Manual labour and industry: a mutual stimulation proven in an intercultural research project

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The project MANUAL LABOUR AND INDUSTRY deals with the production of yarns from the fibres of fruit banana pseudo stems. These stems accumulate on plantation fields in large quantities after the harvest of the bananas. Until now, this biological residue usually ends up in waste dumps or is burned. Instead of considering these pseudo stems as waste, they should be given added value through textile processes and made available for the textile design sector. The aim of this project is to mechanically or manually produce high-quality yarns which can be used to produce woven or knitted textile samples for the clothing and interior sector as well as for composites. The project is thus characterized by an innovative approach which considers the long-established opposition between manual and mechanical yarn production as mutually stimulating. While the analysis of existing spinning processes informs the way we envisage the production of yarn from banana pseudo stems, the findings gained during manual yarn production in turn shed light on how mechanical processes could be organized and are used to adapt them. In addition, this yarn-oriented research already contains first results in the textile design sector, in which both industrially and crafted textiles were developed.

Keywords: Banana fibres; sustainability and textiles; processability of natural fibres; added value; interdisciplinarity

1 Added value out of a waste product: Banana fibres

Every banana plant produces just one bunch of bananas and is then cut in order to leave place for a new banana plant. Banana plants have rhizomes from where the new generation of plants grows. After the harvest of the bananas the cut pseudo stems accumulate on the fields. They are mostly thrown away or burned. Fibres from the banana fruit plant, more specifically from the pseudo stem, can be mechanically extracted with a raspador, a machine with rotating blades. A three-year research project conducted by the Navsari Agricultural University explored the different applications and products which can be gained from the pseudo stems (Chirag et. al. 2016). Researchers did not only extract fibres from the sheaths of the outer layer of the stem, but used the sap as fertilizer, made cardboard or paper and produced candies and juice from the inner core of the stem. When introduced to the fibres four years ago, our research group decided to carry out a research project with two partner universities in order to produce banana yarn for apparel, interiors and composites. We are convinced that new sources of fibres must be found to meet the demand for sustainable material since the cotton production area is limited. We consider new natural fibres as the sustainable path to be explored.

Figure 1. Pseudo stems after the harvest of the banana fruit. Source: Lucerne School of Art and Design.

Figure 2. Pseudo stem with sheaths. Source: Lucerne School of Art and Design.

2 The potential of natural fibres

Since the Second World War the amount of natural fibres has gradually diminished in favor of synthetically produced manmade fibres. The main reasons for this decrease are price and the fact that manmade fibres can be transformed into any shape and guarantee a consistent quality.

However, according to the Food and Agriculture Organization of the United Nations (FAO), farmers earn millions of tons of natural fibres from animals and plants worldwide: wool and animal hair, fibres from seeds, stalks, leaves and shells, e. g. cotton, linen, hemp, sisal, and coir. From these fibres ropes or yarns and twines for woven or knitted fabrics can be made. Natural fibres still play a fundamental role in today’s life.

2009 was proclaimed as the year of natural fibres by the FAO. The aim was to raise awareness amongst consumers, the industry and producers regarding the importance of natural fibres, as they provide important livelihoods for millions of people around the world.

Especially small-scale farmers are challenged with the fact that natural fibres are often replaced by synthetic fibres.

The FAO underlined the importance of natural fibres with five propositions:

1. Due to their structure natural fibres are breathable, which makes them very skin-friendly.
2. Natural fibres are important to the economies of many developing countries because they provide a crucial economic livelihood for millions of people.
3. Natural fibres are a renewable resource which is 100% biodegradable. Therefore, the FAO ascribes them a crucial role in the emerging “green” economy. Plants from which fibres are extracted absorb carbon dioxide during growth. They produce mainly organic waste during processing and leave biological residues.
4. Natural fibres are used in the building sector for insulating, reinforcing or acoustic properties. Their mechanical strength and low weight make them interesting for molded parts in technical applications.
5. Even the fashion sector is looking for alternatives for the production of “clean” clothes.

The following challenges arose during our project:

In 2017 the global world fibre market amounted to a total of 103.4 million tons (The fibre year, 2018). The largest share is accounted for by oil-based fibres with 64.9 million tons (62.76%). The still most widespread natural fibre is cotton with 25.7 million tons (24.85%). Cellulose-based regenerated fibres come to 6.6 million tons (6.38%). All other natural fibres are distributed over the remainder of 5.8 million tons (6.01%) (Müssig, 2010). In view of these figures, the leverage effect and the importance of banana fibres must be located in a niche market.

Matters were complicated further by the fact that the pseudo stems accumulate in India. Due to temporarily difficult communication with our partners in India, we limited our research activities to Europe. The aim was to demonstrate the feasibility and to convince the Indian partners that the value added in India makes sense and thus creates good opportunities for the farmers and the spinning mills.

Socially and economically we depend on the willingness to use a new fibre and to build trust in it. There are also weak points in the methods, because all tests are carried out on well-maintained machines in Europe - this would have to be transferred to the conditions of countries where the banana production is located.

It is known that insecticides, herbicides and pesticides are used for the cultivation of bananas in monocultures, particularly in countries where bananas are grown for export. In order to obtain organically grown fibres for our experiments, we cooperated with an Indian University, which provided the banana fibres for the trials in Switzerland and Europe.

3 Social relevance

Beside food, drinking water and a safe environment, textile materials are a fundamental need of mankind. Due to the growth of population the demand for textiles increases. At the same time, the available cultivation area for cotton is limited and competes with that for food production. In addition, the raw oil for the production of synthetic fibres is finite. Therefore, new resources for textile fibres must be explored. They should be sustainable and allow long-term use without negative environmental impacts. In this context, an interesting area arises for researching the banana fibres, a by-product of the banana production, whose suitability for textile fabrics and composites is assessed.

4 Collaborative Project

4.1 From manual labour to mechanization: Questions and working hypotheses

Textile designers either start with their own developments and design work using suitable yarns to create a textile surface, or they start developing texile designs later on in the textile process chain by refining existing fabrics. The techniques used are felting, weaving, knitting, warp knitting, the analog process of screen printing or the digital variant inkjet printing as well as embroidery to name the traditional textile techniques. This results in the following question:

Which product can be developed from banana fibres that can convince potential users and producers?

The fact that an Indian partner institute initiated the exploration of banana fibres showed that the processes should take place mainly in India. This presumption proved wrong, because the Indian government politically supports the jute industry and mechanically produced yarns were scarce. Therefore yarns and twines had to be produced first. This resulted in the following question:

Which mechanical processes are suitable to spin fibres extracted from fruit banana pseudo stems?

Due to the rich experience in mechanical spinning of natural fibres in Switzerland, the necessary process steps for banana fibres were assessed by precise analysis. Trying to find funding for the project, it turned out that Indian partners were not interested in investing in the development of banana fibre processes. This inevitably resulted in a third question:

Is it possible to prepare and spin banana fibres in Europe on existing machinery?

4.2 Banana - a relevant fruit

Bananas are consumed worldwide. It is difficult to give reliable figures for the total amount of bananas produced as there are many small locally grown crops that are sold in the informal and local sector and therefore are not included in the global figures. The main producers of bananas and plantains are India with an average of 29 million tons and China with 11 million tons (FAO, 2017). The figures collected in 2015 and published in 2017 show that the cultivated land area for bananas reaches 5.5 million hectares of which India features 700,000 ha. Only about one-sixth of the 113 million tons of bananas produced are traded internationally. In many countries the majority is offered on the local market as a staple food. The productivity of banana production per hectare varies from country to country and from variety to variety. The productivity of banana production from the state of Gujarat in India, from which the Grand Naine banana fibres are sourced for the research project, is 61 t/ha (Desai, 2016). There exist around 60 different banana varieties in India. In the state of Gujarat the three most cultivated banana varieties are Grand Naine, Mahalaxmi and Basarai. Banana trees bloom only once. The fruit tufts are wrapped in plastic bags to prevent pest infestation. After flowering, banana perennials are formed with bananas weighing up to 50 kg. The fruits, which reach for the sun and thus get their crooked shape, ripen after 7 to 9 months. After harvesting, the so-called pseudo stem dies. Thanks to the rhizomes, a new shoot grows next to the dead mother plant. The ratio of biowaste to banana production is estimated to be 2:1, which equates to a mass of 226 million tons worldwide. The mass of fresh pseudo stems in Gujarat is given as 60 to 80 t/ha (Desai, 2016). The biomass of the pseudo stems is either left on the field, disposed of at high cost 200-280CHF/ha (Desai, 2016) or sent to landfills. The biomass left on the fields can maintain soil moisture and provide organic material. However, this carries the risk of possible disease transmission (Universidad Politécnica de Madrid, 2016).

4.3 Banana fibres from waste biomass

From the sheaths of the pseudo stems natural fibres can be extracted. These fibres have a light yellow-white color and as natural fibres complement the limited range of the other natural fibres. The textile properties of banana fibres are similar to those of other bast fibres, e.g. jute, sisal and linen. Banana fibres can be processed on the jute spinning line with minor adjustments, which has been proven in a feasibility study but has not been followed up (Roy et al 2014). Accordingly, the results - relatively hairy and thick yarns - are of rather low quality and thus only conditionally suitable for weaving.

The fact that there were no banana yarns available on the market confronted us with a very complex matter, namely the provision of raw fibres for a mechanical spinning process in which several parties are involved and whose process steps need to be precisely coordinated. What further complicated matters was that there is no mechanized process for banana fibres yet. Although the potential of banana fibres as matrix reinforcement in paper or composites has been discussed in several scientific articles in terms of properties and mechanical or chemical processing (Vigneswaran et al., 2015; Kulkarni et al., 1993; Githinji, 2015), all these cases deal with the incorporation of short fibres into a matrix rather than the production of yarns which e.g. have to have a certain load-bearing capacity in one direction. Yet, if textiles are to be developed, the production of yarn is indispensable.

4.4 Interdisciplinary collaboration and intercultural teamwork

The project had to take into account not only the design and engineering of products, namely the production of yarns for the defined applications - according to Buchanan the second order of design -, but also the design of systems, processes and sequences of activities and the interaction of the various stakeholders, the so-called fourth order of design (Buchanan, 2001).

After researching the state-of-the-art the hypothesis was formulated that it should be possible to spin banana fibres on the world’s existing mechanical spinning plants for natural fibres in order to initiate a textile value chain. It should be borne in mind that some existing plants are very outdated and that the slightly different properties of banana fibres have to be taken into account in order to spin them. This requires a great willingness on the part of the owners of these plants to adapt them to banana fibres.

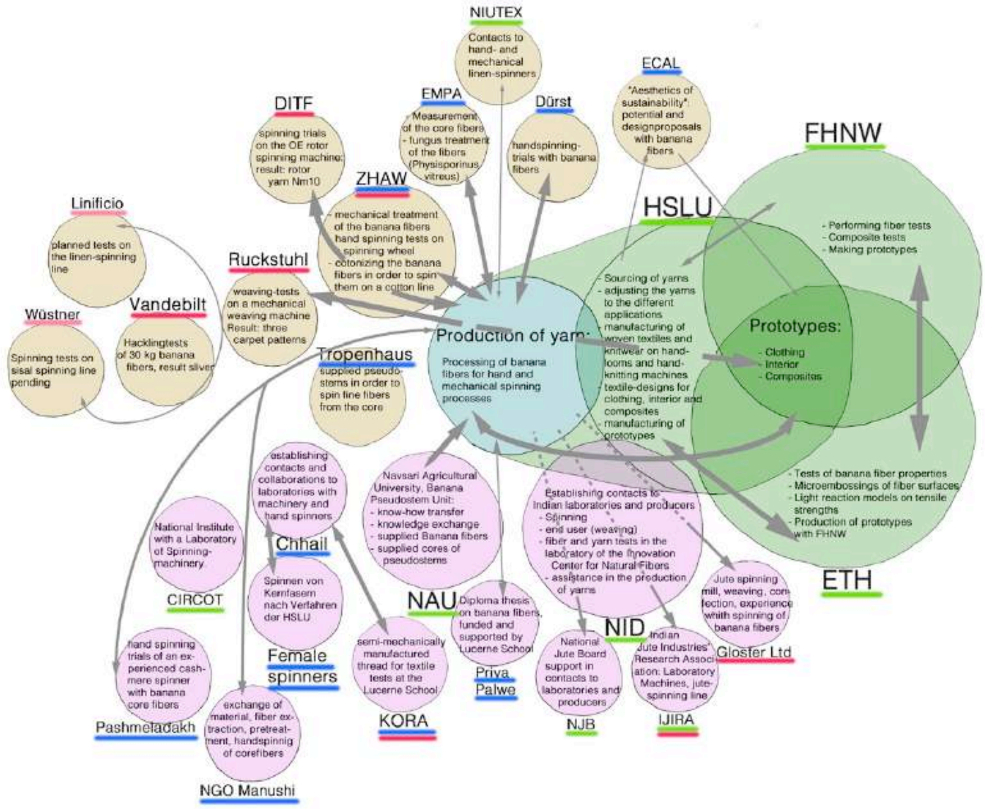

Figure 3. Graphic representation of the protagonists in the project, which show clearly the intercultural dimension. Source: Lucerne School of Art and Design.

- Blue circle in the center of the chart:
  represents the main topic of this project: the yarn production from banana fibres. It took place in a complex structure of institutions, companies, workers as well as hand and mechanical processes.
- Green oval:
  The yarn development was part of the research work of Lucerne School of Art and Design (HSLU – D&K)
- Two green circles:
  Lucerne School of Art and Design researched with the two institutions University of Applied Sciences and Arts Northwestern Switzerland (FHNW) and the ETH Zurich. The three institutions HSLU, FHNW and ETH were financially supported by the Gebert Rüf Foundation.
- Dark green intersection triangular field:
  The topic of these three institutions was the production of prototypes in order to gain interested implementing companies and further research funding.
- Light brown circles (Europe) and pink circles (Asia):
  Numerous European as well as Indian and Nepalese institutions, NGO, companies, persons and processes were involved in the research work.
- The grey arrows
  mark the mutual relationship of the respective research partners, sometimes the relations were balanced, sometimes rather one-sided.
- The blue underlines
  represent all handmade undertakings.

- The red underlines
  are the mechanical tests and processes.
- The green underlines
  are institutions and laboratories that took on a rather theoretical-intellectual or mediating role in the project.

The comparison of the methods and the results of the handmade experiments in the different countries with various approaches (Nepal, India, Switzerland) were very informative for the progress in the project. Only by understanding the craft processes and results, which have the advantage that a good result can be achieved even with small quantities, the further experiments could be planned in an industrial context and scale.

5 Fibre properties

5.1 Criteria for spinnability

Natural plant fibres consist mainly of polymers with the following components: cellulose, hemicellulose, lignins and aromatics, waxes and other lipids, ashes and water-soluble compounds. The chemistry and the structure of the fibres determine their properties, their functionality and their processability. (Bobeth, 1993. Muessig, 2010). The different characteristics of fibres that can be distinguished are fibre length, fibre diameter, strength, chemical composition, extraction of fibres, processing, application. The structure of the fibres has an influence on their tensile strength. The tensile strength is the tensile force required to tear fibres, yarns or fabrics (Schenek, 2001). This force is given in cN/tex. One cN corresponds to the weight force of one gram. The applied force in cN is expressed per tex. Uniform fineness, length and tensile strength are the decisive parameters for assessing the suitability for a textile application. These parameters determine whether a fibre is spinnable to make a sufficiently strong yarn or twine in order to produce a woven or knitted fabric.

5.2 Banana fibres in comparison with similar natural fibres

The table below shows the fibres which are suitable for textile purposes. This means that the fibres are long enough to be spun into a yarn. The table lists the properties of the fibres that are relevant for spinning processes and are compared with those of the banana fibres. The banana fibres of the leaf sheaths of the pseudo stem rank among the bast or hard fibres. Bast fibres are fibres that occur either in the leaf, in the stalk or in the shell. The fibres must first be removed from the plant matrix by mechanical, enzymatic or chemical operations before they are available as fibres and can be spun in further processing steps.

The finer fibres from the core of the pseudo stem can be assigned to the seed fibres because of their fineness, even if they do not originate from seeds. Since banana fibres can be classified as seed, bast or hard fibres due to their properties, and since there is no specific mechanical spinning process for banana fibres, the spinning processes of similar fibres are shown. Afterwards, the process steps in the preparation and processing of the banana fibres are analyzed, which should provide indications for the adaptation of the existing processes.

Natural Fibres Banana fibres in comparison with other natural fibres regarding three parameters Natural Plant Fibres		Fibre length	Fineness dtex	tensile strength cN/tex
Seed Fibres				
Cotton	CO	10 - 60 mm	1 - 4 dtex	25 - 50 cN/tex
Kapok	KP	10 - 35 mm	1.4 - 4 dtex	keine Angaben
Banana		40 - 100mm	1 - 2 dtex	1 - 27 cN/tex
Bast Fibres				
Linen	LI	(technical) 450 - 800mm (treated) 25 - 120mm (elementary) 10 - 70mm	(technical) 10 - 40 dtex (elementary) 1 - 7 dtex	30 - 55 cN/tex
Hemp	HA	(technical) 1000 - 3000mm (treated) 600 - 750mm (elementary) 15 - 28 mm	1.5 - 6 dtex	40 - 70 cN/tex
Jute	JU	(technical) 1500 - 3000mm, (treated) 650 - 750mm (elementary) 1 - 5mm	2 - 250 dtex	20 - 40 cN/tex
Ramie	RA	(technical) 1500 - 3000mm, (treated) 500 mm (elementary) 60 - 260mm	2 - 80 dtex	40 - 70 cN/tex
Banana		(technical) 700 - 1200mm (treated) 50 -80mm	(technical) 61 - 114 dtex (elementary) 5 - 8 dtex*	22.4 - 62 cN/tex
Hard Fibres				
Sisal	SI	(technical) 1000 - 1250mm (treated) 1000 - 1250mm (elementary) 1 -5mm	(technical) 225-450 dtex (elementary) 6 dtex (25my)	35 - 40 cN/tex
Abaca	AB	(technical) 1200 - 2500mm (elementary) 6 mm	(technical) 150 - 300 dtex (elementary) 5 dtex (24my)	53 cN/tex
Banana		(technical) 700 - 1200mm (treated) 50 -80mm	(technical) 61 - 114 dtex (elementary) 5 - 8 dtex*	22.4 - 62 cN/tex
Coir	CC	(treated)150 - 350mm (elementary) 6mm	2 - 100 dtex (10 - 100my)	13 - 22 cN/tex *
Animal Fibres				
Wool				
(fine) Wool	WO	40 - 75 mm	2 - 50 dtex	9 - 18 cN/tex
Banana		(technical) 700 - 1200mm (treated) 50 -80mm	(technical) 61 - 114 dtex (elementary) 5 - 8 dtex*	22.4 - 62 cN/tex
The parameters of the other natural fibers are not listed because the banana fibers fundamentally differ in their chemical structure.				
Animal Hair				
Alpaca, Angora, Guanaco, Camel, Rabbit, Cashmere, Llama, Mohair, Vicunja, Yak	WP, WA, WU, WK, WN, WS, WL, WM, WG, WY	Synthetic Fibres: Polyester: 41 - 81 cN/tex E-Glass: 138 cN/tex		Collocation: Author Literature: Bobeth (1993), Desai (2016), Gries (2014), Kiessling (1993), Latzke (1988), McKenna (2004), Schenek (2001), *Wikipedia (8.12.2018)
Rough Hair				
Beef-, horse- and goathair	HR, HS, HZ			
Silk				
Mulberry Silk, wilde Silk	SE, ST			
Mineral Fibres				
Asbestos	AS			

Figure 4. Table of natural fibres. Source: Lucerne School of Art and Design.

6 Spinning natural fibres: established mechanical process chains

There exist different spinning processes depending on the fibres and the fineness to be achieved:

- The ring spinning process produces fine, uniform yarns. It requires a careful pre-treatment of the staple fibres to obtain a pre-stretched card sliver from which a roving is produced, which is drawn and firmly twisted on the ring spinning machine.
- The rotor spinning process is possible even without making a roving. This kind of spinning is faster than ring spinning, but the fibres are less parallel than in ring spun yarns. It is not possible to spin yarns as fine and strong as in ring spinning.
- Flax spinning differs in the preparation of the card slivers and in the actual spinning process. Since the bast fibres still have pectins (vegetable glue), the so-called wet spinning process is used. The pectins between the fibres soften thanks to the humidity, can thus be warped better against each other and be spun into finer yarns.

The following table shows the individual steps of the process chains of natural fibres from plant to yarn for the categories of seed, bast and hard fibres. The choice was determined by the attempt to card the banana fibres - for which there is no industrial-mechanical process so far -, using the methods of similar fibres in order to integrate them into the process.

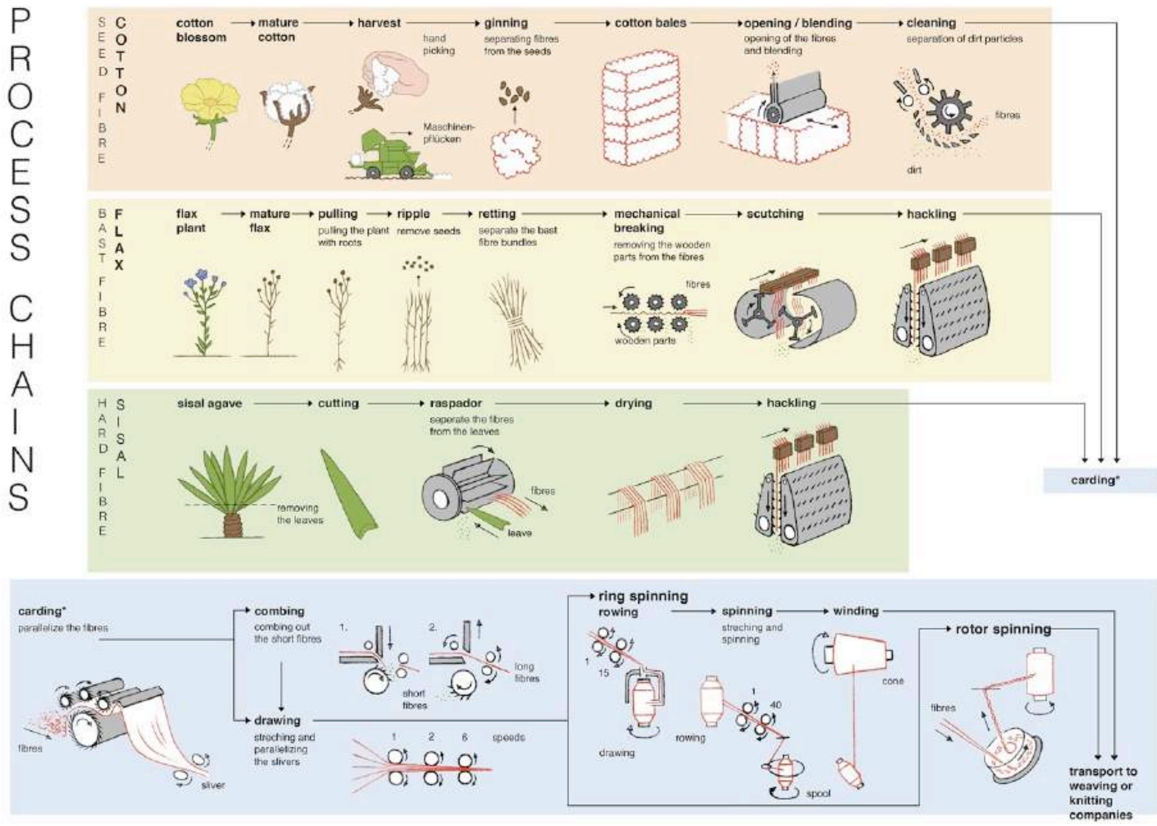

Figure 5. Table of mechanical spinning processes. Source: Lucerne School of Art and Design, Natalie Neff.

7 Description of the experiments

The individual steps used with the selected seed, bast and hard fibres described above demonstrate the similarity of the different processes. However, the fibre length and fibre fineness determine the size of the machines and the individual components that open up and parallelize the fibres. All of these preparations for the spinning processes were carefully analyzed and evaluated for suitability regarding the banana fibres. The analysis showed that the banana fibres can be treated in the same or a similar manner as the fibres discussed, thus incorporating them into these processes for spinning trials.

7.1 Treatment of banana fibres to integrate them into existing process chains

As our goal was to use existing industrial spinning methods to produce yarn from Banana fibres, we focused on the relevant process chains. Accordingly, experts were consulted to assist with the preparation of the banana fibres and the adaption of the spinning processes. The following diagram shows the process chain of banana fibres from field to prototype.

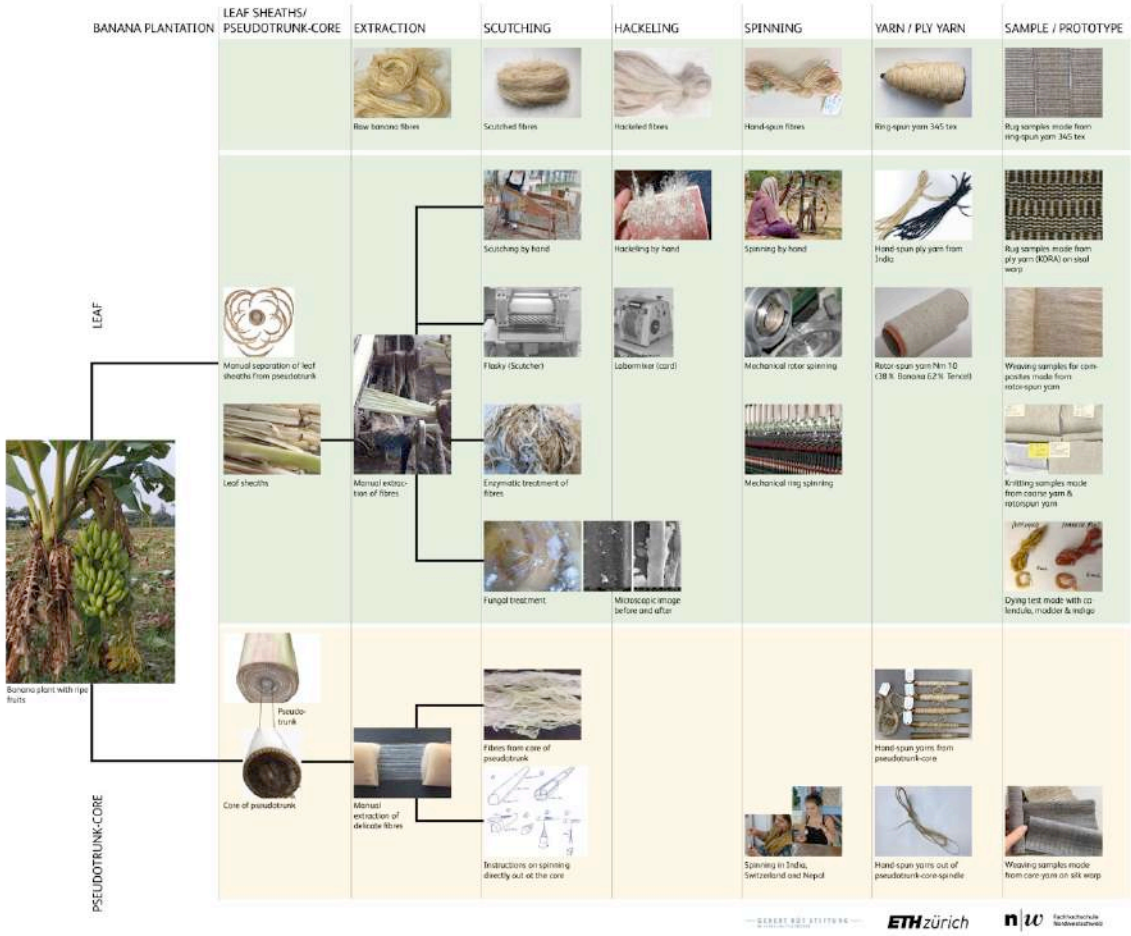

Figure 6. Table of the experiments made in analogy of existing marketable natural fibre process chains applied to banana fibres. Source: Lucerne School of Art and Design.

7.2 Spinning on the jute line and degumming

Spinning on the jute line in India is described in several publications (Desai, 2016; Roy, 2014). Unfortunately, it was not possible to encourage neither national institutes nor companies in India to develop a refined process for the banana fibres in order to obtain thinner yarns. One reason might have been that the Ministry of Textile supports the jute industry and thus discontinued research funding in the banana fibre sector. Yet, we were able to procure two kilograms of a 345 tex yarn from an Indian agricultural university which were produced during research work. With this yarn sample the following experiment was conducted by a partner university which specializes in wet stockage, pretreatment and processability of hemp fibres. The yarn was degummed using a hemp degumming process, in which the yarn is degummed in a chemical solution for half an hour at 123 ° C in the autoclave, then neutralized with hot water and acetic acid dissolved in deionized water and finally dried.

Result: The degumming made the yarn lighter, softer and fluffier. The sample lost 26.5% in weight and therefore reaches a titer of 253 tex.

Conclusion: As the yarn is still quite thick, it is better to do the degumming before the spinning process.

7.3 Weaving tests with the 345 tex banana yarn on a mechanical weaving machine

Since the 345 tex banana yarn is similar to sisal, existing sisal weave patterns were selected and adjusted to banana yarn.

Result: A weaving company wove three carpet patterns, which are usually made with sisal and coconut for their in-house collection.

Conclusion: The weaving test worked, the qualities are comparable to those of the rugs in the company's collection. Better results could be achieved with harder spun or twisted yarns. The price of the yarn per kilo would have to be around 8 CHF in order to compete with Sisal.

Figure 7. Banana yarn 345 tex. Source: Lucerne School of Art and Design.

Figure 8. Carpet samples from a mechanical weaving machine. Source: Lucerne School of Art and Design.

7.4 Hand spinning tests

In order to find out how the banana fibres would behave on a mechanical linen spinning machine, an experienced Swiss linen spinner and weaver made various experiments. First, she prepared three samples of banana fibres for spinning. One sample was left raw, one was treated with a commercial washing agent and one with a bleaching agent. The three samples were then divided and mechanically processed on the flax brake and on the hackle. Some portions were softened with a gel of boiled linseed, followed by wet and dry spinning on the hand spinning wheel.

Result: Seven different yarns were thus created, each with a description and an evaluation of the processes used.

Conclusion: The following assessment of the seven yarn samples showed that adequate pretreatment should make spinning on the mechanical linen spinning line possible.

Figure 9. Handspun yarn from banana fibres. Source: Lucerne School of Art and Design.

7.5 Mechanical treatment and cottonizing of banana fibres

Several mechanical tests on laboratory machines (a squeegee with a grooved surface and a card) were made in order to dissolve the glue between the fibres. The fibres then underwent a chemical and enzymatic process similar to the procedure used for hemp fibres. A total of twelve experiments was carried out twice. There were four arrangements, each with two different chemical and enzymatic degumming solutions.

Result: There were 24 portions of degummed fibres.

Conclusion: Using the hemp procedure for degumming banana fibres should be viewed critically because the elementary fibres in sizes of up to 5.5 mm are lost during this process (Müssig, 2010). This raises the question of how the degumming conditions can be adapted so that only the technical fibres are dissolved without dissolving and losing the fine elementary fibres at the same time.

Figure 10. Protocol of degumming process. Source: Lucerne School of Art and Design.

Figure 11. Degummed fibres. Source: Lucerne School of Art and Design.

7.6 Spinning the cottonized fibres on an OE rotor spinning machine

The customer spinning mill of the German Institute for Textile and Fibre Research (DITF) tried to spin the degummed fibres as thin as possible. Spinning tests were carried out with 100%, 50% and 38% degummed banana fibres.

Result: A Nm10 yarn was produced. The ratio of banana fibres to the added tencel fibres is 32: 68. Compared to a pure Nm10 tencel yarn, the mixed yarn is less tear resistant. It also shows some unevenness from the banana fibres.

Conclusion: The degumming is one way in order to get a fine yarn. On a lab scale, it is costly to produce the blended yarn with the degummed banana fibres. The yarn is used for weaving a sample in order to test its suitability for composites.

Figure 12. OE rotor yarn, Nm 10. Source: Lucerne School of Art and Design.

7.7 Hackling of banana fibres

A Dutch linen hackling company was very open to experiments and hackled several hundred grams of banana fibres. The result was so good that a part was sent to a linen spinning mill in Italy to check whether the mechanically parallelized banana fibres could be spun. After a positive answer, the Dutch company agreed to prepare another 30kg of the banana fibres into a sliver.

Since the banana fibres extracted from the fresh leaf shafts dry on clotheslines in India, all bundles had to be unfolded by hand before they could be transported to the hackling machine.

Result: Since the fibres are coarser than the linen fibres, they sometimes get stuck in the machine and have to be loosened by hand.

Conclusion: It is possible to break the fibres mechanically, but a mechanical pre-treatment is required, which removes the coarsest impurities and makes the fibres softer and more pliable for the hackling machine.

Figure 13. Sliver after the hackling. Source: Lucerne School of Art and Design.

7.8 Fungal treatment of banana fibres

Some meters of the banana sliver have been subjected to a fungal treatment which is normally used for the treatment of wood (Schwarze, 2011). As the surface of the banana fibres is smooth, the fibres do not adhere well to each other when spun. The fungus treatment removes the glue between the fibres and roughens their surface. This results in a refined haptic and better spinning results.

The duration of the fungal treatment was 4, 6, 10 and 12 weeks for the four portions.

Result: The surfaces of the banana fibres were modified by the enzymes released by the fungus Physisporinu vitreus. A clear structuring is visible on the surface after the treatment.

Conclusion: The results from the experiments are promising and should be followed up.

7.9 Sampling: Weaving and knitting of banana yarns

7.9.1 Carpet samples

Fabric tests for carpets were carried out on a hand loom in India. The warp was made of sisal, the weft of banana twine.

Result: The carpet patterns are woven in such a way that the sisal warp only supports the banana yarns and only the banana yarns are visible on the surface. These are very stable carpet patterns that could replace sisal carpets.

Conclusion: Coarse yarns or twisted yarns are very suitable for carpets.

Figure 14. Three carpet patterns with banana twine. Source: Lucerne School of Art and Design.

7.9.2 Woven textiles for composites

With the Nm 10 rotor yarn (38% banana, 62% Tencel) a reinforcement fabric for bio composites was woven. The warp setting was taken from a linen textile, which is normally used for the purpose and which we wanted to replace.

Result: The fabrics for the composites are very similar to the original linen patterns.

Conclusion: Compared to linen yarns, the rotor yarn is less tear-resistant and can be used for composites that do not have to withstand high tensile and compressive loads.

Figures 15. Textile samples with rotor yarn Nm 10 (38% banana, 62% Tencel). Source: Lucerne School of Art and Design.

7.9.3 Knitted samples

Various knitting tests were carried out on a hand knitting machine with a pitch of 5. The yarn is almost too fine, so that tests were carried out with two or three yarns knitted together. A reference pattern was knitted with pure Tencel yarn.

Result: Knitting produces soft textiles. Compared to the reference pattern made of pure Tencel, the surface of the mixed yarn patterns is more irregular and livelier.

Conclusion: The yarns are suitable for knitted fabrics that could be used in the clothing sector because they are soft to the touch and can be dyed very well.

Figure 16. Knitted patterns with rotor yarn Nm 10. Source: Lucerne School of Art and Design.

7.10 The fine banana fibres from the core

Very fine fibres are embedded in the core of the pseudo stems, which can be removed. These fibres were spun by hand. Since the fibres are extracted from the wet trunk, they are glued together by the banana sap which makes them difficult to spin. Hence, they had to be moistened before spinning. Since the fine fibres also have a smooth surface and therefore adhere poorly to each other, ramie fibres were added as carriers, which results in a firmer yarn.

Result: The spinning of the pure banana fibres mixed with ramie yielded viable yarns and twines that are reminiscent of bourette silk or lotus yarn.

Conclusion: Extracting the banana fibres and subsequently spinning them are very time-consuming processes which can hardly be mechanized. This therefore remains a niche product.

Figure 17. Images side by side showing the core of the pseudo stem with fine fibres and extracted fibres. Source: Lucerne School of Art and Design.

7.11 Development of a manual spinning process directly from the core

Since it is very time-consuming to first extract the fine banana fibres and only then spin them, a process has been developed to make spinning directly from the core possible. In order to find out whether spinning can also be done by other people according to our precise specifications, instructions were written down and the process filmed. Women in Switzerland, India and Nepal tried to spin directly from the core following these instructions.

Result: Even though this process is also complex, one can spin viable yarns from the core. Thanks to the sap, the fibres adhere very well to each other when twisted.

Conclusion: Compared to extraction and subsequent spinning, this process has greater potential. Yet, yarns obtained this way too will only have a chance as a niche product.

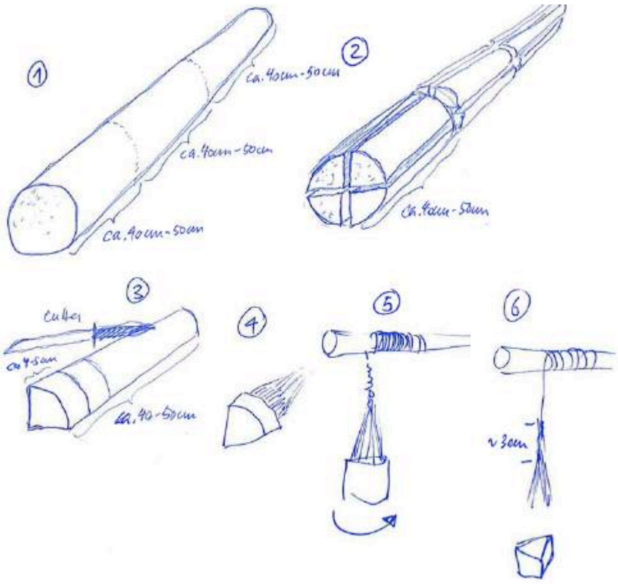

Figure 18. Procedure for direct spinning from the core. Source: Lucerne School of Art and Design.

Figure 19. Images side by side showing spinning trials with Nepalese, Indian and Swiss spinners. Source: NGO Manushi, Nepal and Lucerne School of Art and Design.

7.12 Fabric production from the yarns of the core fibres

On a silk warp several fabric patterns were created with the yarns from the core fibres. Some of the yarns were dyed to achieve a wider range of patterns.

Results: The fabric patterns are very fine, noble in appearance and feel, and suitable for use in outerwear.

Conclusion: The strength of the spun yarns is not yet sufficient for the use as warp. In order to obtain thicker yarn, the process must be adapted. It requires further research to explore the possibilities.

Figure 20. Woven samples with silk warp and banana weft. Source: Lucerne School of Art and Design.

8 The Potential: Conclusion

The research project yielded the following results:

- The coarser yarns can be used instead of other natural fibres in interior textiles. They not only possess similar characteristics, but represent a sustainable alternative since they are generated from waste. There are real opportunities for the fibres and yarns, if they are available in sufficiently large quantities and can be mechanically processed at a price that can compete with coir, sisal, fibre bananas, and linen.
- The finer yarns are suitable for composites. Their tensile strength is sufficient for molded parts that are not exposed to excessive tensile and compressive forces. Yet, they are rendered too expensive to manufacture due to the many process steps needed. In order to lower prices further optimization of the degumming and spinning processes would be necessary.
- The fine knitted and woven patterns are visually and haptically convincing and could be used in the clothing sector. The laboratory-scale effort is currently still too great to process the fibres in sufficient quantity and quality.

Thanks to the manual tests it was possible to gain profound knowledge regarding the preparation of the fibres, which could be transferred to mechanical processes. In addition to generating knowledge, the advantage of the manual tests was that the processes were disclosed in their entirety, which would have been difficult to achieve in an industrial process chain that operates globally. The application of analogies in related fields can help to find solutions to new problems.

For designers, the handwork used during the project revealed to be a well of learning opportunities. Working manually rather than with machines, enabled us to develop a feeling for the material and to gain information about the treatment, the processability and the possible adaptation to mechanical processes. Due to the small quantities of spun material it was inevitable to produce samples on hand looms or hand knitting machines, which led to further important findings about the production of textile surfaces.

The challenge remaining is to scale up the processes. In addition to banana fibres, there are many other vegetable fibres worth reassessing as shown above, e.g. linen, hemp, ramie, nettle, and bamboo. It would be advantageous if all the research into these bast fibres could be bundled and if in a joint effort an attempt were made to establish a medium-scale process chain for a quantity of approximately 30 kg spinning yarn that would be suitable for all available bast fibres. This would close another research gap, because the steps, the financial commitment and the risk of failure are large between the academic laboratory activity of a few hundred grams and the scaling to the industrial production of several hundred kilograms. Finally, I would like to state that specialization in one design field is no longer sufficient to successfully answer research questions. In order to react agilely and to focus on a sideline, it is necessary to know well all adjacent areas surrounding the specialist field.

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