Application Of Natural Fibre Composites In Product Design: A Guiding Framework

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ABSTRACT

The global production of petroleum-based plastics has grown significantly from 1.5 million tonnes in 1950 to 367 million tonnes in 2020, escalating global demand based on the limitations of conventional material resources. The effective use of natural fibre composites can alleviate modern civilisation's reliance on chemical resources, reduce energy shortages and have a positive impact on agricultural development. The objective of this study is to establish a framework for guiding design practice by sorting out the properties and application areas of natural fibre composites from a designer's perspective, and the ways in which the material can be experienced. It also uses coconut fibre as an example to develop design research and promote social innovation. The data is analysed and summarised through theoretical frameworks, qualitative interviews, observations and thematic analysis. Facing new materials outside the education system, it helps design-related staff to find areas of application where material properties are consistent with product properties, consumer needs and environmentally beneficial in the design practice process.

Keywords: *Natural fibre composite, Product innovation, Sustainable applications*

INTRODUCTION

Materials have always been a focus of sustainable design concerns and the introduction of materials can be seen as a sustainable expression in itself. The green economy points to an employment policy that stimulates innovation through access to the right resources and promotes the recycling of existing products rather than the reuse of new ones, with a focus on reducing petroleum-based products through the use of a circular economy. A shift from the previous linear economy of 'extract, produce, use and discard' to a continuous cycle model of products. This has led to the development of a range of new materials and this paper looks at the use of biodegradable biomass-natural fibre composites in product design.

The world has entered the "post-oil era" as a result of excessive energy consumption. On the one hand, the limitations of conventional-based material resources are escalating global demand and significantly increasing the price of raw materials. On the other hand, the recycling rate of plastic waste worldwide is still extremely low, with millions of tonnes of plastic waste being disposed of in the natural environment, including between 75 and 199 million tonnes in marine ecosystems (UNEP - UN Environment Programme, n.d.). In response to resource constraints and the plastic crisis, society is urgently seeking renewable resources to "replace" petroleum-based materials.

The "biodegradable biomass feedstock" (plants, animals, microorganisms, organic waste) is a hot topic of research. There are more than 2000 different plant fibres in the world(Väisänen et al., 2017). Natural plant fibres exist in plants in many forms such as bark, stems, leaves and seeds, and are the largest renewable resource in the earth's biological resources. Natural plant fibre composites are one of the new degradable biomass materials, but natural plant fibres, a sustainable biomass resource, are not fully utilised.

With the general increase in environmental awareness and technological developments, natural fibre composite products already exist in everyday household products, such as disposable bagasse bioplastic tableware and straw tableware. However, industry statistics show that these biocomposites are still not comparable to traditional materials in terms of market share (Dicker et al., 2014; Manu et al., 2022). Designers have expressed unfamiliarity when working with these materials (Taekema & Karana, n.d.). Consumers also report that traditional materials are more familiar and secure, and despite being aware of environmental issues, they prefer to buy cheaper, familiar products rather than pay extra for expensive but environmentally friendly ones. What's more, some of these products are only as "environmentally friendly" as they sound (Dunn et al., 2020). It is clear that biocomposites have not yet made a positive impression on consumers.

LITERATURE REVIEW

Natural fibres are made up of plants and animals, minerals, which are readily available, biodegradable and have biocompatible properties (Syduzzaman et al., 2020; Väisänen et al., 2017a).The present study is concerned with plant fibres in ten fibre composites.

Plant fibres

Plant fibres generally refer to agricultural and forestry residues containing wood fibres, including hemp fibres, bamboo fibres, wood flour, wheat straw, corn straw, bagasse, rice husks, etc. It has the characteristics of abundant source, low price, renewable, degradable, low processing cost, etc (Cheng et al., 2020). The disadvantages of vegetable fibres are their high hydrophilicity and water absorption, which affects their mechanical properties (Uppal et al., 2022). Plant fibres are mainly composed of cellulose, hemicellulose and lignin (lignocellulose) (Singha & Thakur, 2009). According to the application, plant fibres are classified as primary or secondary, with primary plants being those produced for their fibre content and secondary plants being those that produce fibre as a by-product (Summerscales et al., 2010). The age of the plant, the species, the climatic conditions and the fibre processing techniques affect the chemical composition and structure of the fibres. There are six types of cellulose fibre. These are bast fibres, leaf fibres, seed fibres, stem/grass fibres (Barba et al., 2020; Li et al., 2020; Thakur et al., 2011).

Classification of plant fibres

The bast fibres, also known as soft fibres, are located beneath the epidermis of the stem (Zhuang, 2001). The main bast fibre plants are jute (Corchorus cap sularis), flax (Linum vsitatissinum), red hemp (Hibiscus cannabinus), hemp (Cannabis sativa), ramie (Boehmeria nivea) (Chandramohan & Marimuthu, 2011; Li et al., 2020; Zhuang, 2001).The bast fibre has excellent properties in structural applications, is strong and easy to extract. The fibres can be separated from the main stem, usually by maceration, and the separated fibre bundles can often be used directly and have been used since ancient times to make rope, hemp stuffing, packaging materials, etc. Jute fibre is the cheapest bast fibre after cotton (Uppal et al., 2022) and has the highest yield of all in the world (Shahzad, 2012) and is widely used.Flax is also a favourite for everyday use. Widely used for its lightweight, high cellulose content (62-72%) and optimum combination of strength and stiffness, flax can be spun into high-grade yarns, fine linen and other textile products, and also as a reinforcing material in composite materials. Ramie is the stiffest of all bast fibres, as it has the highest cellulose content, but has been relatively little studied due to its lowest production. Nowadays, bast fibres are mainly used in the textile industry and as reinforcement for composite materials.

Leaf fibres, also known as stiff fibres (Zhuang, 2001), are fibres obtained from the leaves or leaf sheaths of plants. Leaf fibres are coarser than bast fibres. They have good strength and mechanical properties and are widely used in composites and are also synthesised into natural fibre composites for exterior and interior automotive applications as a reinforcing material. The main leaf fibres are sisal (Agave sisalana), banana (Musa indica), pineapple (Ananas comosus), Abaca (Musa textilis), Curaua (Ananas erectifolius), of which plantain hemp, sisal is more widely used. Jute fibre is now used to make bags, boxes, mats and other products with high strength.

Seed fibres are seed epidermal hairs, which are single-celled fibres produced by the epidermal cells of some plants, mainly cotton (Gossypium), coconut (Cocos nucifera), oil palm (Elaeis guineensis) . The most familiar is cotton fibre (Zhuang, 2001). which can be used in a wide range of applications and forms, from inexpensive textile products to a variety of high-value products. Cotton can also be used as a reinforcing material in tea-cotton based composites for automotive applications. Coconut is the least absorbent and relatively water resistant of all plant fibres. The low water absorption of coconut fibre is due to the low cellulose content and high lignin content, and it is for this reason that the mechanical properties are low and batch production is challenging (Geethamma & Thomas, 2005).

Stem/grass fibres refer to straw fibres, mainly sugarcane bagasse (Saccharum officinarum), bamboo (Bambusa vulgaris) barley and rice. Compared to bast and leaf fibres, sugarcane fibres are the shortest, less brittle and have the lowest tensile rates (Hajiha & Sain, 2015).Compared to bast and leaf fibres, this fibre has lower tensile properties and is mainly used for making pulp. Panels made from bamboo fibres are hard and stiff and can be an effective substitute for hardwood items. And bamboo fibre absorbs different frequencies of UV light, making it a very useful fibre and a quality alternative to wood. However, the mechanical properties of stem fibres are generally poorer materials compared to bast and leaf fibres, and are often used to make disposable tableware and packaging materials.

Natural fibre composites

Natural plant fibres can be processed into threads for weaving and textile production (Mohanty et al., 2018), It can also be chopped as a filler, reinforcement and binder (matrix) to form natural fibre composites(Rognoli et al., n.d.). Natural fibres (NF) are one of the most commonly used green fillers or reinforcing agents in polymer matrices. Natural fibres are embedded in thermoset or thermoplastic polymers to create composites (Mohammed et al., 2015) .

With the advantages of being cheaper than synthetic composites, biodegradable, resourceful, renewable and lightweight, natural fibre composites are being used as an alternative to petroleum-based materials (Elanchezhian et al., 2018; Li et al., 2020; Safri et al., 2018). Scholars in different contexts have modified the properties of materials to suit different applications, such as adding reinforcements (in the form of fibres or particles) to form different composites, such as natural fibre-reinforced composites (NFRC), 100% green biocomposites - plant-based natural fibre-reinforced composites (PFRPC), and plant-based natural fibre-reinforced composites (PFRPC). Natural fibre reinforced composites (NFRC), 100% green biocomposites - Plant-Based Natural Fiber Reinforced Composites, and natural fibre reinforced polymer composites (NFRPC), are now considered to be one of the most emerging materials for many engineering applications. NFRC is also known as "green composites", "eco-composites" and "bio-composites".

Natural fibre composites in household products

Natural plant fibres are commonly found in the textile and paper industries and are also used in everyday products such as rope, mattresses and planting soil. Natural fibre-reinforced composites (NFRC) are now considered to be one of the most emerging materials for many engineering applications. The most prominent of these are automotive parts, aerospace, architectural panels and medical applications (Mohan & Kanny, 2012; Uppal et al., 2022; Zhao, 2022). However, this sector is more concerned with technology than with aesthetics. In the textile industry, plant fibres are used more widely and are concerned with aesthetics, often woven into threads for fabrics, clothing, shoes and bags. Natural fibre composites are also used in clothing accessories such as buttons and zips, and on the bottoms of shoes. Natural fibre composites are used in everyday products as an alternative to petroleum-based materials, in tableware, disposable products and disposable packaging materials.

Natural fibre reinforced composites are used extensively in the automotive industry for their high strength and light weight (Figure1), especially in European countries where government legislation encourages the use of natural fibres in 'end-of-life vehicle regulations' (Li et al., 2020). In automotive components, the main solution is to reduce the total weight of the vehicle, reduce costs and improve fuel efficiency (Naik & Kumar, 2021). For example, the Mercedes-Benz A-Class (2018 model) has components made of natural fibre composites that reduce the weight of the vehicle by up to 34% (Fantuzzi et al., 2021), achieves a high level of material utilisation (Barba et al., 2020). Other leading car manufacturers such as BMW Audi Fiat, GM, Honda, Volvo, Mazda Kai, Toyota and Volkswagen are also incorporating natural fibre composites into their products (Li et al., 2020). However, consumer demand for such products is mainly for technological improvements, with very little demand for interaction and styling, and the sector is more concerned with the technical aspects of sustainability than with the aesthetics of materials.

Figure 1. Model of the Mercedes-Benz A-class car and its component parts made of natural fibre composite
(Source: Barba et al., 2020; Mercedes-Benz Sustainability Dialogue 2022, 2022)

In addition to the above-mentioned use of NFC in the automotive sector, NFC is also often used to make panels, which is the most common way of exploring the initial application of the material in a flat form to explore how the material can be formed. It is of great significance to explore NFC forming in a flat form. Flat panels are used in a wide range of styles, such as veneer, laminate, and panels of different thicknesses can be used in architectural interiors, interiors, furniture, and product design. The emergence of panel furniture allows for modular assembly, freedom of assembly while saving transport space and reducing the weight of the product. Banana fibre FIBandco veneers from the Banana trunk veneer brand -

the green blade® range (Veneer–Fibandco, n.d.) are used in various forms in architecture, interior spaces, furniture design and product design (Figure 2). It is worth noting that this brand of material is already on the market and has been awarded LEED certification. Natural plant-based panels can replace wood and plastic panels, reducing the strain on wood and oil resources.

Figure2. FIBandco- green blade® banana fibre veneer in design
(Source: Veneer – Fibandco, n.d.)

NFC is gradually replacing disposable packaging for disposable products (Nor Salwa. et al., 2021) and tableware (Sathish et al., 2021) in the application trend. Plant fibres can be made into pulp and pressed into everyday items, such as paper cutlery. However, mankind's reliance on paper-based products has led to the over-consumption of wood resources. Waste plant fibre materials such as wheat straw can be pulped and also combined with a matrix to form composite materials such as wheat straw plastic. wheat straw plastic is very durable and heat resistant, withstanding temperatures of up to 200 degrees Fahrenheit, and is therefore often used as an alternative to plastic for everyday household items. Similarly, bagasse, a straw fibre material, is also made into biodegradable plastics for a range of dishes, cutlery, cups and plates (Figure 3).

Figure 3 : Sugarcane bagasse bioplastic tableware
(Source: Compostable Bagasse Plate Supplier In China-GangXuan, 2022)

Compared to plastic, metal, glass and wood, plant fibre composites are relatively less used in product design. Natural fibre composites are used as an alternative to plastics in the field of disposable packaging materials and filling materials. In some respects natural fibre composites can be similar to other materials in terms of physical and chemical properties. However, consumers have their own impressions, emotions and expectations of familiar materials that are difficult to meet.

Products Material properties and product properties

In *the Material of Invention*, Manzini (1986) stressed that the primary characteristic of new materials is their functionality. Instead of asking "What is it?" When referring to a newly familiar material, the designer needs to ask "What does it do?" What are the properties of the material and for what area and function is it suitable? This is considered to be one of the most powerful strategies for reducing the gestation time of material innovations (Ashby & Johnson, 2003). Material selection in product design is defined as the selection of suitable materials for a designed product by considering relevant design criteria such as manufacturing process, availability, cost, function, shape, use, etc (Karana et al., 2010). In product design, materials should not only meet technical requirements, but also appeal to the user's senses and contribute to the intended meaning of the product (Ashby & Johnson, 2003). It is the responsibility of the product designer to consider the relationship between material properties and product characteristics in order to use materials to effectively convey certain meanings.

The consistency of material properties with product properties can also have a significant impact on the environment, for example, plastics can cause irreversible damage to the environment not because they have environmentally unfriendly properties, but because humans have given long-lived materials short-lived features. Similarly, natural fibre composites, although naturally harmless, renewable and biodegradable, can also be harmful to the environment if they are given functions that are inconsistent with the material's properties.

Material properties

In 2009 Karana summarised 'material properties' as technical and sensory properties of materials, where technical properties of materials (strength, elasticity, thermal conductivity, etc.) are used to differentiate materials, e.g. the technical characteristics of glass - transparent, brittle materials (Karana, 2009). The sensory experience is a multiplicity of sensations that are triggered by the human experience of the material, e.g. the "brightness" of the glass is inspired by its "transparency" and "brittleness". "light", "fragile", etc. The properties of a material include both the physical and chemical technical characteristics of the object and the feelings that are evoked during the experience of the material.

2015 Karen's study of the literature has inspired a hierarchical model of material properties (Figure 4), which divides material properties into two categories-physical properties and 'experiential characteristics. physical properties correspond to the physical-chemical properties of materials, while experiential characteristics correspond to experience-oriented and user-driven material properties, including sensory, associative and emotional characteristics. The senses are the bridge between physical properties and 'experiential characteristics'. Technical properties of materials interact with sensory, associative and emotional properties (Hasling, 2015).
(11pt space)

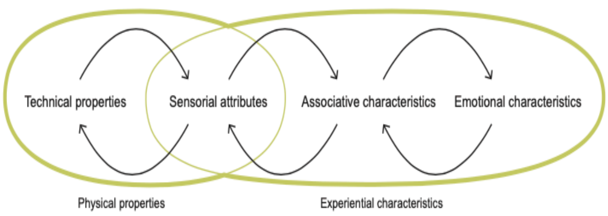


Figure 4. Hierarchical model of material properties
(Source: Hasling, 2015)

Product properties

Product characteristics refer to the product's function, form, people who use it and how it interacts. The physical and chemical properties of the material have a direct influence on the function, surface treatment and interaction of the product, while the emotional needs of the consumer also have an impact on it. This means that a product that works, works well and is loved must satisfy both the material and emotional functions of the product.

The form, colour and texture of the product also influence the sensory experience of the person, who in the process of experiencing it will stimulate/create associations and thus emotions towards the product. How to capture/create associations and emotions inspired by the interaction between the technical and sensory properties of materials is a key concern for product designers.

METHODOLOGY

This study focuses on natural fibre composites made from mainly plant fibres. Knowledge generated in practice through theoretical frameworks, material experiments, qualitative interviews to collect data. The data is grouped and coded by transcribing the text from the recordings and processed through thematic analysis methods.

Theoretical framework

The following guiding framework for design practice for this study (Figure 4) was developed based on the material-driven design approach (Karana et al., 2015). The guiding framework for design practice for natural fibre composites focuses on the transformation of form, function, and interactive experience between material properties, product properties, uncovering the unique properties of the material, capturing factors that touch consumer empathy, how to enhance the recognisability, acceptability of natural fibre composites, and expanding the direction of application areas consistent with the material properties. To help design-related workers realise the value of materials in their design practice and promote social innovation.

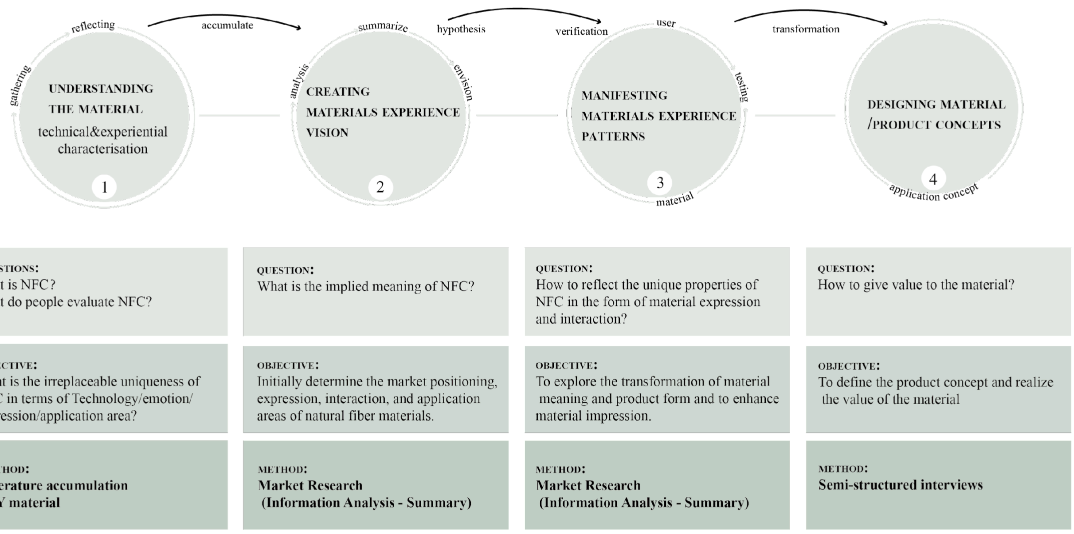


Figure 4. A guiding framework for the design practice of natural fibre composites

Step 1: Understanding the material (technical & experiential characterization)

Through the accumulation of existing literature, what are the unique characteristics of natural fibre composites that are irreplaceable in terms of technical/emotional/expressive form/application areas? The main questions revolve around the following (Table1):

Table 1. Step 1 key Issues

1: What are the main technical characteristics of plant fibre composites? (strength, permeability, water absorption)?
2: What are the drawbacks of plant fibre composites?
3: How are plant fibre composites formed?
4: What do people say about plant fibre composites?
5: How do people interact with plant fibre composites?
6: What are the main areas of application for plant fibre composites?
7: What are the main areas of application for bio-based materials?
8:How do these natural fibre composite products now reflect the material characteristics?

Step 2 : Creating Materials experience vision

The literature research and the analysis of market data initially predicts the market positioning, presentation, interaction and application areas of plant fibre composites, and summarises them in a visual image. The main focus is on what is implied by plant fibre composites (Table2):

Table 2. Step 2 key Issues

1:Envisioning the field of application of the material
2: Imagining the way people and materials interact
3: Envision the emotions that people evoke as they experience the material
4: What factors (fibres/cultural symbols/methods of use/etc.) are envisaged to influence the emotional characteristics evoked by a person during the experience of the material?
5:What kind of representation do the envisaged materials take in the product?
6:What emotional characteristics are evoked by the envisaged presentation of the material?

Step 3 : Manifesting Materials Experience Patterns

The transformation of data analysis and elements explore the transformation of material meaning and product form to enhance the impression of the material. This is developed around the following questions (Table 3):

Table 3. Step 3 key Issues

1:What factors influence human behaviour during the experience of material?
2:What factors influence the emotional characteristics that a person evokes during the experience of the material?
3:How do you translate emotional characteristics into design elements?
4:What emotional changes are stimulated by changes in the presentation of materials?
5:How can the unique properties of the material be reflected in the form of expression?
6:How can we enhance consumers' emotional identification with the material in terms of its presentation and interaction?

Step 4 : Designing Material/Product concepts

Semi-structured interviews with people working in the field, combined with material samples and design proposals (sketches of intentions, models), generate knowledge and refine concepts through construction, reflection and exchange. This leads to the expansion of the field of application and the realisation of the value of the material. The following questions were developed (Table 4):

Table 4. Step 4 key Issues

1:Positioning of materials/products (function, population)
2:What are the areas of application of the materials, how they interact, how they are presented, and whether they meet the needs of the consumer?
3:Are the technical characteristics of the material consistent with the function and lifetime of the product?

Material experiments

Data on material properties such as strength and tensile strength can help designers to understand whether the material properties meet the performance requirements of the product. But in design practice theoretical data is difficult to stimulate emotional perception. Designers need to feel the material with their hands, experience it and combine theory with practice.

In this study, coconut fibres were selected for the material experience. The material experiment focused on the variation of the 'fibre degree' after the matrix (binder) was determined, with the variation of the length, thickness and number of fibres resulting in different sample forms being experienced. The natural binder used here is made from gelatine, glycerin and fermented milk, a ratio obtained from the Product Design Studio of Zhejiang Normal University, China.

The materials experiment plan (Figure 5) looks at different types of binder, different proportions of binder, different fibre forms, and different proportions of fibre forms. For example, 5g of corrugated paper was combined with 3g, 5g, 10g, 15g, 20g, 25g, 30g of long & fine fibre to produce 6 material samples, and so on to produce more than 114 samples for the whole experiment. Using "material strength", "material characteristics", and "fibre size" as selection indicators, 12 representative samples were selected for the next step of the study.

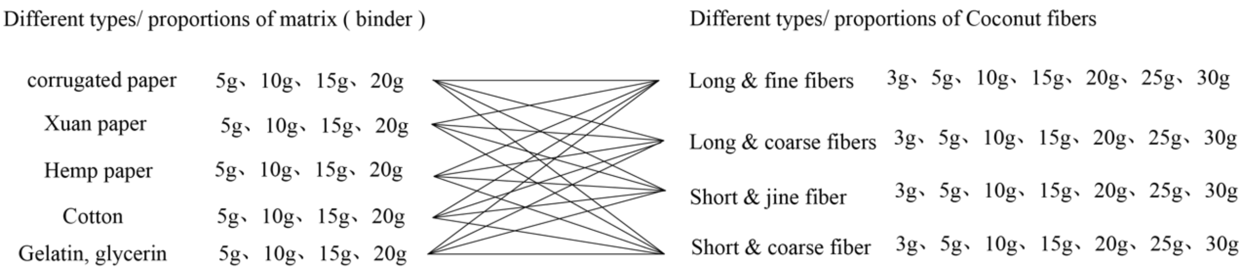
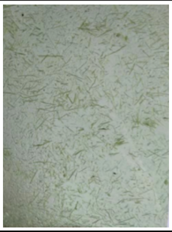


Figure 5. Materials Experimentation Programme

Semi-structured interviews

The interviews were conducted in Jinhua, Zhejiang Province, China, with a total of 15 interviewees who were junior designers, senior designers and material experts. The researcher conducted 1-to-1 interviews with 12 material samples(Table 5) and recorded the entire interview with the consent of the interviewees. The samples were observed and touched through visual and tactile means, and the interviewees were encouraged to interact with the materials in a variety of ways such as touching, folding, tearing and smelling. The interviewees were also encouraged to observe the samples under different light sources in order to obtain sensory perceptions, evaluations, impressions and associations during the material experience on the one hand, and to explore the application areas of the material together with the interviewees on the other.

Table 5. 12 sets of sample materials

Sample 1	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**	**Sample 6**
					
10g corrugated paper: 10g coconut fibre (long fibre)	10g xuan paper: 10g coconut fibre (long fibre)	20g corrugated paper: 10g coconut fibre (staple fibre)	20g corrugated paper: 10g coconut fibre (short fibre)	1g coconut fibre residue (coarse fibre): 5g natural binder	1g of coconut fibre residue (fine fibre): 5g of natural binder
Sample 7	**Sample 8**	**Sample 9**	**Sample 10**	**Sample 11**	**Sample 12**
					
0.7g coconut fibre residue (fine fibre): 5g natural binder (dyeing)	0.5g coconut fibre residue (fine fibre): 5g natural binder (dyeing)	5g of coconut fibre (short & fine): 5g of natural binder	5g of coconut fibre (short & coarse): 5g of natural binder	5g of coconut fibre (long & thin): 5g of natural binder	5g of coconut fibre (long & thick): 5g of natural binder

Data analysis

The material samples are mainly divided into coconut fibre paper and coconut fibre bioplastic. Coconut fibre paper has the characteristics of paper, light transmission, weakness, fear of water, bendable but tearable, with the addition of coconut fibre the paper is tougher than ordinary paper and has a unique fibre aesthetic under light, especially the short fibres. Coconut fibre bioplastics, with very good strength can be adapted to different functions. The long fibre samples, in particular, retain the strength of the material and at the same time have a unique fibre aesthetic and breathability.

Respondents subconsciously touched and bent the samples when they first touched them, and had no obvious requirements for the smell of the samples. The material samples were rated positively as "natural", "original", "safe" and "approachable". There were also negative comments such as "low quality", "brash" and "poor finish". The men in the study valued the sturdiness of the samples, tried to rip and tear them, and preferred the tougher samples. Women were more concerned with the texture, pattern and feel of the material.

Respondents felt that the coconut fibre material samples were natural and environmentally friendly, with natural materials that gave a feeling of safety. However, respondents also raised concerns about the stability of the material and whether the purely natural material would be able to cope with changes in temperature and humidity. In terms of application direction respondents were concerned about the aesthetic changes of fibres under light, the biodegradable nature of the material and the creation of natural ambience in the space. Further thematic analysis was carried out by summarising the following six groups of high frequency keywords: tactility, fibre sense, softness , toughness, texture, colour and stability.

Design applications

Through design practice and data analysis, the three keywords that cannot be replaced by natural fibre composites are "fibre degree", "air permeability" and "vitality". The design of coconut fibre composites in the field of planting and nursery is proposed to explore the application direction. Coconut fibre has moderate strength, low water absorption and high water fixation, and it can adjust the ratio of acidity to alkalinity in the soil, making it very easy for plants to grow.

Coconut fibre seedling trays (Figure 6), on the one hand, provide seedlings with an airy, water-fixing environment, and when the seedlings grow up they can be transplanted into the soil along with the plants to fertilise the soil again with fertiliser. A natural cycle of material from cradle to cradle is achieved.

Figure 6. Coconut fibre seedling trays
(Source: Author's collection)

RESULTS AND DISCUSSION

Natural fibre composites are made from plant fibres of natural origin, which are renewable, biodegradable and have the plasticity of plastic, and have great potential to ease the strain on petroleum-based resources. The current use of natural fibre composites in the automotive and construction sectors is widespread, but the focus on the technology of the material rather than the aesthetics of the material and the application of the material in design has made it clear that, compared to traditional materials, natural fibre composites are less commonly used in everyday products and are less distinguishable. This study establishes a framework for guiding design practice with natural fibre composites and proposes to explore the material from a designer's perspective, in terms of material aesthetics, application areas, ways of human interaction with the material, and material meaning.

Plant fibres are of natural origin, renewable and biodegradable, but do not necessarily retain their "ecological properties" when made into composites, as the binder in the composite is not necessarily a "green matrix". At the end of a product's life, recycling is also far more complex and difficult than we might think, and unconditional degradability is difficult to achieve. Design practitioners also need to look at the binder of the material at an early stage of design practice, the legislation governing the application area and whether the conditions for recycling and biodegradability are met at the end of the product's life. Designers should take a critical look at the 'green' and 'eco-friendly' labels attached to such materials and incorporate sustainability assessment strategies at an early stage of design practice.

CONCLUSIONS

"Natural" is a characteristic that distinguishes natural fibre composites from other materials (Karana & Nijkamp, 2014; Rognoli et al., n.d.), But all natural materials can be 'natural' without over-treatment. The mention of natural fibre composites is hardly evocative, the material is poorly differentiated and the material has a single application area. The design practice of natural fibre composites guides the framework, helping designers to confront new materials outside the education system and to develop design projects based on material properties. To drive the diverse use of materials, explore the many possibilities of application areas and promote social innovation.

Society has tended to replace petroleum-based materials with 'environmentally friendly' materials, This is not the design approach encouraged by this study.No material is good or bad. plastics are causing irreversible damage to the environment because society has given long-life material properties to short-life products. Purely natural materials used in the wrong areas can also be harmful to the environment. Purely natural synthetic materials are susceptible to changes in temperature and humidity, and the short life span of materials and biodegradable properties require certain conditions to be met in order to achieve them. Designers need to be aware of the relationship between the environment and the economy and, in this regard, focus groups are needed to systematically assess the sustainability of material applications with stakeholders.

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