2,82
8	3 x 6 h, 20 ºC/ 3 x 0,5 ml/g	3,69	2,11 – 4,85 (2,74)	40,2	19,0 – 54,2 (35,2)	2,9	2,1 – 4,3 (2,2)	3,40
9	2 x 8 h, 20 ºC/ 2 x 0,5 ml/g	-	-	-	-	-	-	4,04
10	3 x 8 h, 20 ºC/ 3 x 0,5 ml/g	4,31	2,42 – 5,35 (2,93)	41,1	22,8 – 62,1 (39,3)	2,9	1,9 – 3,7 (1,8)	3,15
	Cotton	1–4		15–50		15–50	15–50	0
* = no result - = not measured								

In sensory evaluation seven samples were to be put in order according to opposite characteristics: soft-hard; smooth-coarse; glossy-dull; light-dark and general impression of the best sample was given in words. Samples of linseed that had been retted 3 x 6 h/3 x 0.5 ml/g and 2 x 6 h/3 x 0.5 ml/g in room temperature or treated for 2 hours in stirring apparatus (2h/14 ml/g, 57 °C) were evaluated to be the softest and best samples. These samples were characterized as being silky, warm, glossy, and because of their pleasing touch suitable for clothing. The washed raw fibre was distinguished from the other samples for being the coarsest, hardest, darkest and dullest.

The spinning experiments were carried out at the Tampere University of Technology. The treatment included carding the lap and sliver and rotor spinning. Spinning with 100 % flax there was a problem with sliver formation. To help fibres twist easier together pre-treated cotton fibre was added to batches, so that the portion of cottonized flax was 80–90 %. With these propositions yarn formations succeeded.

4. Study 2: The production and the environmental study

The second aim of the study was to develop environmentally sound production methods to minimize the amount of waste straw in fields and production. The major aspect in the state of the art technical and textile application of flax is the heterogeneity of the material, which became the main focus of the study. Each step of fibre extraction and processing alters the properties of the material. To make the production chain sustainable, this part of the study aimed at increasing the stability of production chain by minimizing process-stages.

In linseed cultivation, straw becomes a by-product and a major environmental issue. In 2005, about 50 000 milj. tons of straw was produced worldwide, and most of this residue was burned in the field. Linseed fibres are generally considered too short, coarse, highly lignified and less uniform than fibred from flax. But the fact is that linseed fibre qualities are not known well. [2, 9] Improving the environmental record of linseed cultivation, the second study explored whether the method provides material that is scalable to industry. It dealt with the processing of fibres using semi-industrial rotor spinning. The aim was to modify fibre characteristics so that they would be similar to cotton. The spinning experiments were carried out with rotor spinning including also phases carding the lap and sliver. The carding machines were not set especially for flax instead settings for cotton was used. That means that delivery speed and withdrawal speed were not optimized. In the spinning experiments were four different material examples treated with Fusarium: 1) Mechanical stirring, 3 x 2,15 h, 40 °C, 3 x 1 ml fungus per 1 g fibre; 2) Mechanical stirring, 3 x 2,15 h, 40 °C, 3 x 3 ml fungus per 1 g fibre; 3) Static retting 3 x 6 h, 20 °C, 3 x 0,5 ml supernatant per 1g fibre and 4) Static retting 3 x 8 h, 20 °C, 3 x 0,5 ml supernatant per 1g fibre.

A production concept based on "total fibre" lines was created, including the following phases: linseed harvesting, refining processes (like scutching, carding), cottonizing with Fusarium, and rotor spinning. Various material experiments were designed and fabricated with different processing techniques, such as knitting, weaving, needle-felting, moulding and wet-laying. [10.]

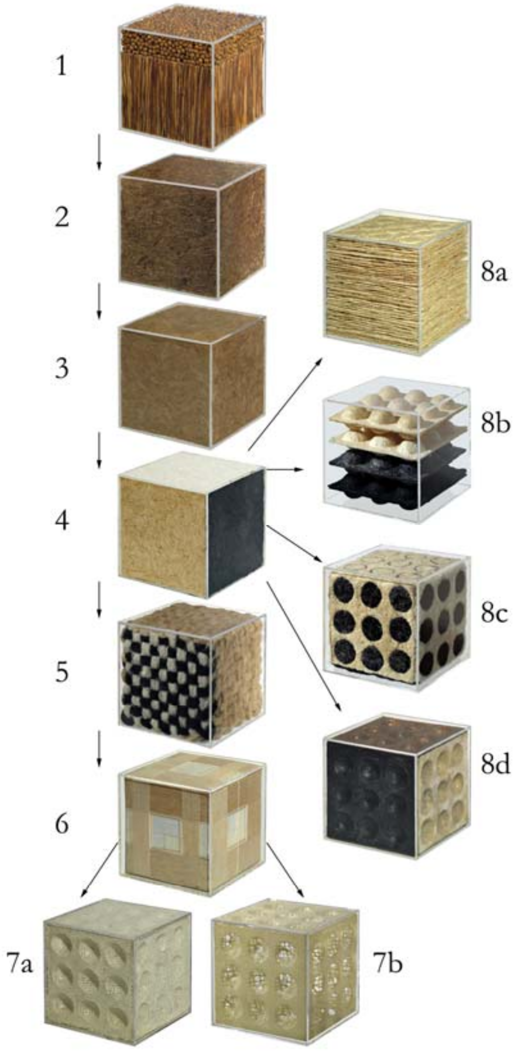

Figure 2. The phases of Study 2 “The production model”

1.
2. As a raw material linseed flax, cultivar Laser was used. The linseed fibre used in the study comprises relevant renewable material worldwide.
3. In harvesting and deseeding was done with existing light farm machinery. It is possible to produce industrial materials this way because the whole production is based on short-fibre fraction. The straw was moved and cut up as a pre-cortication when deseeding.
4. The refining processes included decortication to break wooden parts of the straw and carding to remove the shives.
5. In Fusart®-treatment removing lignin, gluing substances were removed; dying and bleaching were combined in one wet-process. As a pre-treatment fibres were washed to separate dust and water-soluble materials.
6. Pre-spinning processes included formation of a lap and a sliver with cards.
7. Rotor spinning
8. Fabric production
   a) Knitting
   b) Weaving
9. Technical application
   a) Wet-laying
   b) Compressed moulding
   c) Needle-felting
   d) Moulding

5. Study 3: The Design Study

The third study consisted of design explorations that were done to explore the tactility of the materials and their usefulness for textile design. Knowledge of the differences and nuances of the bast fibres were embodied in artefacts under the theme "total utilization". As raw materials were used flax and hemp plants to compare the fibre characters of these materials.

In the final instance, the raw material is the core of any textile. The material implies f.ex. quality, usability and comfort. In company textile designer's task is to combine the demands of the used technology and marketing sector. So, in practice the designer is a user of yarn that has been developed by fibre technologists. In this case the designer was also a participant in material development process.

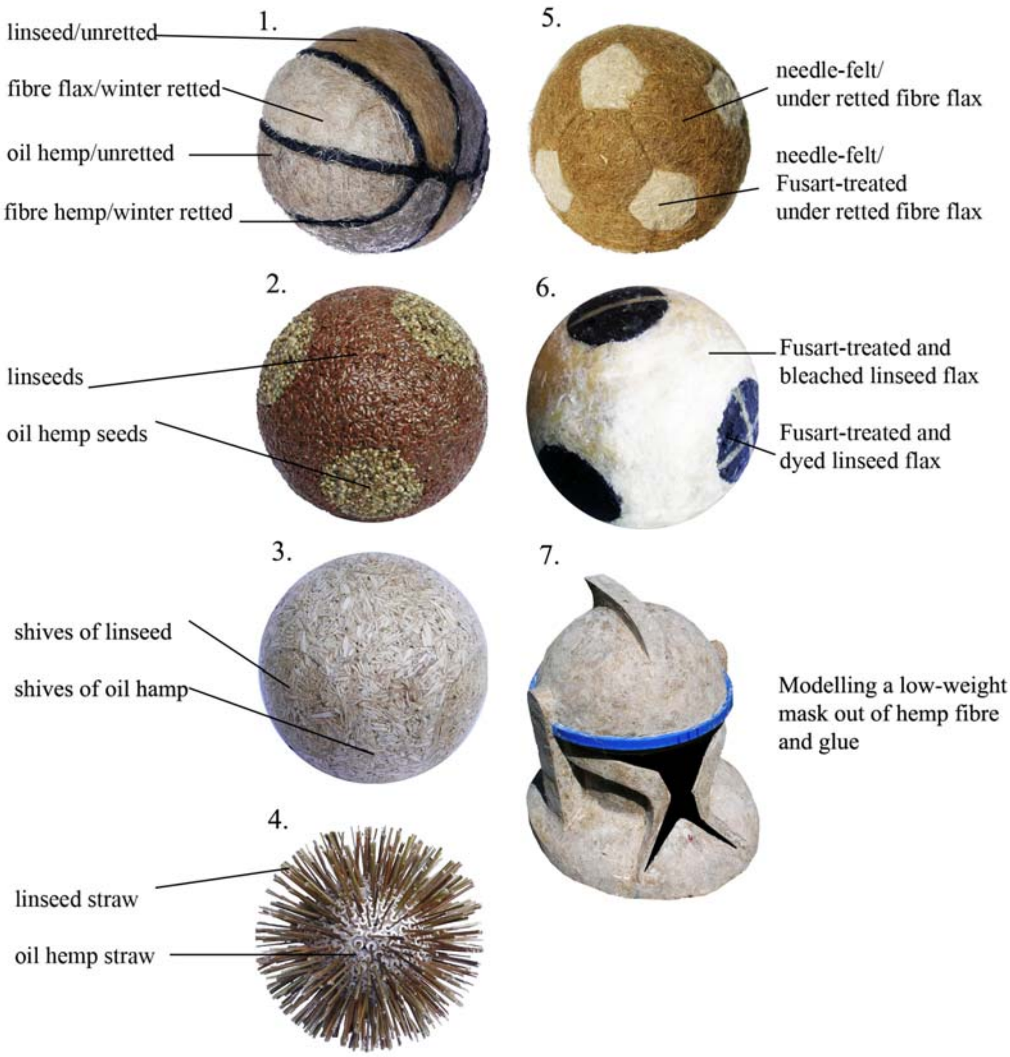

Figure 3. Material experiments of linseed, fibre flax, oil hemp and fibre hemp plants. 1) Comparing colour and fineness of bast fibres retted with different methods. 2) Bast fibre seeds are very oily and have to been removed before decortication, otherwise the fibres get dirty. 3) Shives, residue of decortication. 4) Comparing the size of linseed (Ø 1–3 mm) and oil hemp (Ø 4–10 mm) straw. 5) Under-retted needle-felt can also be cottonized. 6) Experiment of fibre composite with bleached and dyed fibres. The round die reflects the "schizophrenic" feelings during the study. 7) Clone trooper -mask in process. Star wars, Episode 2½, Endor (coming soon!)

In design research it is typical to use different methods. Artefacts, subjective material experiments were essential to find new solutions for fibre processing and enlarged the understanding of raw materials (Figure 3). They worked as a playground for testing ideas and the experiments were free from predominated methods. The artefacts were made in ball-form (Ø 16 cm) to disrupt the current conventions of two dimensional surface of textile and open new ways of seeing the material. The bast fibre materials were oil and fibre hemp, linseed and fibre flax. Along with ready-processed data from these artefacts comes concrete sensory evidence and direct subjective experiences that helped achieve new understanding. The artefacts were also a tool for concretise the ideas that have their basic in intuition and tacit knowledge.

6. Discussion

This paper has reported a study that combines unusual competencies in creating a new method for working with flax fibres. The study had three parts, all requiring different competencies. The first study developed Fusart®-method for retting, smoothening and cottonizing linseed fibres and for removing lignin from linseed fibres. The second phase focuses on industrial scalability by using industrial methods to Fusart®-treated fibres. This study also had an environmental aim. After these long detours, the third study aimed at demonstrating that fibres produced through this process can have interesting design properties. This paper shows that a designer can learn to do laboratory science with biological substances and can solve problems that have their origins in aesthetic perception.

Specifically, this study has shown that short-fibre methods give an impetus for the expansion of bast fibres in new application fields. In this study, co-operation with natural scientists opened a new world of concepts and working methods for a designer. She learned to isolate and cultivate fungus. She also conducted hundreds of treatment experiments with fibres. Finally, she used design-specific ways of working to show that the research does lead to interesting design conclusions too. She did free experiments aimed to explore the feel and tactility of the materials and designing the production concept. The result was a Fusart®-method for cottonizing bast fibres (Patent application PCT/FI2009/050059). In practise it means that lustrous and soft fibres can be produced cost-efficiently and environmentally-consciously for textiles and potential for producing high-quality bio-based material with tailored properties.

Within the context of design, research on bast fibres can be characterized as material research with an emphasis on material. A typical characteristic of research on applied materials and on product oriented design is the interaction between science, art and technology, with the key goal of creating prerequisites for product design.

For the design research community, this case opens a fascinating window into how designers can go beyond art in cooperating with laboratory scientists. Interdisciplinary approach is very challenging especially when design research, which more or less draws its orientations from design-driven practices, art history and hermeneutics, is combined with the natural sciences. Material science is driven by technologists and nature scientists. In this case the main gap was the way of viewing the subject. The priority for the designer was the end product and practice. For her, the fungus is only a tool for improved fibre quality and innovative industrial applications. The role of solid basic science was to support the practical goals. For natural scientist cooperating with her, the designer's sensory evaluation and random experiments to find out differentiation of raw materials lacked scientific rigour. Although validity of all these results have been measured with objective, scientific methods. The difference is in this opposite direction of working, from practice to the theory compared to the natural scientists. After all these experimental methods produced new scientific information that can be evaluated systematically and relies on empirical findings.

7. References

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