Investigation of bark cloth for its surface texture and durability for apparel applications

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Abstract

Ugandan bark cloth has been recognised by UNESCO as a masterpiece of the 'Intangible Cultural Heritage of Humanity', to protect the knowledge, traditions and livelihoods associated with its production. Bark cloth is a non-woven, fibrous textile that has been produced from the wild fig or *mutuba* tree (*Ficus natalensis*) by the Baganda people of southern Uganda for hundreds of years. A typical bark cloth has a rich, terracotta colour and is worn by kings and chiefs during coronations, religious ceremonies and cultural gatherings, as well as for funeral shrouds.

This research is part of a project that explores the properties and significance of bark cloth from cultural, ethical, technical and aesthetic perspectives to determine its feasibility as a sustainable fashion textile. It will highlight the potential of bark cloth specifically in relation to the characteristics of luxury fashion (craftsmanship, quality, rarity, heritage and story-telling), through using techniques that include embroidery, appliqué, gilding, laser cutting, natural dyeing and fusing.

In addition, the bark cloth has been investigated for its practical suitability for apparel end use. Various fabric tests have been carried out to investigate its performance including fabric drape, stiffness, surface morphology and tearing strength. The material was also subjected to laser etching to implement design patterns. The bark cloth was subjected to CO_2 laser etching and sublimation printing to incorporate surface patterns. Based on the trials, an optimum set of parameters were identified to use laser and sublimation printing. As the material is stiff when it is heat-pressed and to facilitate the garment making process the bark cloth was fused with different types of knitted and woven fusible linings, and its drape and strength were also tested. A basic test garment (size 12 female full-sleeve top) was developed with the fused bark cloth that offered good drape and its shape and fit were evaluated on a mannequin. Outcomes indicated that bark cloth could be satisfactorily developed into outer garments with specific treatment.

It is anticipated that this research will indirectly create demand for bark cloth from Uganda and help to support the artisans involved in the production of sustainable bark cloth.

Key words: Bark cloth, sustainable luxury, fabric test – tensile strength, tearing strength, fabric drape, laser etching, sublimation printing, fusing and fit evaluation.

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Introduction

Bark cloth is an endangered, non-woven, fibrous textile that has been produced from the wild fig or *Mutuba* tree (*ficus natalensis*), by the Baganda of southern Uganda, since the thirteenth century. It has been designated a masterpiece of the 'Oral and Intangible Cultural Heritage of Humanity' by UNESCO (2008) and remains deeply tied to Baganda identity and tradition (Coombe, 1993, Nakazibwe, 2005, Musinguzi, 2005). Traditionally used in clothing, bark cloth has historic associations with royalty and status; it is still worn for ceremonial occasions by the Kabaka of Buganda. Historically, the wearing of bark cloth at the royal palace was a sign of position or favour – with subtle variations of style or the addition of skins to denote rank (Nakazibwe, 2005).

Bark cloth making is a highly skilled, gendered craft, passed down through generations of men. It requires careful harvesting of the bark by splitting its outer layer down the length of the tree before gently peeling it off. This activity is performed during the rainy season, when the trees have more sap, the bark is suppler, and the tree is less likely to be damaged by the process (Nakazibwe, 2005). The naked trunk is then wrapped in banana leaves for a few days, which serves to replenish the bark and prevent dehydration; in this way, the bark may be sustainably harvested every year. Therefore, the processes associated with the harvesting of bark cloth show a consistent respect for and harmony with the local environment.

The bark is steamed or soaked, and may be burnt with dried banana leaves, to soften its texture, before being pounded by a series of well-designed wooden mallets. Through this process, the bark fibre felts, becomes finer, smoother and more pliant and grows in size significantly (Figures 1, 3 and 4). It is then spread out in the sun for the natural, rich red-brown colour to develop that is favoured in the region (Rwawiire, Luggya and Tomkova, 2013 and Rwawiire et al., 2012), although it may be dyed by burying in iron-rich mud. Finishing includes the darning of any small tears in the cloth with raffia and the patching of any larger irregularities, before a final beating (Nakazibwe, 2005).

For centuries, bark cloth was an item of local and regional economic importance, being traded across central and east Africa (Figures 1 and 2). However, the introduction of woven textiles, by Swahili-Arab traders in the mid-1800s and later by the British, undermined barkcloth's importance and production (Nakazibwe, 2005, Trowell and Waschmann, 1953). Successive political and economic issues have impacted on the viability of barkcloth production - which was even prohibited in the 1970s and 1980s (Rwawiire and Tomkova, 2014); as a result, the number of expert makers had diminished.

Figure 1: Bark cloth sheet
(Scott, 2014)

Figure 2: Bark cloth garments, Kibinge
(Scott, 2013)

During fieldwork in Uganda in 2014, a bark cloth project at Kibinge, Masaka District was visited (Figures 2, 3 and 4). Through this UNESCO funded initiative, the Bukomansimbi Organic Tree Farmers Association (BOTFA) was working to promote the growth of more wild fig trees and of bark cloth production. An apprenticeship programme enabled ten elderly bark cloth makers each to train ten apprentices in their craft and to engage in activities to promote its cultural value within the community (UNESCO, 2018). The social and economic benefits to the region have great potential. The local people are proud of their work and ready to engage in more trade but a sustainable market is needed for their cloth. In addition, its wearability must be improved for contemporary fashion contexts and the ability to adapt it to new markets.

Figure 3: BOTFA visit in 2014
(Scott, 2014)

Figure 4: Purchasing bark cloth from BOTFA
(Scott, 2014)

Figure 5: Printed bark cloth
(Scott, 2014)

Figure 6: Jose Hendo at Kampala Fashion Week, 2014
(Karmali, 2014)

Adams (2015) and Worden (2016) reported that the meaning of traditional bark cloth, although having become associated with funerals and the wrapping of deceased bodies in the Baganda community, is being transformed in Uganda. Several Ugandan artists and fashion designers currently are using bark cloth, as they rediscover it as a medium for cultural revival and expression and value its sustainability. Ivan Yakuze, Sanaa Gateja, Ronex Ahimbisibwe, Wasswa and Fred Mutebi are artists who are using it in collage, product design and even as canvas; Xenson Znja, Jose Hendo and Gloria Wavamunno have used it in fashion collections

(Robertson, 2015, Worden, 2016), (Figures 5, 6, 7). Fred Mutebi is actively involved in encouraging *mutuba* tree planting and bark cloth production as part of the BOTFA project.

Figure 7: Art work by Yakuze Ivan
(Robertson, 2010)

'Bark Cloth Europe' was established in 1999 by a Ugandan-German couple who work with ethically sourced bark cloth to develop textiles that have improved and varied properties for multiple uses, including as a leather substitute for shoes or even for car upholstery, as well as for interior design purposes. They have contributed to the growing awareness of bark cloth overseas, but its potential needs further exploration for fashion garments.

Recently, bark cloth has been evaluated for a number of technical applications, such as epoxy resin biocomposites for automotive panels (Rwawiire et al., 2015). Researchers (Rawawiire and Tomkova, 2014) also evaluated the thermo-physiological properties and comfort parameters. The paper identified bark cloth's lower thermal absorptivity compared to cotton, which the researchers claimed would have a warm feeling next to the skin. They further concluded that water vapour permeability was higher compared to cotton fabrics. Although previous researchers have identified bark cloth for various uses, this paper focuses on its potential as a fashion fabric and addresses some of the practical - as well as aesthetic - garment making considerations in using bark cloth.

Bark cloth has a stiff texture and to enhance the appearance, drape, and stability of the garment, there is a need to fuse it with the interfacing. Traditionally, interfacing (Nagano, 1985) contributes extra body, support, shape retention and increased wearability (Collier et al., 1989). Koenig and Kadolph (1989) evaluated a range of interfacing fabrics and reported that it affected the drape and contour of the garment shape. They added that the construction of the interfacing material affected the drape of the main fabric. When using interfacing fabrics, there are a number of factors to be considered. Collier et al., (1989) studied the effect of interfacing on shear and drape behavior of apparel fabrics. They reported for woven interfacings that three factors affect composite fabric stiffness: density, stiffness ratio of main fabric and interfacing, and the stiffening effect of adhesives. Fabric and garment drape have been widely studied for woven and knitted fabric structure. Süle (2012) reported that the bending rigidity of the woven fabric increased with thick weft yarns and weft yarn densities and when warp yarn tension is increased. In addition, drape coefficient of woven fabrics increased when the weft yarn density and weft yarn thickness were increased. These researches demonstrated that influence of interfacing in drape and rigidity of the fabric.

Methods

This research has investigated bark cloth for its practical suitability for fashion clothing, through a series of tests, as well as for its aesthetic potential through experiments with surface and technique. Therefore, these two lenses through which to examine bark cloth are presented in this section.

Due to bark cloth's natural origin, its structure is not uniform, its texture is coarse and fibre strands are irregular as it has thick and thin areas. It is generally stiff, creased, possesses low strength and is hydrophilic in nature. Hence, in order to determine its practical suitability for apparel end use, several parameters were assessed including fabric thickness [BS 5084], area density, bulk density, fabric drape [BS 5058], flexural rigidity [BS 9073-7: 1998], tearing strength [BS EN 13937-3:2000], bursting strength [BS EN ISO: 13938:2 1999] and surface morphology were studied using Carl Zeiss, Supra 40VP scanning electron microscope (SEM). EDX -Energy dispersive x-ray spectroscopic analysis was performed on Apollo 40SDD EDAX using an acceleration voltage of 20kV and a working distance of approximately 15mm. It is an analytical technique to determine chemical characterisation of materials. Samples were mounted onto aluminium pin stubs using adhesive carbon tabs. The stubs were then loaded into the SEM for imaging and analysis. The backscattered electron detector was used to obtain images of the samples under variable pressure conditions (30 Pa). Prior to fabric testing, all fabrics were conditioned in standard laboratory conditions 20±2°C and relative humidity 65% for 24 hrs. The fabric was fused with interfacing for 12 seconds, at 162°C and 500 kg pressure was applied to ensure the fabric is conducive to wear. To determine a suitable fusing interface, woven, knitted fusible interlinings were trialled. Bark cloth was also etched to produce surface designs that can be embedded, and several laser parameters were tested to identify an optimum laser engraving parameters. In addition, sublimation print design was carried out using Heatjet heat transfer machine, 44 Evo1 and design was printed on to heat transfer paper using Epson Sure colour F6200 ink jet printer. During the final stage, the fused bark cloth was assembled into a garment and its fit was evaluated on a mannequin.

Three different fusible interfacings were selected, a knitted fusible interfacing (A), a light weight woven interfacing (B); and a heavy weight woven fusible interfacing (C). Following fusing, the composite fabric was evaluated for its fabric weight, drape, strength and results are presented in Table 1. Fusible interfacing, A is a warp knit fabric with weft insertion, with a fabric count 13 x 14 (wales/cm x courses/cm); B is a woven fabric with fabric count 36 x 23 (ends/cm x picks/cm) and C woven fabric with fabric count 29 x 22 (ends/cm x picks/cm).

Table 1 Physical parameters of bark cloth

	Area density (g/m^2)	Thickness (mm)	Bulk density (g/cm^3)	Drape coefficient (%)	Flexural rigidity (µNm)		Tearing strength (N)		Bursting strength (kPa)
					Grain	Cross	Across cross	Across grain	
Bark cloth (BC)	143	0.672 (0.05)*	0.213	94.70	127	117	2.94	2.61	NA
BC + Fusible lining A	201	0.87 (0.03)*	0.231	96.2	612.3	112.6	NA		149.2 (10.19)* Distension 21.6 mm
BC + Fusible lining B	218	0.74 (0.05)*	0.294	95.54	345.8	624	1.63	2.45	NA
BC + Fusible lining C	234	0.88 (0.06)*	0.265	97.80	501	318	9.15	4.57	NA
Fusible interlining A	53	0.256 (0.01)*	0.207	NA	NA	NA	NA	NA	NA
Fusible interlining B	59	0.212 (0.01)*	0.278	NA	NA	NA	NA	NA	NA
Fusible interlining C	112	0.45 (0)*	0.248	NA	NA	NA	NA	NA	NA

*indicates standard deviation; NA – Not applicable

Figure 8 Bark cloth

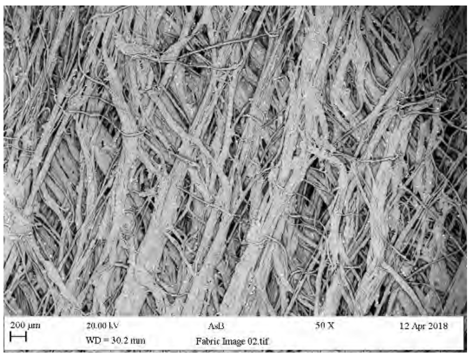


Figure 9 Fibre alignment in bark cloth 50x

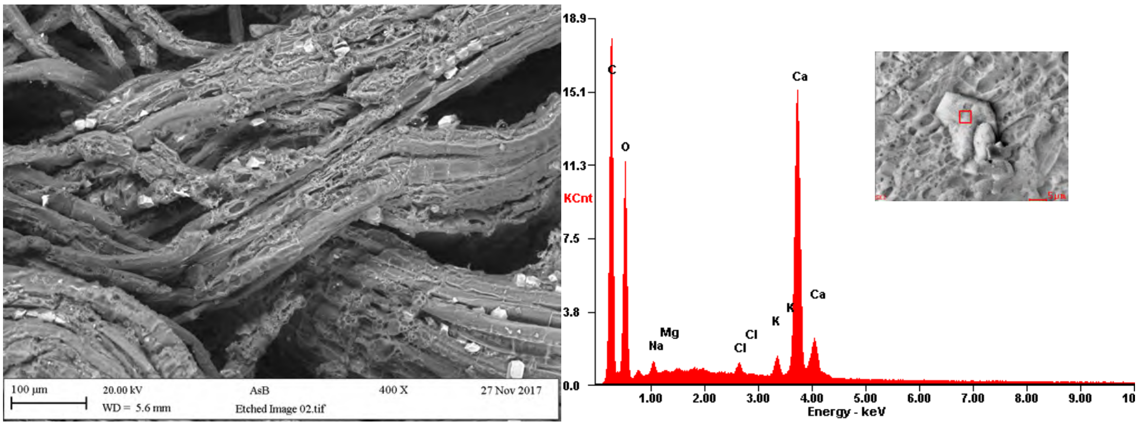


Figure 10 SEM bark cloth – calcium traces on bark cloth – Energy Dispersive spectroscopy (EDX)

Results and discussions

Bark cloth had a fabric weight of 143 g/m^2, thickness 0.67 mm (SD 0.05) and there were variations due to natural formation of the bark. Figures 8 and 9 illustrates a typical bark cloth with its characteristic terracotta colour and SEM image (x50 magnification) shows the alignment of fibre strands. A close-up examination of bark cloth revealed white particles (Figure 10) which was examined further using EDX analysis for identifying elements and it revealed that bark cloth had traces of calcium and sodium on its surface. SEM images (Figure 9) revealed that fabric has random or criss-cross alignment of fibre strands and it affects the surface thickness. Fabric drape evaluation revealed that cloth was firm and stiff (94.7%) and behaved like a paper. Fabric drape is a method of determining multi-directional curvature of a circular specimen and its ability to drape under its own weight (Taylor, 1993 and Saville, 1999). The bark cloth when fused with interlining, the drape coefficient increased marginally across all the fusible interlining, however fabric handle with knitted interlining (A) was good.

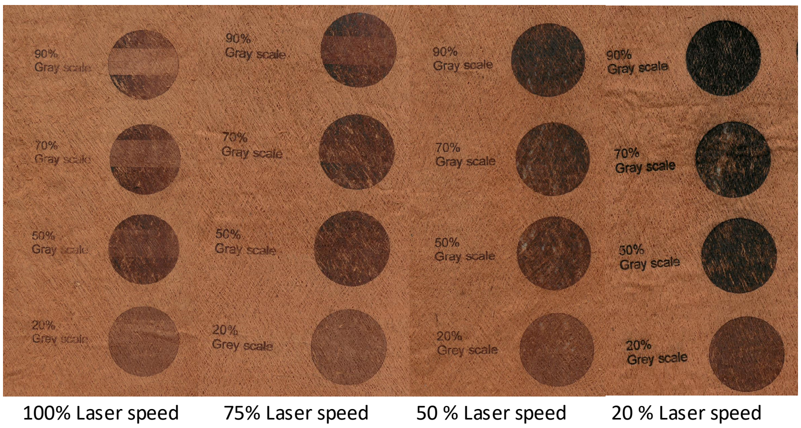


Figure 11 Bark cloth laser etching at 5% laser power and 500 pulses per inch (PPI)

Fabric stiffness was evaluated to understand the resistance to bending on its weight using Shirley stiffness tester. Stiffness is dependent on fabric density, closeness of fibre strands and thickness of the material. The stiffness of the bark cloth was determined in grain and cross direction and it affects how a material drapes over an object/body. Flexural rigidity of the bark cloth was calculated from bending length and mass in gram per square metre. The flexural rigidity of the bark cloth in the grain direction was marginally higher compared to cross direction and this was also noticed was when the bark cloth was fused with interlining A (knitted fusible) and C (woven fusible). However, in the case of light weight fusible lining (B), the flexural rigidity in the cross direction was higher than in the grain direction. This could be associated to the density of resin that creates an adhesive layer with the bark cloth. The flexural rigidity of the composite fabric fused with interlining A was lower in the cross direction compared to composite fabrics fused with interlining B and C. Hence, this interlining was selected for garment making. The tearing strength of the bark cloth on its own was negligible, however, when the cloth was fused with the interlining there were reasonable amount of strength. The bursting strength was evaluated for the composite bark cloth with knitted fusible lining and it offered reasonable resistance. Its strength was 149.2 kPa, 21.6 mm distension and it took 8.0 seconds to rupture. This could be comparable to a typical medium weight single jersey fabric.

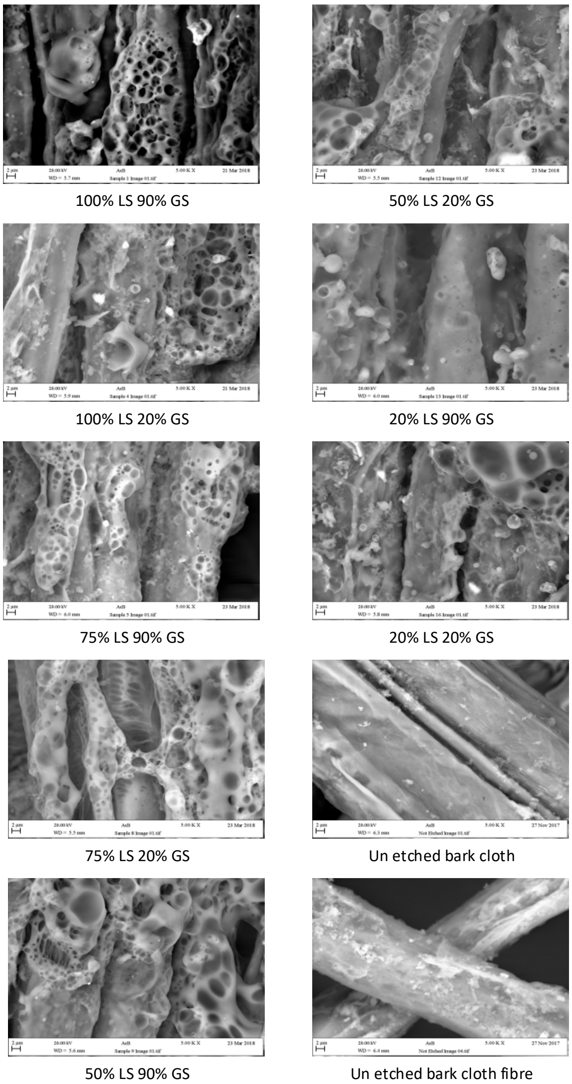
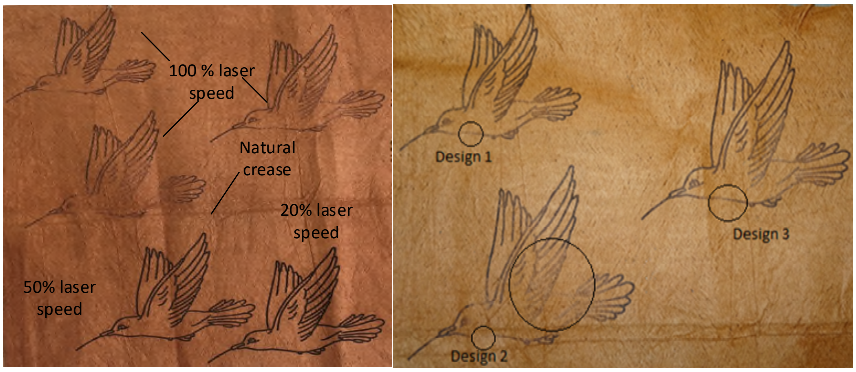


Figure 12 SEM bark cloth analysis x5000



Different laser speed

Design 1 – lack of fabric thickness; design 2 no etching; design 3 medium etching

Figure 13 Bark cloth laser engraving - different laser speed

Laser etching or patterning is a method of creating design on the surface of the bark cloth. Some of the parameters that were varied was laser speed [100%, 75%, 50 and 20%] and gray scale, GS [90%, 70%, 50%, and 20%] (Figures 11, 12). The other parameters including laser power was maintained at 5% and 500 laser pulses per inch. At 100% laser speed (5% Laser Power [LP] and 500 PPI) bark cloth produced less darkening, in other words, thermal degradation was lesser, and it produced lighter shade. At 75% laser speed (5% LP and 500 PPI) fabric produced darker shade in the design, where the thermal degradation was comparatively higher than the 100% laser speed. It can be noted that at 50% and 20% LP the cloth degradation was higher compared to 70% and 100% laser speed. All the fabrics were etched at the lighter side of the cloth after fusing the bark cloth with interfacing. This was because in the darker side of the fabric the thermal degradation was severe as the material was dry.

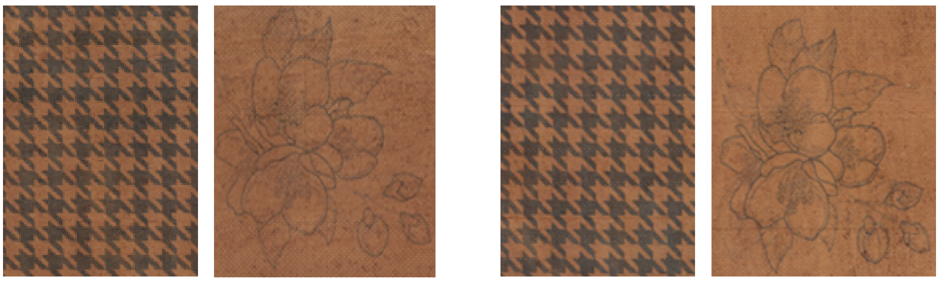
The SEM images (Figure 12) reveal that at 100% LP and 90% GS the amount of surface degradation due to laser etching was evident that the removed the surface fibres compared to 100% LS and 20% GS. A similar trend was noticed across 75%, and 50% laser speed. However, at 20% laser speed and 20% gray scale the surface damage was less. It should also be noted, that the laser engraving at 20% GS and 20% LS did not affect the entire thickness of the bark cloth. Figure 13 revealed that at 100% laser speed, the amount of laser etching surface was less compared to 50% and 20% laser speed. This was due to the fact the laser does not produce burning effect on the surface fibres, hence the pattern or design was less visible. In addition, since the bark cloth does not have a uniform surface thickness and texture, the laser etching on the bark cloth was less consistent. However, by fusing the bark cloth with interlining and reducing the laser speed, patterns had been produced (Figure 13). 50% and 20% laser speed produced more thermal degradation compared to 100% laser speed resulting in darker designs on bark cloth.

Point of measure	Dimension (cm)
Chest	36
Waist	45
Shoulder	36
Sleeve length	57
Body Length	62.5

Figure 14 Bark cloth on a mannequin

Garment specification and construction

A female jacket/top - size 12 was constructed to determine the clothing fit (Figure 14). Lockstitch was used for hem and twin needle seams were used to join front and back panel. The bark cloth was fused with a knitted fusible interlining to offer desired drape, fit and apply prints. The garment was fitted on to a size 12 female mannequin to determine the fit. The garment offered satisfactory shape and handle, and it was easy to don and doff the garment from the mannequin. Sublimation printing trials revealed that print designs were transferred instantly using heat transfer machine. Three different feed speeds were tested – feed speed 4.0, 6.0 and 8.0. There was no print dye penetration at the reverse side of the fabric for all the trials. However, there were minor differences in quality of print designs when fed at speed 4 and 6 as illustrated below (Figure 15). The sublimation prints were tested without fusing with the interlining.



Houndstooth design Floral design Houndstooth design Floral design

15 a Sublimation print feed speed - 4.0 (1.16 cm/sec) 15 b Sublimation print feed speed - 6.0 (1.66 cm/sec)

Figure 15 Sublimation printed bark cloth

Aesthetic experimentation

To better understand the aesthetic (as well as the practical) potential of bark cloth, an open-ended, process-led research approach was adopted by three designer-makers: Karen Spurgin, Michelle Lowe-Holder and Kirsten Scott. Through sampling and experimentation - using both traditional and non-traditional crafting techniques - the bark cloth was investigated to discover the potential to add value, refinement and to change the surface of the cloth, while maintaining the qualities required in garment making, such as flexibility, strength, durability and comfort. A series of samples were made to determine ways in which it might be treated to offer a more refined effect. Treatments included embroidery, print, appliqué, gilding, laser cutting and natural dyes. Table 2 outlines the results of this first round of sampling.

Table 2 Decorative surface treatments of bark cloth

Treatment	Techniques	Results	Recommendations
Embroidery	Gold work Black work Cut work Motifs Top stitching Blanket stitch	No obvious limitations to these techniques for bark cloth. All approaches tried so far have worked well. Can add structural support to the cloth. Time consuming.	Very adaptable to individual aesthetic demand. Some approaches/ stitches/motifs convey modernity better than others at this point in time. Lots of potential for further development.
Patching	5cm x 5cm Random	The technique can add value to the cloth and provides structural support. Time consuming.	While this technique strengthens the bark cloth, it also has potential in seamless shape making.
Print	Ink Jet Sublimation	Both techniques have worked well on small samples of bark cloth.	Larger scale tests are needed to better establish potential.
Appliqué	Using: Bark cloth Beads Reflective fabric	Successful initial experiments that ranged from quite traditional to more contemporary approaches. Time consuming.	Lots of potential to add aesthetic value to bark cloth with these techniques.
Gilding	Gold leaf	Effective treatment of the surface, adding strength and lustre. Obscures the natural aesthetic of bark cloth and gives a smoother finish.	Works well for certain projects. Potential for further exploration.
Fusing	With cork	Adds strength to the bark cloth and gives leather-like properties.	Limits the flexibility of bark cloth – best used for smaller items, accessories etc. Potential for further exploration.
Laser cutting	Cut out effect with cork	Strong contemporary finish. Cutting out a lot of material limits the strength of bark cloth, even when fused.	Best used for smaller items, accessories etc. and mounted on another fabric.

In addition, some natural dye tests were carried out to determine the effectiveness of indigo and logwood on bark cloth (Figure 15, 16). While bark cloth has potential as a sustainable fashion textile, its natural rust colour and rough surface carry connotations of rural handicraft and therefore limits its versatility. This natural colour may be lifted with bleach, but early tests suggested that this would eat away at the fibres leaving a much more delicate material.

Tests with dyeing small pieces of bark cloth with indigo proved successful in achieving a black shade, with double dipping and washing with cold water (Figure 15). However, large sheets of bark cloth immersed in an indigo dye vat had limited success: the high absorption rate of bark cloth made it quickly become saturated and heavy, leading to some tears in the cloth as it was lifted. The colour obtained was a dark blue rather than black. Further testing is needed to resolve this. Early tests with a logwood 'paint' achieved a good black shade.

Figure 15 Indigo dyed bark cloth

Figure 16 Logwood dye experiments

Tests have shown that bark cloth is quite versatile in creating different decorative, surface effects; it does not fray and absorbs dye well. The research to date suggests that bark cloth has a lot of potential as a sustainable luxury fibre, that may be sourced directly from the makers for small scale, fashion design initiatives.

Conclusions

This study had highlighted the need for bark cloth to be fused with interlining to facilitate good garment fit. A number of physical parameters were evaluated for bark cloth and with interlining including thickness, strength, stiffness, and fabric drape. The raw bark cloth had variations in thickness, texture and density. To counteract these structural variations, facilitate fabric handle, garment making and to incorporate print designs and laser etching, the bark cloth was fused with a suitable interlining.

Scanning electron microscopy revealed that laser etching occurred only on the surface of the bark cloth without affecting its structure. This was noted at 20% gray scale and 20% laser speed. EDX analysis illustrated the surface of the bark cloth had traces of sodium and calcium.

Fabric was etched with laser to incorporate surface designs and sublimation print was also carried out. Optimal laser parameters were identified – 500 PPI, 20% GS, 20% laser speed and 5% laser power that could allow surface designs following fusing with a medium weight knitted interlining.

Sublimation print revealed that print dyes did not penetrated the surface of the fabric; hence, by varying the fabric feed speed the print quality could be optimised.

Figure 14 revealed that garment made out of bark cloth fused with knitted fusible interlining offered good fit and shape. Bark cloth has the potential to be used as a sustainable fashion textile, but in its natural condition carries connotations of rural handicraft. In order to effectively propose bark cloth as for use in the sustainable fashion market, an initial exploration took place to determine the ways in which it might be treated to offer a more luxurious effect.

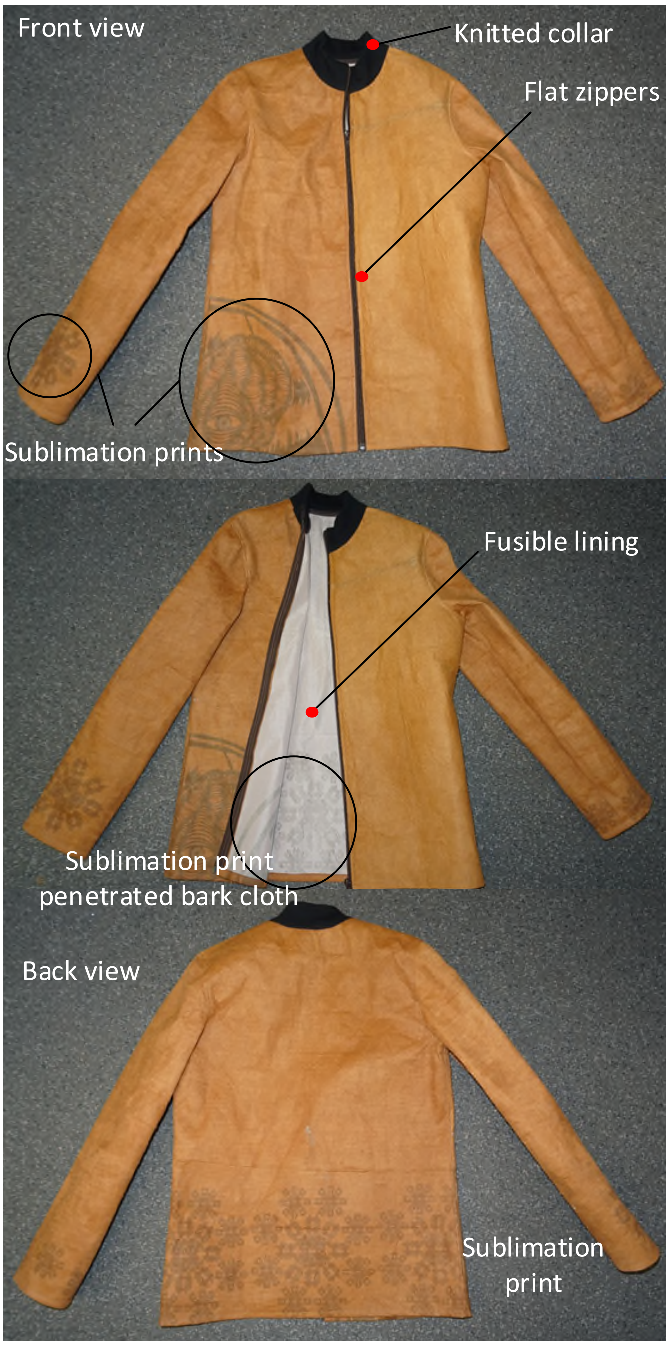


Figure 17 Bark cloth Garment

Previous research had looked at bark cloth suitability for its technical applications such as automotive panels for cars (Rwawiire et al, 2015), comfort next to the skin and thermo-physiological properties (Rawawiire and Tomkova, 2014), whereas this research indicated the potential of bark cloth to be worn as fashion garments when fused with an appropriate interfacing and surface treatment [laser engraving and sublimation printing]. The current research also addressed the natural variations of the bark cloth and to counteract the issue an interfacing was recommended, which reinforced the structure and facilitated garment making. This research adds new information to the literature: previous research did not attempt to focus on garment shaping and draping with bark cloth, following surface treatment.

This research will enable methods of producing apparel with bark cloth with desired garment properties and will indirectly create demand for bark cloth from Uganda and help to support the artisans involved in the production of sustainable bark cloth. The research can be applied to develop surface patterns using laser, sublimation print, embroidery and natural dyeing strategies, so that interesting designs and textures could be produced which influence designers and clothing professionals' choices when using bark cloth for the luxury market. The outcomes from this research will benefit the Ugandan community making bark cloth, local designers; Higher education [HE] in academic practice, UK and clothing designers-makers in producing luxury crafts and garments this sustainable material.

Further work

Based on the current investigation, it is proposed that the research will develop further garments to determine the effect of interfacing on garment performance including drape, user comfort, garment aesthetics, fit, and tactile sensation, using wearer trials.

Limitations

During this research, bark cloth was limited in quantity, hence only two garments were made, however, during the next stages, a suitable quantity of bark cloth will be sourced, tested, and its relevance to apparel applications will be examined.

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