VOLUME: 1 NUMBER: 1 MAY 2019 ISSN

ETHIOPIAN JOURNAL OF TEXTILE AND APPAREL

EiTEX

ETHIOPIAN INSTITUE OF TEXTILE AND FASHION TECHNOLOGY
BAHIR DAR UNIVERSITY, ETHIOPIA

Inaugural message from the Editor-in-chief

Bahir Dar University is one of the leading public Universities in Ethiopia engages in teaching, research and community service. Undertaking research and disseminating research findings is a principal activity as it is mentioned in the mission of the University. In line with the mission of the University, the Ethiopian Institute of Textile and Fashion Technology (EiTEX) also engages in teaching, research and community service activities in fields of Textile, Apparel and Leather.

Being a research and teaching organization, Journal publication is important for improving education and research quality of the Institute and as well as for its renowned. Having journal in the field of Textile and Apparel Technologies and Management, creates an additional opportunity to students and researchers of the Institute to access publication and disseminate their research finding, the Institute has established the Ethiopian Journal of Textile and Apparel (EJTA). I am delighted to introduce EJTA: Ethiopian Institute of Textile and Fashion Technology, Bahir Dar University EiTEX's new, the first Journal from the publisher in the area of Textile, Apparel and leather processing.

It is with profound pleasure, humility and anticipation that we celebrate the launch of Ethiopian Journal of Textile and Apparel (EJTA) with this inaugural issue. On behalf of the EJTA Editorial Team, I would like to extend a very warm welcome to the readership of EJTA. I take this opportunity to thank our authors, editors and anonymous reviewers, all of whom have volunteered to contribute to the success of the Journal.

EJTA is a blind peer reviewed open access journal. It is a biannual journal open to all interested contributors in the area of textile and apparel technologies and management. EJTA aims to be the leading international journal for Textile and Apparel. It will provide the primary forum for advancement and dissemination of scientific knowledge on the field. EJTA works for the advancement and dissemination of knowledge in Textile and Apparel sciences. It provides a platform for the research community to share their findings; insights and views in textile and apparel technology. The Journal serves as a forum of critical, constructive and problem-solving and knowledge creation means in Textile and Apparel and related fields.

EJTA publishes scholarly works focusing on textile fibers, spinning, weaving, knitting, technical textiles, textile wet processing, dyeing and printing, various forms of textile finishes, apparel and fashion technology, latest trends in the field of textile and apparel, greener technologies relating to textile and apparel production and management. Contributions for the Journal should include full-length original research articles, review articles, book reviews, short communications and letters.

To ensure rapid dissemination of information, we aim at completing the review process of each paper within 2 months of initial submission. EJTA will strive to attract and engage an international readership that is primarily academic. University libraries and individual academics are the primary target group for the journal. However, given the scarcity of rigorous and well marketed journals with similar focus, the Journal seeks to attract professional audiences as well. This is important given that the ultimate test for theoretical contributions is the application of the new knowledge in the practices of organizations and in the praxis of individuals.

Any papers that you wish to submit, either individually or co-operatively, are much appreciated and will make a substantial contribution to the development and success of the Journal. I close this message by inviting everyone to submit their exciting research to EJTA. All papers receiving a high degree of enthusiasm in the peer-review process will find a home in EJTA. Therefore, we are committed to publishing all discoveries, methods, resources, and reviews that significantly advance the field of Textile, Apparel and related fields.

Once again, I welcome you to this Journal – your Journal! With your support as authors, reviewers, and editors, I see very bright prospects for EJTA to serve science and the scientific community even better in the future. Ultimately, we will improve more lives and, consequently, our communities. Best wishes and thank you in advance for your contribution to the Ethiopian Journal of Textile and Apparel.

If you have any questions, suggestions, or concerns, please address them to tamrat_tsfy@yahoo.com

Dr. Tamrat Tesfaye (Asst. Prof.), Editor-in-Chief
Ethiopian Institute of Textile and Fashion Technology, Bahir Dar University
Email: tamrat_tsfy@yahoo.com/abushatsfy@gmail.com

Content

Surface Modification of Cotton Using Slaughterhouse Wastes

Granch Berehe[1*] Lodrick Makokha Wangatia[2]
[1]Textile and Leather Engineering Department, Wollo University, Ethiopia
[2]Institute of Technology for Textile, Garment and Fashion Design, Bahir Dar University, Ethiopia
([*]Author for correspondence: mygranch@gmail.com)

Abstract: Cotton dyeing using reactive dyes is one of the major water polluters, due to large amounts of dye and salt discharged in the water effluent. Recent adverse climate change and its associated effect to human life have led to search for more sustainable industrial production. Cationization of cotton to improve its affinity for reactive dye has been earmarked as a major solution for dyeing of cotton with no or less salt. Synthetic cationizing agents of ammonium salt have already been commercialized. However, in nature we have proteinous products which are rich in amino and ammonium salts which can be harnessed to be used as cationizing agent for cotton. This research paper reports the use of cattle hoofs and horns to cationize cotton so as to improve cotton affinity to the reactive dye. The cationization action of the hoof and horn extract on cotton was confirmed by dyeing the pretreated fabric without salt and comparing it with conventionally dyed sample. Using UV-VIS spectrophotometer better absorption (62.5% and 50% for dye bath exhaustion percentage for cationized and untreated respectively) were recorded for the cationized fabric, while K/S values of treated samples were similar to conventional sample.

Keywords: Slaughterhouse waste; cationization; cotton; reactive dyes; proteinous products

1. INTRODUCTION

Dyeing is one of the essential processes of materials for value addition. Among the industrial sector, Textile industry has been one of the largest dye intensive industries in the world. Cotton is the world's most widely used natural fiber being versatile in its application and easily available. For cotton dyeing, anionic dyes have been used very often and they are, by consumption, the most important textile dyes.

The coloration of cotton involving anionic dyes, require vast amounts of salt for efficient dye utilization and fastness requirements. As a result, large amount of salt is discharged in the dye bath effluent (Chattopadhyay et al., 2007; Montazer et al., 2007). Therefore, an alternative approach to cut on salt consumption and improve dye utilization is important. Processes that consume less dye and salt are more sustainable and less polluting. Many academic researchers and industry professionals have developed alternative methods for more sustainable coloration practices of cotton. However, many of these improvements have not been commercialized and may require large capital investments, and/or increased processing costs. Additionally, none of these innovations provide a fully sustainable method for the coloration of cotton goods. Cationized cotton had presented itself as one of the most viable and sustainable alternatives to conventional reactive dye applications to cotton. However, cationization using synthetic agents is not also sustainable alternate as the chemicals are non- biodegradable, toxic and expensive (Chattopadhyay et al., 2007; Montazer et al., 2007; Knudsen et al., 1996). Higher electrolyte concentration in the effluent causes worst effect such as; impairing the delicate biochemistry of aquatic organism, destructive attack on pipes if sodium sulphate is used as electrolyte due to the formation of alumino-sulphate complexes which swell and crack concretes with considerable alumina content. This may lead to emission of hydrogen sulphide gas under anaerobic conditions, dissolution of such sulfides and subsequent bacterial oxidation, which may form the corrosive sulphuric acid. The aforementioned process will lead to higher Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Absorbable Oxygen Halides (AOX) (Sabramarian, 2006). Finally, if the effluent must be treated, i.e. desalinated, the additional cost of the process renders desalination unattractive just from an economical point of view.

Even with all the environmental drawbacks of utilizing fiber anionic dyes on cellulose, their use is unparalleled for cotton dyeing (Saleh et al., 2013; Ali et al., 2009). To present a viable sustainable alternative to anionic dyes requires that similar colors and similar fastness properties be maintained while improving the ecological aspects of cellulosic coloration.

At an academic level, several improvements and technological advancements have been made and suggested, however, the practicality of many of these improvements is questionable.

In coming years, the textile industry must implement sustainable technologies and develop environmentally safer and efficient methods for textiles processing to remain competitive. Thus, seeking environmentally safer options to cut or reduce salt and improve dye utilization is important. The options to reduce salt are; process improvements, recycling the salt contaminated dye bath after dyeing, molecular engineering of anionic dye to have higher affinity and good wash off properties and, molecular modification of fiber to have greater affinity and attraction towards anionic dyes (Sabramarian, 2006; Wang et al., 2014; Ristic et al., 2012; Biswas et al., 2010)

For decades, very little research was undertaken on the effects of the bath ratio of batch textile dyeing equipment because water, dye, and chemical use were of little concern. The liquor ratio, the mass or volume of water compared to the mass or volume of the fabric is now recognized as a very important and critical variable for processing of reactive dyed cellulose. Traditionally, liquor ratios ranged upward of 1:20 to 1:40 because color yield and salt utilization were not important. Typically, the amount of salt and alkali required for batch reactive dyeing are based on a concentration, therefore in order to maintain that concentration at higher liquor ratios requires much more salt and alkali than the same process run at a lower liquor ratio.

One approach of working towards sustainable anionic dyeing practices of cotton, many researchers have recognized that the greatest efficiency and utilization of dyestuffs can be obtained by modifying cotton itself at a molecular level to contain a cationized charge and to utilize existing anionic dyestuffs. Several surface modification techniques can be used to alter the surface charge on a substrate. In spite of the great number of existing modification methods no consistent classification is available as yet. Some authors divide the methods into two groups depending on whether they involve changes in fiber composition (chemical modification) or changes in fiber structure (physical modification) (Matthew et al., 2012; Shahid, et al., 2013). Chemical modification techniques can include surface patterning, photo-bleaching, plasma treatments and cationization, with the first three methods needing higher initial investment (Hyde et al., 2007).

The process of modifying cotton by developing cation site on its surface without affecting its bulk property is called cationization. Modifying the cotton fibre to increase dye-fibre interactions is thus one of the routes to overcoming the lack of affinity for cotton for commercial reactive dyes, so that it can be dyed without salt. It was found that during cationization of cotton, etherification of primary hydroxyl groups on cellulose takes place (Ristic, et al., 2012, Chaiyapat, et al., 2002).

A number of processes have been proposed from early 1930s, till date to improve the substantivity of anionic dyes towards cellulosic fibers by introducing cationic sites on the fibres. Schlack was the first to report improved affinity of acid dyes towards cellulose modified through the introduction of aminated epoxy groups and then Rupin and Rupin studied the dyeability of cellulose towards direct and reactive dyes after pretreatment with glycidyltrimethyl ammonium chloride (Chattopadhyay et al., 2007). It was reported that the Glytac pretreatment improved the dyeability of cotton with reactive dyes in the presence of alkali and salt. Wu and Chen (Hauser et al., 2001) treated cotton with polyepichlorohydrin (PECH) dimethylamine which was manufactured by initial polymerization of epichlorohydrin, followed by amination with dimethylamine. The epichlorohydrin was polymerized in carbon tetrachloride using boron trifluridee therate as catalyst. The dyeability of treated cotton towards direct dyes was investigated and it was found that PECH-amine could improve the direct dyeability of modified cotton. In another work Wu and Chen (Hauser et al., 2001) reported the effect of PECH-amine treatment on the reactive dyeability of cotton. It was found that the modified cotton can be dyed with selected low reactivity dyes under neutral condition using limited salt concentrations or with selected high reactivity dyes without salt. The effect of modification of cotton using various N-ethylolacrylamide derivatives has also been investigated by El-kharadly et al (Chattopadhyay et al., 2007).

Currently, there is a growing interest in the development of biodegradable cationizing agent in keeping with the ever-growing environmental awareness. In terms of environmentally friendly, cost, and ease of application, using bio product cationizing agent, is without a doubt one of the methods for cationization of cellulose, which may provide a viable salt-free cotton dyeing method. Thus, this study has focused on cationization of cotton using cattle hoof and horn keratin hydrolysate. Cattle hoof and horn have 93.3% crude protein, Keratin, which is a poly peptide. Although it has been known for many years that these keratins differ markedly in amino acid composition, it has been shown only recently that this variability in composition is due to variations in their content of three constituent protein groups which have vastly different compositions. The keratins appear to be built to the same plan with filaments (microfibrils), often aligned, of about 7•0 nm diameter embedded in a non-filamentous matrix (Mokrejš et al., 2011). The filaments appear to be composed of proteins (low sulphur) which are lower in sulphur content than the parent keratin, whilst the matrix contains two groups of proteins-one group is rich in cystine (high-sulphur proteins) and the other is rich in glycine and tyrosine (high-tyrosine proteins) (Karthikeyan et al., 2007).

Ethiopia is believed to have the largest livestock population in Africa. The estimates of the total cattle population are 53.99 million (Fig. 1). Livestock is a significant contributor to economic and social development in Ethiopia at the household and national level. The cattle horns and hoofs are simply disposed to the nearby environment without any treatment. Keratins are difficult to degrade by the common proteolytic enzymes and their disposal leads to environmental problems (Omole & Ogbiye, 2013). Moreover, hoof and horns are hard keratin material which have very slow decomposition rate.

If the waste could be used as a valuable resource, it could not only turn waste to treasure, but also reduce environmental pollution. This has been reported in many studies in relation to the application of other waste. However, no one has conducted a study on the use of hoof and horn keratin as a dyeing auxiliary. From theoretical considerations cattle hoof and horn keratin will have good reactive properties due to the presence of a large number of reactive amino hydrophilic polar groups (nucleophilic groups) within its molecular structures. If it is possible to synthesize a kind of protein derivative agent, the agent can be applied to cotton, and hence enable salt-free dyeing of cotton using reactive dyes. Such an attempt will lead to use of locally available bio products (animal hoof and horn) as source of keratin hydrolysate to cationize cotton for salt free dyeing. If the experiment is successful there will be dual advantages, one the environment will be protected from accumulation of the slaughterhouse wastes and secondly the dyeing process will be able to reduce electrolytes in the dyeing water effluents. The two advantages will be a welcomed by the advocates of greener production. The aim of this paper is to study the use of cattle hoof and horn as a sustainable material, which can be used in the cationization of cotton during the dyeing of cotton using reactive dyes.

Figure 1 Cattle in Ethiopia

2. MATERIAL AND METHODS

2.1. Materials and Chemicals

The fabric used for this study was a fully bleached cotton fabric, whose warp and weft count were 21 and 58 ends per inch and 50 picks per inch. Cattle hoof and horn was collected from Bahir Dar slaughterhouse. Chemicals used for extraction, cationization and dyeing included; NaOH, $NaCO_3$, H_2SO_4, NaCl, $NaSO_4$, Acetic acid and red DCT reactive dye.

2.2. Equipments/Apparatus

For extraction, cationization as well as dyeing all dyeing accessories; pH indicator, thermometer, beakers, measuring cylinders and pipettes were used, together with;

i. PerkinElmer UV/VIS Spectrometer Lambda 25 for measuring colour absorption
ii. Gretag Macbeth COLOR-EYE 3100 for measuring reflectance, K/S and CIE L*a*b*
iii. FT-IR Spectroscopy PerkinElmer

2.3. Pre-treatment of Cattle Hoofs and Horns

The collected hoofs and horns were washed to remove impurities and dirt on the surface of hoof and horn using synthetic detergents, and then dried before crushing by manual hammering to convert to small pieces.

Hoof and horn keratin itself may not be reactive with cellulose. Therefore, the keratin in the hoof and horn must be dissolved and converted into the reactive keratin hydrolysate. Keratin protein was hydrolyzed by hydrothermal process; using NaOH at various temperatures. Extraction parameters were then optimized. Keratin hydrolysate was applied in the same processing techniques used for conventional dyeing and finishing of textiles. Pad-dry-cure was the technique that was employed to cationize cotton. The dyeing of cationized and untreated cotton was undertaken using exhaust method, and the samples evaluated using FTIR of cationized fabric. The reflectance, colour strength and K/S of dyed samples were measured using Color eye 1500. The colour absorption was measured using UV/VIS spectrometer.

3. RESULTS AND DISCUSSIONS

Extraction of keratin hydrolysate Extraction was done at different temperatures for different time interval in different pH values and optimum extraction was found at room temperature for 3 days and 100 ^{0}C for 3-hour treatment with extraction efficiency 94% and 93% respectively using 20 g/l NaOH at 12 pH.

3.1. Cationization

The sample was impregnated in 40 g/l keratin hydrolysate and was subjected to drying and curing at 100 and 135 degree centigrade for 4 and 3 minutes respectively. The peaks in FT-IR curve (Fig. 2) showed that there was a change in chemical composition after being cationized, thus the keratin hydrolysate was fixed to the fabric.

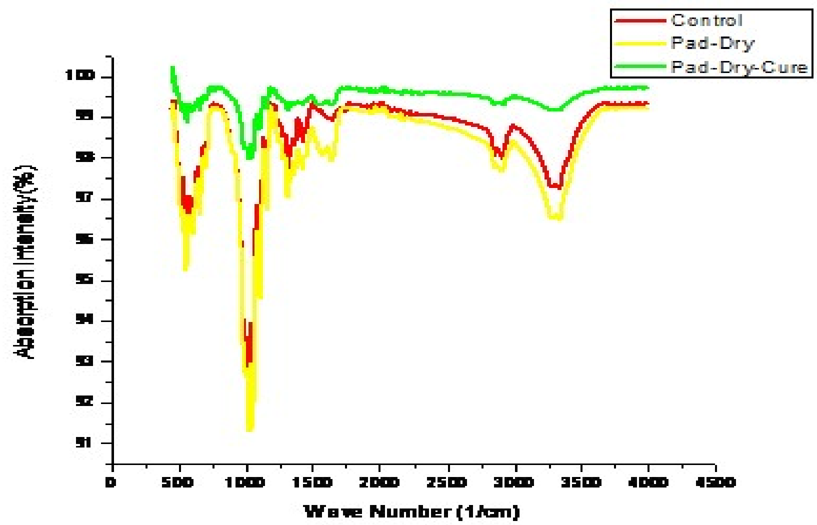

Figure 2 FT-IR Curve of Cationized and Control (Untreated)

3.2. Dyeing with DichloroTrazline (DCT) Red Reactive Dye

Dyeing was carried out as per the conventional dyeing procedures at room temperature for one hour. Washing and soaping was done for the samples. The visual observation confirmed that colour yield was higher in the cationized sample as in Fig. 3. The K/S values measured using colour eye computer colour matching equipment also confirmed the colour yield was better in the cationized fabric as given in Fig. 4. Table 1 showed that there was no significant difference in the 'L*' (lightness) and the trichromacity coordinates of the treated and untreated samples.

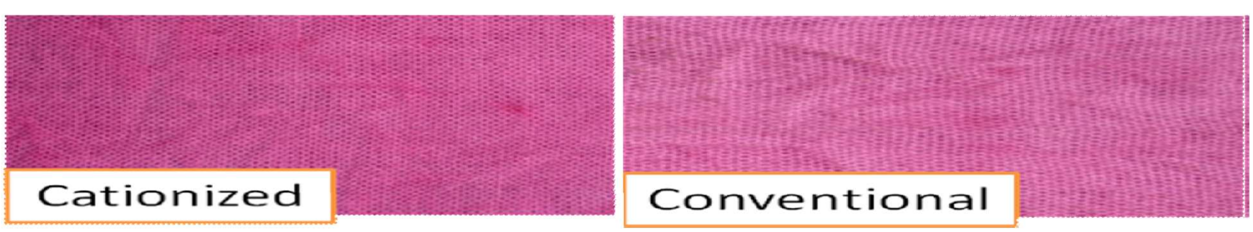

Figure 3 Dyed samples of Cationized and Conventional (using salt)

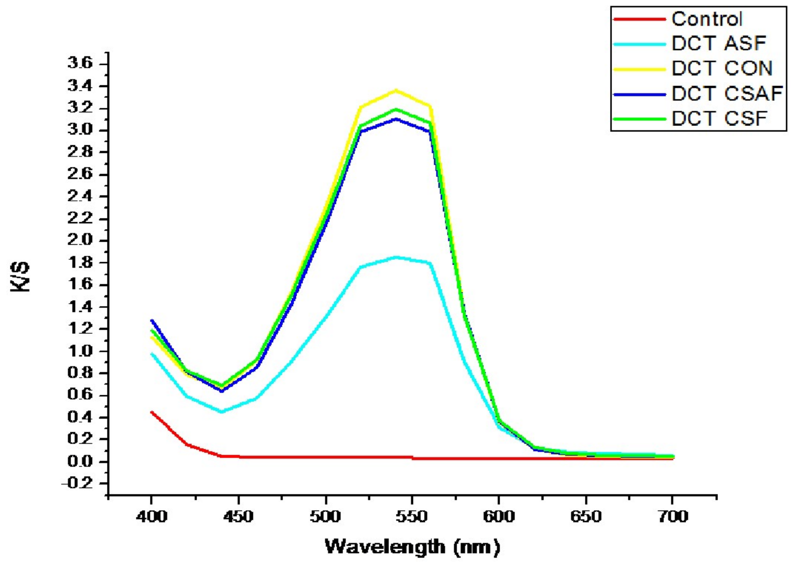

Figure 4 K/S values of Cationized and Control (Untreated) after dyeing

The cationized sample showed lower ‘a*’ value meaning redder and higher ‘b*’ value meaning bluer. The yellowness index was lower in the cationized fabric. The whiteness index was lower also which confirmed more dyes are retained in the cationized fabric.

3.3. UV/VIS Spectroscopy Result

The result showed that dye absorption is better in cationized cotton than the conventional method of reactive dyeing as indicated in Fig. 5. The dye bath exhaustion percentage was calculated using equation (1) and obtained 62.5% and 50% for cationized and untreated samples respectively.

$$\%E = (A_0 - A_1) * 100 / A_0 \quad (1)$$

Where A_0 and A_1 are the absorbencies at maximum wavelength of dye originally in the dye bath and of residual dye after dyeing respectively.

Table 1 Color Eye Computer Colour Matching Details for D Standard 10°

Colour Factors	Control Bleached fabric	DCT Conventional	DCT Cationized
L*	89.51	55.39	55.34 a*
-1.09	46.07	43.92 b*	3.78
-8.18	-7.74		
X	70.96	33.65	32.98
Y	75.24	23.31	23.26
Z	76	30.41	30.05
x	0.3194	0.3851	0.3822
y	0.3386	0.2668	0.2695
Yellowness	7.05	38.89	36.97
Whiteness	57.15	74.68	72.29

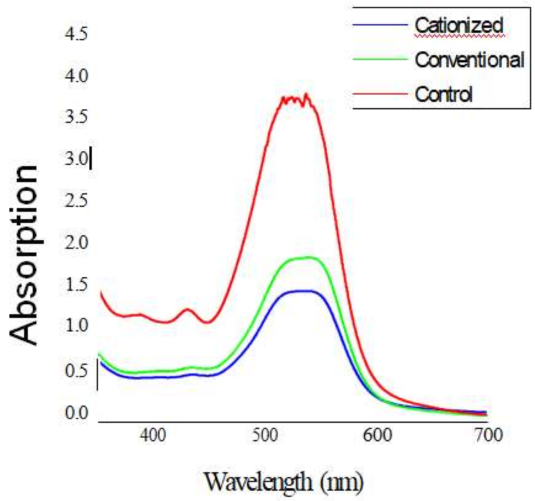

Figure 5 UV/VIS values

4. CONCLUSION

Cationization caused the change of ionic character of the cotton fabric, with 62.5% and 50% dye bath exhaustion percentage was obtained for cationized and untreated respectively. Based on all achieved results, it is evident that alkaline extract of keratin from slaughterhouse wastes imparts cationic character to cotton. Therefore, from the environmental point of view it is a good substitution of cationizing agent. That is providing not only a strategy for reducing risks and pollutants from salt and unutilized dye, but also an opportunity for new markets and new businesses that could be developed in the selling of cattle horn and hoof, which are currently considered as waste in Ethiopia.

Reference

Ali, S., Saleem, S., Umbreen, S., & Hussain, T. (2009). Cationizing efficiency and performance of antimicrobial agent on cotton fabric dyed with vinyl sulfone based reactive blue dye.

Biswas, S., Huang, X., Badger, W. R., & Nantz, M. H. (2010). Nucleophilic cationization reagents. Tetrahedron letters, 51(13), 1727-1729.

Chaiyapat, P., Nantaya, Y., & Edgor, A. (2002). Surface modification to improve dyeing of cotton fabric with cationic dye. Color Tech, 118(2), 64-68.

Chattopadhyay, D. P., Chavan, R. B., & Sharma, J. K. (2007). Salt-free reactive dyeing of cotton. International Journal of Clothing Science and Technology, 19(2), 99-108.

Cook, L. (1994). Increase of cotton's apparel market share has caused salinity in textile effluent streams to become a major issue. Textile World, 66(9), 1530-1534.

Hauser, P. J., & Tabba, A. H. (2001). Improving the environmental and economic aspects of cotton dyeing using a cationised cotton. Coloration Technology, 117(5), 282-288.

Hyde, K., Dong, H., & Hinestroza, J. P. (2007). Effect of surface cationization on the conformal deposition of polyelectrolytes over cotton fibers. Cellulose, 14(6), 615-623.

Karthikeyan, R., Balaji, S., & Sehgal, P. K. (2007). Industrial applications of keratins–A review.

Knudsen, H. H., & Wenzel, H. (1996). Environmentally friendly method in reactive dyeing of cotton. Water Science and Technology, 33(6), 17-27.

Matthew, J. F. (2012). Sustainable cotton dyeing. Fiber and Polymer Science, 1(1-234).

Mokrejš, P., Krejcí, O., & Svoboda, P. (2011). Producing keratin hydrolysates from sheep wool. Oriental Journal of Chemistry.

Montazer, M., Malek, R. M. A., & Rahimi, A. (2007). Salt free reactive dyeing of cationized cotton. Fibers and polymers, 8(6), 608-612.

Omole, D. O., & Ogbiye, S. A. (2013). An evaluation of slaughterhouse wastes in south-west Nigeria. American Journal of Environmental Protection, 2(3), 85-89

Ristic, N., & Ristic, I. (2012). Cationic modification of cotton fabrics and reactive dyeing characteristics. Journal of Engineered fibers and fabrics, 7(4), 155892501200700408.

Sabramarian, M. (2006). Influence of cationization of cotton on reactive dyeing. Journal of Textile and Apparel Technology and Management, 5, 1–16.

Saleh, M. S., & El-Badry, H. (2013). Dyeing of cationized cotton fabrics with natural dye extracted from acacia. International Journal of Textile Science, 2(2), 21-25.

Shahidi, S., Wiener, J., & Ghoranneviss, M. (2013). Surface modification methods for improving the dyeability of textile fabrics. In Eco-Friendly Textile Dyeing and Finishing. IntechOpen.

Wang, X. Y., & Liu, Y. (2014). The dyeing dynamics and structure of modified cotton fabric with cationic chicken feather keratin agent. Textile Research Journal, 84(6), 561-571.

A study of Terry woven fabrics' dimensional stability and areal density during wet processing

Lloyd N. Ndlovu*, Sizo Ncube, Pethile Sibanda, and L. Nkiwane
Department of Textile Technology, National University of Science and Technology, Bulawayo, Zimbabwe.
(*Author for correspondence: tonnylloyd@gmail.com)

Abstract: Experimental work on three fabrics, made from 100% cotton, with different pile ratios and yarn densities was conducted during wet processing. Areal density, dimensional stability, yarn crimp and yarn densities were investigated at three different stages of wet processing namely greige state, bleached state and dyed state. Results showed an increase in dimensional contractions as pile ratio was increased. Fabric dimensions were measured after each processing stage, and the widthwise contractions were between 2.4% and 7.9% for all the fabrics whereas the lengthwise contractions were between 9.7% and 14.6%. Areal density was determined using two methods thus by manual measurement and also by calculation. The measure and calculated result both showed that the areal density for each fabric increased during all stages of wet processing. Generally, warp crimp was higher than weft crimp for all the three fabrics, at all three stages of fabric ion. Weft crimp was between 2% and 7% whereas warp crimp was between 6% and 14%. The measured and calculated results were compared and analyzed using regression analysis methods, and it was found that there was a correlation between the measured and the calculated results. It was concluded that wet processes have a significant effect on dimensional stability and areal density. Also, it was concluded that the effect of wet processing is dependent on the fabric construction parameters which include the pile ratio and yarn density.

Keywords: terry woven fabrics, areal density, dimensional stability, wet processing

1. INTRODUCTION

Terry fabrics are used in various fields such as bath towels because of their water absorption properties. Terry fabrics are pole fabrics that can be woven or knitted. Terry fabrics should conform to specific areal density (weight per square meter) so as to fulfil their design purpose (Frontczak-Wasiak et al., 2002; Karahan & Eren, 2006). Fabric areal density is dependent on physical properties and is affected by wet processing. Dimensional stability of the fabric is a measure of the extent to which a fabric keeps its original dimensions subsequent to its manufacture. It is possible for the dimensions of the fabric to increase but any change is more likely to a decrease or shrinkage. Wet processing causes lengthwise and width contractions, hence a change in areal density and fabric sett (Zervent & KoC, 2006). The width and lengthwise and widthwise contractions differ due to different tensions and yarn crimps suffered in both warp and weft yarns. Some terry fabric manufactures, such as Merlin Zimbabwe Limited, make assumptions that 100% cotton fabrics have 5%-dimensional shrinkage despite differences in the fabrics structure and pile ratio. Since shrinkage affects areal density. It is therefore important to determine the exact shrinkage values. Much of the planning that is carried out in the industry is based on calculations hence there is a need to have a calculation system that is reliable and accurate. Areal density changes strongly depend on pile ratio, warp and weft densities (Zervent, & Koc, 2006; Hsieh, et al., 1996). It is also important to establish between tarn densities and pile ratio so as to attain an optimum in areal density values. The relationship can be established through close monitoring of the changes in the fabric properties during wet processing. Ignorance of the actual fabric changes lead to assumptions that will result in wrong cost, wrong yarn requirement calculations and wrong fabric areal density which will result in inaccurate costing of fabrics, wrong yarn requirement calculations and wrong fabric areal density. The wrong yarn requirements calculations can cause interruptions in fabric manufacture because of shortages of required yarn or overstocking due to an excess amount of yarn in the storeroom because of inaccurate calculations.

Wet processing in a typical cotton fabric manufacturing facility, will involve processes such as desizing, scouring, dyeing, bleaching and applications finishes such as softeners. During wet processing of fabrics, fabrics are agitated to achieve penetration of the fabric by the solution be it dyeing, bleaching or any other wet process. This agitating results in mechanical forces being applied to the fabric, and combined with other chemical actions from substances such as alkali and acid, may affect the fabric shrinkage and stability of the fabric. Mechanical forces on the yarns lead to stressing of the yarn hence there will be shrinkages in the fabric structures. During processes such as scouring, the structure of the cotton fibers is affected since the opens up pore by removing material from the surface of the fibers resulting in improved wetting. This improved wetting according to Thompson et al . leads to the shrinkage of the fabric.

The fabrics were processed in rope form in Winch dyeing machines. Fabrics were subjected to wet

Moisture diffuses into polar polymers such as cotton, nylon and wool. Water and water vapor are highly polar materials hence they are absorbed in natural fibers like cotton. When water is absorbed into a fiber a number of phenomena occur. New, strong secondary bonds may result and facilitate the liberation of heat. Water is absorbed and diffuses to the center of the fiber. When water is absorbed into the fiber, physical properties of the fibers change. The absorption of water into the fiber causes swelling of the fiber polymer. The swelling continues and stops when the fiber is saturated completely with the equilibrium amount of water. Moisture absorption is known to be proportional to moisture uptake. An increase in the amount of moisture taken up will result in an increase in the dimensions of any fabrics. Properties such as stiffness, size, and permeability will be affected by the uptake of moisture.

In relation to hydrophilic terry fabrics, especially those made from cotton, the pile ratio decreases the sinking in time, which is interpreted as the increasing the hydrophilic degree. This increased hydrophilic degree is due to the increased surface area that is exposed to water. The loop structure of the terry fabrics means that there are areas of the yarn that are easy to reach for the water drops. The presence of the looping structure also means that the base structure is has bigger pores where the foot of the loop meshes with the yarn from the base yarn.

2. MATERIAL AND METHODS

2.1. Materials

Fabrics were made using the three-pick pile formation principle. Yarns for the manufacture of the towels were 100% cotton yarns. Pile yarns had a linear density of 42 Tex, weft yarns were also 42Tex while the warp yarns were 50Tex. All the yarns were manufactured using the Open-End spinning Machine.

2.2. Weaving

The terry fabrics were woven on a 250cm wide Sulzer Ruti G6100 terry weaving machine utilizing the Dobby selection system. Humidity in the weaving room was kept at 65% while the temperature was kept at 24°C.

2.3. Wet processing

The fabrics were processed in rope form in Winch dyeing machines. Fabrics were subjected to wet processes namely scouring, bleaching and dyeing. During scouring all the terry fabrics were treated with caustic soda (alkaline) at 90°C for about 45 minutes. The fabrics to be dyed (fabric Band fabric A) were taken for pre-bleaching to remove the natural dyes and impurities. Pre-bleaching was carried out 90°C for an hour after which the fabrics were bleached dyed at 80°C for an hour.

2.4. Testing

2.4.1. Areal density

Samples of 100cm^2 were prepared for each of the types of fabrics under laboratory conditions. The areal density of each was measured using an electronic scale. The samples for different terry fabrics were taken from greige state, pre-bleached and dyed states for fabric A and fabric B while fabric C samples were taken from greige and fully bleached states.

2.4.2. Warp density

A pick glass was used to measure the number of picks per centimeter and number of ends per centimeter. The instrument has a 9cm2 observation area and a magnifying glass that enables the counting of picks and ends.

2.4.3. Pile length

The ratio in a terry fabric affects the weight per square meter (areal density) and the weft ground warp ratios. For such a sample the pile warp yarn was measured, thus the pile length was measured using a ruler.

2.4.4. Dimensional stability

From the woven terry fabrics units were measured both lengthwise and widthwise in the greige state. The fabrics were taken for wet processing in the dye house. The dimensions for the fabric B and fabric A were then measured in pre-bleached and dyed states while the dimensions for the fabric C were measured in the fully bleached state. The lengthwise and the widthwise dimensional changes were then calculated.

2.4.5. Crimp

Warp and weft yarns were drawn out in from the greige, bleached and dyed terry fabric samples. The crimp was found by measuring the length of the drawn yarn at its relaxed state and straightened states. Respectively. The difference between the two lengths was divided by 100 to get the crimp percentage. Crimp was calculated using equation 1

$$\text{crimp} = \frac{\text{l} - \text{S}}{\text{S}} \times 100 \qquad (1)$$

Where

S is the relaxed state and

l is the straightened length

2.4.6. Areal density of terry fabrics

There are three yarn systems in terry fabrics in a terry fabric namely weft, ground and pile yarn. The terry fabric areal density (W), was formulated by taking into account of the weight of each of the yarn systems, and by using equations 2, 3 and 4, leading to the derivation of equation 5.

$$W_1 = \frac{n_1 \times 100\left(1 + \frac{C_1}{100}\right) \times Tex_1}{1000} \qquad (2)$$

Where

W_1 is the weight, in grams, of weft yarn in a square meter of terry fabric

n_1 is the weft density in picks per centimeter

C_1 is the weft yarn crimp in percentage

Tex_1 is the weft yarn count in Tex

$$W_2 = \frac{n_2 \times 100\left(1 + \frac{C_2}{100}\right) \times Tex_2}{1000} \qquad (3)$$

Where

W_2 is the weight, in grams, of warp yarn in a square meter of terry fabric

n_2 is the warp density in ends per centimeter

C_2 is the warp yarn crimp in percentage

Tex_2 is the warp yarn count in Tex

$$W_3 = \frac{(n_3/3)100 \times n_2 100 \times h \times Tex_3}{1000 \times 1000} \qquad (4)$$

Where

W_3 is the weight, in grams, of pile warp yarn in a square meter of terry fabric

h is the pile length in mm

Tex_3 is the weft yarn count in Tex

$$W = W_1 + W_2 + W_3 \quad (5)$$

Where

W_1 is the weight in grams per square meter of the weft yarn

W_2 is the weight in grams per square meter of the warp yarn

W_3 is the weight in grams per square meter of the pile yarn

2.5. Regression analysis

Regression analysis was used to compare the measured values against the measured values.

3. RESULTS AND DISCUSSIONS

3.1. Fabric dimensions

The results in Table 1show that the widthwise and lengthwise contractions vary between 2.4% and 6% depending on the fabrics. Fabric A and fabric B fabrics, generally, had higher lengthwise contractions than widthwise contractions while fabric C had fabric C had lower lengthwise contractions than widthwise contractions. Fabric A being the fabric with the lowest pile ratio had the lowest width and lengthwise contraction of 4.8% and 13.0% respectively.

Fabric B which had a higher pile ratio than fabric A had its width and lengthwise contractions being 7.9% and 14.6% respectively. These two fabrics underwent the same wet processing stages and had different stages, and had different physical changes. From the results obtained (Table 1), it is clear that as pile ratio increased so did the dimensional contractions. Fabrics with higher pile ratio, in this case Fabric B, absorb more water and have higher dimensional contractions due to fiber swelling and yarn shrinkages. From Table 2 it is clear that fabric A and fabric B have almost the same yarn crimp but Table 1shows that they have different dimensional changes.

Table 1 Fabric contractions during and after wet processing

Fabric	Pile length (mm)	Contractions during and after wet processing (%)			
		Bleached state		Dyed state	
		Width	Length	Width	Length
A	8.0	2.4	9.7	4.8	13.0
B	8.5	2.8	11.7	7.9	14.6
C	9.0	5.8	4.2	-	-

This shows that the pile ratio has a significant effect on dimensional changes. From all the fabrics the shrinkages in width and lengthwise directions increase at each stage of wet processing. For example, fabric A had its widthwise shrinkages increasing from 2.4% to 4.8% and lengthwise shrinkages increasing from 9.7% to 13%. In the case of fabric C the widthwise shrinkages re 5.8% and 4.2% respectively. The shrinkages of fabric Care less than those of fabric A and fabric B because fabric C did not go through the dyeing stage. When terry fabrics get wet the internal stress in the yarn is removed and the volume of cotton yarns increases because of the swelling of cotton fibers. As a result the yarns have to follow a longer path around each other and this causes contractions in the lengthwise and widthwise directions when there is sufficient space between the yarns, the changes in the yarn volume are fully reflected to the width and lengthwise contractions. As the fabric becomes denser the space between the yarns decreases and after some contractions the yarns rest on each other and prevent further contraction.

3.2. Yarn crimp and yarn density

From Table 2 warp crimp is between 6% and 12% whereas weft crimp is between 2% and 8%. Generally, warp crimp is higher than the weft crimp. This is because of different tensions applied to warp and weft during weaving. All the fabrics have the same pattern of increases in the crimps during stages in wet processing.

From the obtained results in Table 2, it shows that fabric C has the highest warp crimp changes, meaning that it has the highest width contractions as witnessed from Table 2. The results also show that the yarn crimp changes increase with the pile ration. Weft crimp and warp crimp increase during wet processing due to swelling and water uptake.

Table 2 Fabric yarn crimp during and after wet processing

State	Yarn crimp (%)					
	Fabric A		Fabric B		Fabric C	
	Warp	Weft	Warp	Weft	Warp	Weft
Greige	10	2	8	2	6	2
Bleached	11	5	9	6	10	4
Dyed	12	8	11	8	-	-

Fibres are subjected to swelling when they absorb water. Fibre swelling then leads to increase in yarn diameter. Warp yarn then takes a longer path around the swollen weft yarn resulting in more crimp in warp yarn than weft yarn. The swelling of fibres also causes the yarns to move closer to each other as they absorb water during wet processing. From Table 3, it can be seen that both warp and weft density increase during wet processing as a result of crimp. Thus, all the fabrics have both warp and weft moving closer to each other during stages of wet processing.

Table 3 Fabric yarn densities during and after wet processing

State	Yarn density					
	Fabric A		Fabric B		Fabric C Picks/cm	
	Ends/cm	Picks/cm	Ends/cm	Picks/cm	Ends/cm	
Greige	9.3	11.7	10	11.7	13.7	11.3
Bleached	10.7	12.3	11.7	12.7	14.3	12
Dyed	10.3	12.0	11.3	12.3	-	-

3.3. Areal density

The measured areal density of each fabric increases during wet processing because of an increase in both warp and weft density which increase in weight due to swelling on absorbing water. Fabric A recorded the lowest areal density in all wet processing stages while fabric C has the highest areal density. The difference in areal density is due to differences in pile ratio of the fabrics, thus fabric C has the highest areal density because of its higher pile ratio than other fabrics. Fabric C had a high change in areal density despite undergoing fewer stages in wet processing. Fabric Ahad less areal density changes though it had many stages in wet processing. The results in Table 4 show that as the pile ratio increase, the greater the change in areal density. The pattern in the measured areal is also seen in calculated results in Table 5.

Table 4 Fabric measured areal densities during and after wet processing

State	Measured weight (g/m2)		
	Fabric A	Fabric B	Fabric C
Greige	248.5	251.9	324.5
Bleached	261.1	294.1	375.4
Dyed	271.1	313	-

Table 5 shows that all fabrics have the pile yarn with the highest calculated density as compared with the warp and weft yarn. This is because of the loops that are formed by the pile on the terry fabric. On the other hand, the weft yarn records the lowest density in all fabrics. Table 2 and 3 show that the weft has the lowest crimp and density (picks/cm) which explain the reason why the weft has the lowest density or weight in Table 5. Fabric A and fabric B have almost similar warp and weft weight but different areal density, the reason being that fabric A has lower pile ratio than fabric B.

As expected, the increase in weft density, warp density and pile ratio increase the areal density. The increase in the pile ration causes the areal density to increase because of an increase in the total pile warp length in a square meter of the fabric.

Table 5 Fabric calculated areal densities during and after wet processing

State	Yarn type	Calculated weight (g/m2)		
		Fabric A	Fabric B	Fabric C
Greige	Warp	64.34	63.18	59.89
	Weft	39.84	42.84	58.69
	Pile	137.11	147.42	205.88
	Areal density	241.3	253.44	324.46
Bleached	Warp	66.6	67.04	66
	Weft	45.42	50.3	62.46
	Pile	147.08	175.12	228.22
	Areal density	259.1	292.46	356.68
Dyed	Warp	68.88	70.49	-
	Weft	48.54	53.07	-
	Pile	156.62	187.23	-
	Areal density	274.04	310.79	-

An increase in the warp density and weft density increase the areal density due to an increase in the amount of ground warp and weft yarn in a square meter. Generally, width and lengthwise contractions cause and increase in areal density. When fibres absorb water or moisture they increase in diameter and density hence the weight of the fibre. After absorption of water swelling results and yarn move close together becoming more packed on the structure of the fabric hence the increased yarn density the areal density of the fabric will therefore increase due to the closeness of the yarns.

3.4. Regression

In Figure 1, the correlation coefficient (R^2) between the measured and the calculated values was found to be 0.9912. The correlation proves that the measured and calculated areal density results have no significant difference. This shows that there is a strong relationship between the measured and the calculated values. The results also show that the calculation approach can be used to determine the areal density of terry fabrics.

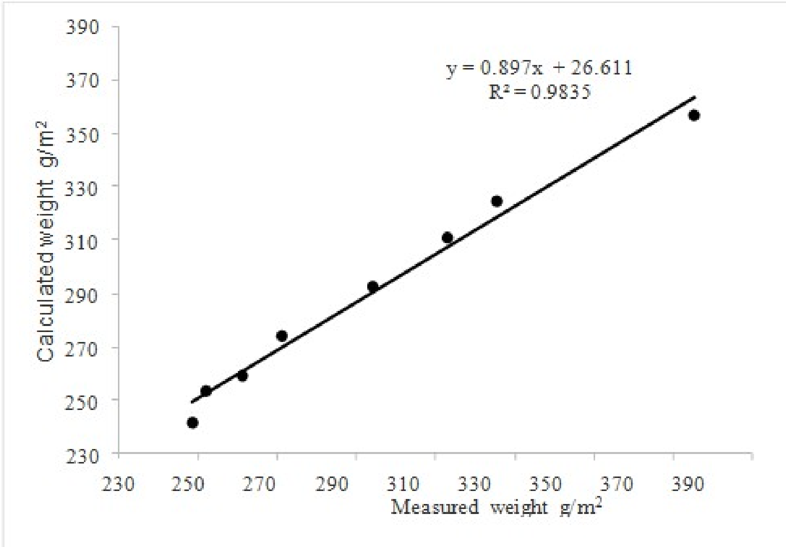

Figure 1 Regression curve of measured and calculated areal densities

4. CONCLUSION

From the experimental and theoretical study of terry woven fabrics, it was found that the fabric properties are affected by wet processing and these properties include areal density, warp and weft density, yarn crimp and dimensional stability. These properties also depend on each other thus a change in any of them result in a change in others. In this study it was seen that fabrics experience dimensional shrinkage which differ from fabric to fabric depending on the structure. The study proved that dimensional changes affect areal density. Since terry fabrics should be produced at a required areal density, it is therefore essential to know the fabric dimensional changes so as to attain an optimum in fabric areal density. It is also concluded that the calculation approach can be used to quickly determine an approximation in fabric areal density without cutting out samples for measurement.

References

Frontczak-Wasiak, I., Snycerski, M., Kunicki, M., &Cybulska, M. (2002). Weft Take-up Distribution Over the Width of Woven Fabrics Manufactured with the Use of Jet Looms. FIBRES AND TEXTILES IN EASTERN EUROPE, 10(4), 25-30.

Karahan, M., &Eren, R. (2006). Experimental investigation of the effect of fabric parameters on static water absorption in terry fabrics. Fibres and Textiles in Eastern Europe, 14(2), 59.

Hsieh, Y. L., Thompson, J., & Miller, A. (1996). Water wetting and retention of cotton assemblies as affected by alkaline and bleaching treatments. Textile research journal, 66(7), 456-464.

Karahan, M., Eren, R., & Alpay, H. R. (2005). An investigation into the parameters of terry fabrics regarding the production. Fibres& Textiles in Eastern Europe, (2 (50)), 20-25.

Saville, B. P. (1999). Objective evaluation of fabric handle. Physical Testing of Textiles, Woodhead Publishing Limited, 77-114.

Warner, S. B. (1995). Fiber science. Pearson College Division.

Zervent, B., & KoC, E. (2006). An experimental approach on the performance of towels-Part II. Degree of hydrophility and dimensional variation. Fibres and Textiles in Eastern Europe, 14(2), 64.

A study of the Quality of Kenyan Cotton rotor Spun Yarn

Josphat Igadwa Mwasiagi[1,2*], Lusweti Kitiyu[3], Mbwana Suleiman Ndaro[4], Simiyu Sitati[4], Ambrose Kiprop[5]

[1]Ethiopian Institute of Textile and Fashion Technology, Bahir Dar University, Bahir Dar, Ethiopia

[2]School of Engineering, Moi University, Kenya

[3]University of Eldoret, Eldoret, Kenya

[4]Tanzania Industrial Research and Development Organization (TIRDO), Dar es salaam, Tanzania

[5]School of Science, Moi University, Eldoret

([*]Author for correspondence: igadwa@gmail.com)

Abstract: The textile industry has been identified as one of the key industries which could spur industrial growth in Kenya. Efforts are being made by the Kenyan government and other institutions to revive the textile industry. One area which could contribute towards the revival of the Kenyan Textile industry could be the optimization of the cotton processing in Kenya. Cotton processing includes ginning, spinning, weaving and wet processing. In cotton spinning, the Kenyan industry uses ring and rotor spinning technologies. While ring spinning is the traditional spinning process, rotor spinning has established itself as a great competitor especially when dealing with course counts. This paper looks at the quality of cotton rotor spun yarns, in comparison with the USTER standards. While the Kenyan cotton lint reported good quality characteristics when compared to USTER standards, the quality of the rotor spun yarn was poor especially for yarn evenness and hairiness. It is therefore recommended that the rotor spinning process adapted to spin the Kenyan yarn should be carefully evaluated so as to unearth the sources of the shortfall in yarn quality.

Keywords: cotton, rotor spinning, quality, fiber

1. INTRODUCTION

The garment and textile industry in Kenya dates from the colonial period and has been regarded as one of the key sectors that could spur rapid industrialization in Kenya. After independence in 1963, the Kenyan Government invested heavily in the garment and Textile industrial sector and it was regarded as one of the key employers (World Bank, 2011). The government also enacted policies which shielded the local industries from international competition. The environment attracted private investors and many textile and garment factories were established. Unfortunately, the textile and garment industry slowly moved into a state of complacency. It failed to create strong vertical and horizontal linkages with other sectors, which, left them vulnerable when the protectionist policies were abandoned. Coupled with other difficulties which includes poor infrastructure, high energy cost, changes in world trade policies and aging machineries the textile sub-sector has continued to report a negative growth in the last two decades.

The ailing textile sub-sector has adversely affected the Kenyan economy and there is need to look into possible ways of reviving the industry. Some of the cost factors in the textile industry include the raw material, technology and labor. Other factors like energy, infrastructure, cost of borrowing finance, government policies and the world market will also have a bearing to the profitability of the textile industry.

2. COTTON SPINNING

2.1. Raw Material and Technology

Raw material (fiber) is one of the most important factors influencing yarn quality. The main fiber characteristics that influence the spinnability of cotton include: fiber length, length uniformity, fineness (micronaire), maturity, strength, color, elongation, trash and short fiber content (Klein 1987: Lawrence, 2003). Given that the raw material accounts for a major portion of the production cost of cotton yarn, considerable effort has been devoted to the measurement of cotton fiber quality characteristics. One of the internationally accepted systems for measuring cotton fiber characteristics is the High-Volume Instrument (HVI). A complete unit may include any combination of the following measuring modules: color and trash, length and strength, micronaire and moisture (Ghorashi 1999; USTER, 2007). The measurements and calculations done by the system include: fiber length, length uniformity index, strength, elongation at break (elongation), micronaire, color, short fiber index (SFI) and trash measurements. The quality of the cotton lint can be affected by the cotton growing conditions. Cotton neps can be caused by the growing season and conditions. (Mangialardi, et al., 1987), has reported that growing conditions within a location affects the number of neps and other imperfections for ginned lint, yarn and fabrics. This is due to the fact that even within a particular field cotton balls matures at different times. The higher the variation of cotton maturity period within a field the higher the percentage of immature fibers. This will also lead to higherneps in the cotton lint, yarn and fabrics (Frydrych et al., 2001). Cotton maturity can be a measure of the optimization of the cotton growing conditions.

Apart from the raw material which in our case is cotton lint, the technology used in the manufacture of cotton yarn is an important factor, which affects the cost and quality of the yarn. In Kenya yarn manufacturing is done using several methods. Ring and rotor spinning account for most of the cotton yarn manufactured. While ring spinning is the traditional spinning process, rotor spinning has established itself as a great competitor especially when dealing with course counts. The spinning process (ring and rotor spinning) processes can be summarized using Fig. 1 (Lord, 2003; McCreight et al., 1997). Ring spinning is the oldest and one of the most important cotton yarn manufacturing technology. The spinning process can be summarized into the following stages: cotton mixing, blowroom, carding, drawing, speedframe and ringframe. From the mixing to carding stages the cotton bales received from the ginnery undergo a series of processes which involve opening, cleaning and fiber individualization. The cotton material is then gradually drafted (reduction in the diameter) in drawframe. The ring spun yarn goes through one more drafting stage called speedframe, while the material from the drawframe can be taken straight to rotor spinning. Rotor spinning is sensitive to dust, so the opening stage is very critical, and should eliminate micro-dust.

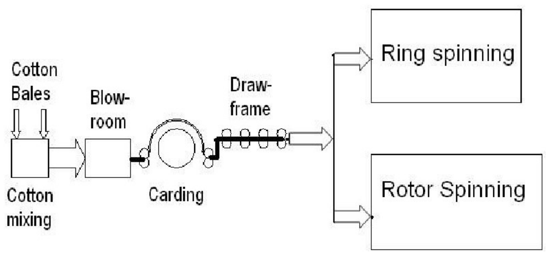

Figure 1 Typical cotton spinning process in Kenya

3. QUALITY CONTROL

The control of manufacturing factors is important so as to ensure that the quality and cost of cotton yarn is optimized. Quality control is one method used to monitor and hence control the quality of yarn. In the cotton spinning process quality control involves the inspection of the; raw materials prior to entering the production line, products at every stage in the spinning process, and final product (yarn) prior to dispatch. In this research paper we have concentrated our efforts on the study of the final product of the cotton yarn spinning process, which is the yarn. Some of the important yarn quality characteristics measured to check the quality of a rotor spun yarn include: yarn count, tensile properties, evenness and imperfections (Klein, 1987; Saville & Manchester, 1999). A study carried out by Moghassem and Bahramzadeh (Moghassem & Bahramzadeh, 2010) reported that knitting machine efficiency is affected by yarn tenacity and hairiness, followed by evenness, imperfections, and elongation. Therefore, a study of the aforementioned yarn characteristics cannot be overemphasized.

A case study of the Egyptian cotton spinning industry revealed that the main reason for quality problems were: Unsuitable quality levels, large quality variations and unexplained quality exceptions (Azzam & Mohamed, 2005). Unsuitable quality levels arise due to individual factories coming up with their own quality standards. This makes it difficult to compare products from different factories. This problem can however be solved by adapting internationally acceptable standards like Uster quality standards (Uster, 2007), which contains Uster statistics. Uster Statistics are quality reference figures which permit a classification of the quality of fibers, slivers, rovings and yarns with regard to worldwide production. Uster standards can be used for quality benchmarking, product specification and comparison of spinning factories and products. All the data obtained during the measurement of cotton lint and yarn samples in this research work were compared to Uster standards.

4. MATERIAL AND METHODS

The cotton fiber and yarn samples were collected from a textile firm in Kenya. The cotton lint was tested using High Volume Instrument (HVI) for quality parameters which included; Fiber length, micronaire (Mic), Uniformity

Index (UI), strength (str), reflectance (Rd), yellowness (+b), trash area (TrA) and trash count on the surface (TrC) (Ghorashi, 1999). The manufacturing process, included; blowroom, carding, drawframe (two passages) and finally rotor spinning. Yarn counts of Ne 8, 13 and 27 were spun. These are some of the popular counts spun in Kenyan factories. The rotor spinning machine parameters used in this research work are given in Table 1. The yarn samples were tested for yarn count, strength, evenness imperfections and hairiness (Nawaz et al., 2002). All the yarn characteristics were compared to Uster standards.

Table 1 Rotor machine parameters

Count (Ne)	8	13	27
Rotor speed (Rpm)	57000	68000	68000
Opening rollers speed (Rpm)	7700	8300	8800
Rotor diameter(mm)	46	40	36
Draft	58	96	207
Twist per inch (TPI)	12.4	16.6	28

5. RESULTS AND DISCUSSIONS

5.1. Quality of Kenyan Cotton lint

The quality of the Kenyan cotton lint was measured using HVI instrument. The cotton lint characteristics were compared to Uster Standards (Uster, 2007) and the results are given in Fig. 2. The uster level for the Kenyan cotton lint was at 50% for micronaire and Uniformity Index, 25% for fiber strength, reflectance, trash cent and trash surface area. Only fiber yellowness was at 95%.

An Uster level of 25% implies that the Kenyan cotton lint was among the 25% good cotton lint world-wide. Therefore the Kenyan cotton lint is among the upper 25% in its class (based on staple length) as concerning strength, reflectance and trash.

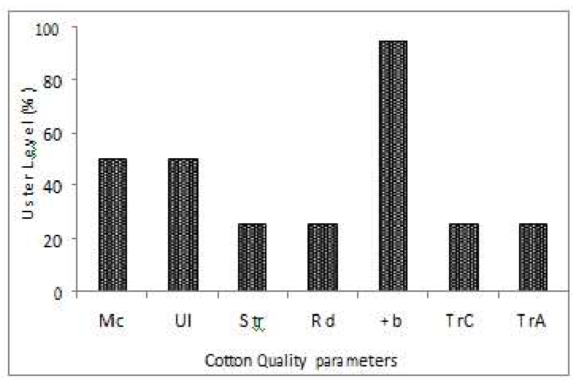

Figure 2 Uster levels for Kenyan cotton Lint

The trash measurement could be excellent because the Kenyan lint is hand-picked. Compared to machine picking, hand picking of cotton normally produce lint with less trash. Yellowness could be an indication of immature fibers. This could be due to the fact that the Kenyan cotton is rain fed, and not irrigated. Even in good rains the coming of the rains are uncontrolled and so rain fed cotton may have some traces of immature fibers.

The Quality of the Kenyan Rotor Spun Yarn

The quality parameters for the Kenyan rotor yarn were measured and compared with relevant Uster standards. The Uster standards levels are given in Table 2. The Uster levels for yarn CV of count, which is equivalent to the mass variation along the length of the yarn is poor. The best is at 75%. Poor CV% will lead to poorer efficiency in the subsequent processing (knitting and weaving) and poor fabric quality. The yarn hairiness also recorded a poor result. Higher levels in yarn hairiness will adversely affect the quality of the dyed/printed fabric.

Higher levels of unevenness and hairiness could be caused by machine or raw material related factors. For rotor spun yarn the selection of rotor diameter and navel size and types are the main rotor machine types which affect yarn evenness and hairiness (Nawaz et al., 2002).

Due to the higher levels of unevenness and hairiness in the Kenyan yarn there is need to optimize the selection of the rotor diameter and navel size and type. Yarn tension is also affected by the spinning tension which is affected by the rotor diameter, rotor speed and other rotor parameters.

Except for yarn elongation and hairiness the quality of the finer count (Ne 27) was mostly at the 95% level. These are poor results. The courser count (Ne 8), showed good results except for hairiness and CV of count. Yarn imperfections especially thick places and neps need to be checked. According to a report given by Rieter company (Rieter, 2011) one of the leading spinning machines manufactures, higher levels of imperfections could be due to raw material and machine related causes.

Table 2 Uster levels for Rotor Yarn Quality Parameters

Yarn Count	Uster 4 Levels (%)						
	CV of Count	CV of Hairiness	CV of Strength	CV of Elongation	Thick places	Thin places	Neps
8	75	95	25	25	50	5	25
13	75	95	50	25	50	5	95
27	95	75	95	25	95	95	95

Since the cotton lint reported good results the higher imperfections in the Kenyan yarn could be attributed to machine related causes. A higher level of thick places and neps could have been caused by defects in spinning elements or other fiber-guiding machine components. Bent, broken or notched clothing teeth on the opening roller in particular can cause steep increases in the numbers of neps and thick places. Wear or deposits in the fiber guide channel also result in fibers accumulating at these points. The accumulated fibers might be fed in uncontrolled manner to the rotor as larger or smaller clumps of fiber. Higher levels of neps and thick places could also have been caused by problems in the preparatory machines (carding and drawing). If the processing of the carding machine is not optimized it could lead to neps generation, which could lead to an increase in neps.

6. CONCLUSION AND RECOMMENDATIONS

Cotton rotor spun yarns were manufactured in a Kenyan factory were collected and tested. The cotton lint used to spin the yarns was also characterized. The quality characteristics of the cotton lint and yarns was compared to Uster standards. According to the results obtained in this research work, the cotton fiber showed good quality results. The rotor yarn spun from the fiber however showed poor uster results, especially for yarn evenness and hairiness. It is therefore recommended that the rotor spinning process adapted to spin the Kenyan yarn should be carefully evaluated so as to unearth the sources of the shortfall in yarn quality.

Reference

Azzam H.A. & Mohamed, S.T. (2005). Autex Research Journal, 5(4), 246-258.

Frydrych, I., Matusiak, M. & Swiech, T. (2001). Cotton Maturity and Its Influence on Nep Formation, Textile Research Journal, 71(7), 595-604.

H.M. Ghorashi, H.M., (1999). New generation of High Volume instrument, 58th plenary meeting of ICAC, Charleston, USA.

Klein, W., (1987). The Technology of Short staple spinning, Short Staple Spinning Series, The Textile Institute, Manchester

Lawrence, C. A., (2003). Fundamentals of spun yarn technology. CRC Press, New York.

Lord, P.R. (2003). Handbook of yarn technology science, technology and economics, Boca Raton, Fla. CRC.

Mangialardi, G.J., Lalor, W.F., Bassett, D.M., & Miravalle, J., (1987). Influence of Growth Period on Neps in Cotton, Textile Research Journal, 57(7), 421-427.

McCreight, D., Feil, R.W. Booterbaugh, J.H. & Backe, E.E. (1997). Short Staple Yarn Manufacturing. Durham, North Carolina: Caroline Academic Press.

Moghassem, A.R. & Bahramzadeh, H. (2010). Textile Research Journal, 80(20), 2176-2187.

Nawaz, S., Jamil, N.A., Iftikhar, M. & Farooqi, B. (2002). International Journal of Agriculture & Biology, 4(2), 256-258., 2002.

Rieter. Imperfections (thin places, thick places, neps) - Rieter. Rieter - Rieter. Retrieved February 3, 2011, from http://rieter.com/cz/rikipedia/articles/rotor-spinning/technology/yarn-structure-and- physical-textile- characteristics/imperfections-thin-places-thick-places-neps/print/

Saville, B.P. & Manchester, E. (1999). Physical testing of textiles. Cambridge, England: Woodhead Publishing, Ltd, in association with the Textile Institute.

Uster,(2007). Uster Statistics 2007. Wilstrasse, Switzerland

World Bank, World Development Indicators 2011, CD-ROM, World Bank, Washington DC, 2011.

Development of indigenous design and fabrication of manually operated sock knitting machine

Ayano Koyrita Banale[1*]
[1]Ethiopian Institute of Textile and Fashion Technology, Bahir Dar University, Ethiopia.
([*]Author for correspondence: ayubanale@gmail.com)

Abstract: Currently Africa has a great plan to produce and export textile products to improve regional economy and foreign exchange rate. To carry out this plan cotton cultivation expansion and establishment of textile mills is drastically changing from time to time in Africa especially in Ethiopia. However, the owners of the cotton processing mills are the well-to-do families. This is unachievable for the rest of the people. Importing machineries is beyond the economy of low-income people. Currently, for example the simplest to latest circular sock knitting machine costs from 60 thousand to 1 million Ethiopian birr. In this paper low cost manually operated sock knitting machine was designed and fabricated in Ethiopia. Except needles all parts were designed and fabricated in Ethiopia. The machine can produce one pair of socks in twenty minutes. The machine costs about 22,000 Ethiopian birr. A machine can return on its investment within five to eight months. Socks are some of the largely consumable textile products that many people can invest on it. The local people can easily use cotton yarn to process it. It is therefore, very useful to invest on the newly developed machine. This is the right investment for lower economy people.

Keywords: sock, circular knitting machine, cylinder, cam shell, bevel-gear

1. INTRODUCTION

All over the world, the majority of knitted fabrics are manufactured on circular knitting machines. The high performance level of these machines, the different materials and the range of yarn counts that they are able to process; the wide variety of designs and stitches are some of the reasons which have granted circular machines the market leadership in the knitting sector (Spencer, 2001; Ajgaonkar, 1998; Ajgaonkar, 1998; Carmine & Paola, 2002; Chandrasekhar et al., 1995). The variety of knit fabrics that can be manufactured with these machines can meet the needs of a very large end user market; from the traditional outwear and underwear sectors to hosiery, household and car interiors, without forgetting technical textile applications (Spencer, 2001; Aldrich, 1992; Roy, 1993).

During the 1870s, the patents granted to Henry Griswold virtually perfected the hand- powered sock machine (Spencer, 2001). This world-famous small-diameter latch needle machine has a single rotating cam-system (and yarn feed) that can be oscillated (reciprocated) for heel and toe pouch knitting, and an attachable dial needle holder for knitting the integral rib tops at the start of the sock (Spencer, 2001; Kerms, 1992).

Mechanically-controlled double-cylinder machines of the Bentley Komet type used to dominate the manufacture of socks but, with the encroachment of microprocessor controls, the simpler and cheaper single-cylinder machines now account for two thirds of new machinery sales (Spencer, 2001). Bogan Harmony Auto Knitter, American Family Knitting Machine, Bickford Family Knitting Machine and Ainslie Auto Knitter Knitting Machine are some of the most commonly used manually operated sock knitting machine. The cost of these machines is elevated due to many reasons. Cost of the metal modification, salary of the workers in the metal workshops, retailers benefit and the reduction in demand of production of manually operated machine as high-performance automatic machines are produced in western countries.

In this paper low cost manually operated sock knitting machine was designed and fabricated in Ethiopia. Except needles all parts were designed and fabricated in Ethiopia. The machine can produce one pair of socks in twenty minutes. The machine costs about 22,000 Ethiopian birr. A machine can return on its investment within five to eight months. Socks are some of the largely consumable textile products that many people can invest on it. The local people can easily use cotton yarn to process it. It is therefore, very useful to invest on the newly developed machine. This is the right investment for lower economy people.

2. MATERIAL AND METHODS

2.1. Materials selections

All parts of manually operated circular sock knitting machines were made of medium grade iron. However, bronze can also be used for fabrication of the machine.

2.2. Computer Aided Design and preparation of engineering drawings Selection of needles

The needle selection is made based on type of socks to be produced. Most of the places in Ethiopia are hot, and does not need to use too heavy socks. Therefore; for most common use E-8.5-gauge needle type is selected and dimension requirements were set as given in Table 1.

The cylinder is made of medium grade iron. The cylinder height is found from cam slot height, bellow slot of thecam shell, butt to needle hook height and the needle excess out. While cam slot height is the sum of butt height, setting height, and needle reciprocating height.

2.3. Bolt holes

Two bolt holes at the opposite ends of the cross-section edge of the cylinder, on the same diameter. Hole to hole distance = 98.6mm and hole diameter of 3mm, with appropriate bolt. The bolt hole needs to have a stainless steel insertion to increase life of the cylinder.

Table 1 Dimension requirements for needle selection

Requirements for needle design	Dimension
The needle thickness	1mm
Slot depth	4mm
E gauge	8.5
Slot width	1.5mm
Teeth width	1.5mm
Total mm/needle	3mm
Slot height	100mm
Working height	30mm
Needle excess out on cylinder during knitting time	24mm
The reciprocating height of the needle for 6mm loop length	27mm

Table 2 The relation between sock size and needles

Sock size	Number of needles on the cylinder
Heavy socks	60 and bellow
Medium socks	60 to 100
Finer socks	More than 100

Finer socks, for fixed diameter of the cylinder 4.75 inch, the number of needles can be greater than or equal to 100, as the standard given in table 2. For 115 needles cylinder 8.5 E gauge needles are used. For the 110mm diameter cylinder, Fig. 1, if N = 115neeles then the English gauge, E = 8.5. The number of needles means the number of cylinder slots. Therefore, the cylinder has 115 external slots.

The slot size is defined based on the needle type and slot size varies bellow the spring slot and above the spring slot. The slot size for 24-gauge needle type is as follows;

a. Below the spring slot
   Slot size 2mm x 4mm x 67mm
   Tooth size 1.14mm x 4mm x 67mm

b. Above the spring slot (for placing the needle in to the slot)
   Slot size 2.5mm x 4mm x 33mm
   Tooth size 0.64mm x 4mm x 33mm

3. RESULTS AND DISSCUSSIONS

3.1. Cylinder

The cylinder is made of medium grade iron. The cylinder height is found from cam slot

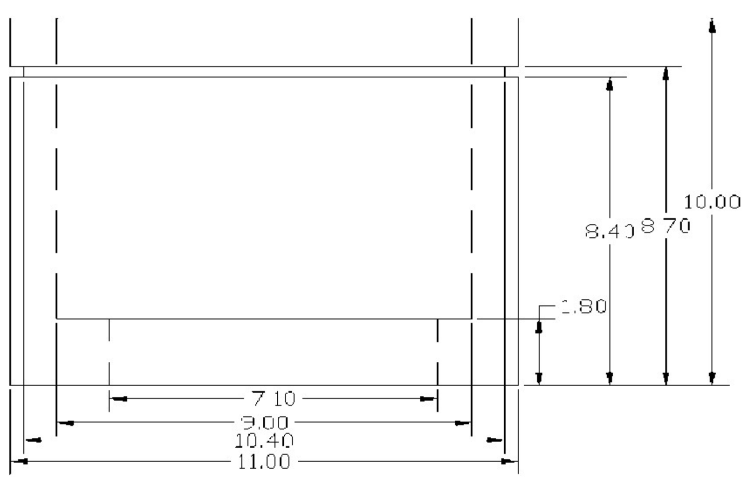

Figure 1 cylinder design

3.2. Cam shell

The external diameter of the cam shell is 136mm, internal diameter of 110.5mm and total height of 78mm as shown in table 3. Within the cam shell the cylinder is inserted where the cylinder is fixed and the cam shell is rotating around. The camshell has a triangular curved bore where cam is fixed. The cam is used to raise and lower the needle to knit yarn. Camshell has a circumferential groove on the inside diameter almost at mid position of the camshell height. It also has a cut on one side at the middle of which is cam bearing fixed bullet. Cam shell provides various functions during knitting process. The camshell rotates while the cylinder is fixed at a position. The butts of needles placed in the cylinder slots are supported by the camshell groove while the fixed bullet holds the knitting cam. The up and down movement of the needle is made by angular knitting cam.

Table 3 Dimensions of cam shell

Dimensions of Cam shell	Dimension length, mm
Inside diameter	110.5
Bore diameter	122
Outside diameter	136
Cam shell height	78
Needle step height	53
Cam bore height	15
Cam bore width	108

3.3. Bevel gears

Bevel gears are used when it is necessary to transmit power from one shaft to another where the communication shaft is located at an angle, with their axial lines intersecting . Bevel gears are not restricted to shafts at right angles. There are right angle bevel gears and angular bevel gears. In cases where the ration of a pair of bevel gears is 1:1, both gears being the same size and having the same number of teeth, they are known as miter gears, shown in equation, 1, 2 and 3. These gears permit the driving of one shaft at right angles to the other. In a bevel gear the teeth are cut on a conical cone. A pair of gears is used to transmit power from one shaft to another, and share the two shafts have their extended axial lines intersecting at some angle other than 90o . The gears are called angular bevel gears. Based on the calculation of bevel gear parameters, the number of gear, equation 1 and 2, shaft angle, equation 3 and 4 were calculated. The number of teeth on both the gears is equal, equation 5, as per the principle of miter gears.

$$Z_{v1} = \frac{2\pi_{b1}}{P} = \frac{Z_1}{\cos\gamma_1} \qquad (1)$$

$$Z_{v2} = \frac{2\pi_{b2}}{P} = \frac{Z_2}{\cos\gamma_2} \qquad (2)$$

Where

Z_{v2} Virtual number of teeth

R_b Back cone radius

P Circular pich o f the bevel gear

Z_1 Number of teeth on the pinion

Z_2 Number of teeth on the gear

γ_1 Pitch cone angle of pinion

γ_2Pitch cone angle of teeth

3.4. The base

The base carries the cylinder, the camshell, gear ring and yarn mast. On one side of the base, flattened surface helps the crank shaft to fit the gear ring. The base caries all these loads including the cranking force during knitting. On the base of the machine the cylinder, cam shell and the pinion gear are fixed on the steps formed, as shown in fig. 2. The rotating gear is fixed 90 degrees to the horizontal pinion so that they mesh and rotate as operated by handle on the initiating gear. Four stands are welded together with the base to make better operation position.

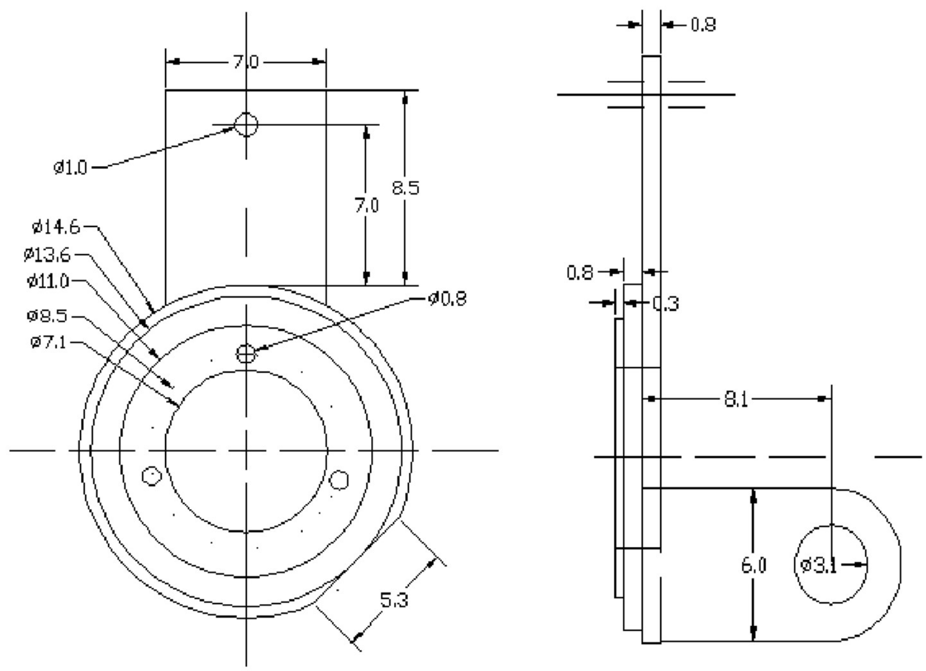

Figure 2 The base of the machine

3.5. Assembly of the Machine and Knitting Trial

The cylinder, the camshell, and the gear ring were assembled on the seat. Needles were placed in their slots. After assembling all parts, knitting was made on the new developed machine. The machine was partially gauged; half of the needles were inserted by jumping one. The sock produced was good.

4. CONCLUSION

In this project manually operated circular sock knitting machine was designed and produced in Ethiopia. Previously, this machine was not available in the country.

All the parts of the machine are produced in the country except the needles. Needles for one machine cost not more than two hundred fifty Ethiopian birr.

The use of the machine has various advantages. It can be designed and produced by fifteen to twenty thousand Ethiopian birr. Lower economic class people can purchase the machine, operate it, produce socks using local yarn, enjoy in its profit, and distribute the product to their own people at low price. Therefore, it is the right investment for lower economic class people. Development and utilization of the machine can substitute machines and socks imports. The machine is simple to apply and efficient to produce but needsan appropriate needle for higher quality and productivity. The needles can be imported at lower costs. The machine is very simple to operate that women can use and generate their income. Being designed well, from an appropriate metal, the machine can work for long time under normal operations.

The future scope of this study is more important than what is given here. The small diameter circular knitting machine (sock knitting machine) developed in this project can be improved to larger diameter circular knitting machine. This is because knitting mechanisms are similar except few modifications. Developing a mechanism to perform in a given operation is more difficult than automating it. Possibly some gear systems, motor, stop motions, traducers and controllers are required to automate those manual machines. Therefore, I say that there are few years we have to stop importing of those machines (knitting machines) purchased at tens million levels, by producing them at 50 to 70% reduction in cost.

References

Ajgaonkar, D.B., (1998). Knitting Technology, Universal Publication, Mumbi

Aldrich, w. (ed.), (1992), CAD in clothing and textiles, Blackwells, Oxford, UK.

Carmine, M. & Paola, Z., (2002). Knitting reference books for textile technologies, Fondazione Acimit publication, Torino

Chandrasekhar I., Bernd M. &Wolfgang S., (1995). Circular Knitting, Reisenbach GmbH, Bamberg,.

Krems, W.S. (1992). Knitting Technique, 143, 163-169

Roy A. K., (1993). Knitting Industry centenary International Conference Papers, New Delhi

Spencer, D.J. (2001). Knitting technology, a comprehensive hand book and practical guide, third edition, Woodhead Publishing, Sawston

Paradigm shift of functions of organic dyes and pigments

Lodrick Wangatia Makokha[1*] Fredrick NziokaMutua[1]
[1]Ethiopian Institute of Textile and Fashion Technology, Bahir Dar University – Ethiopia
([*]Author for correspondence: lodricksw@yahoo.com)

Abstract: Color plays an important role in adding value to textile products. Organic dyes and pigments have traditionally been used to color the textile world, in fact the word dyes is almost synonymous to textile. However, in the last two decades there has been a major shift of interest on organic dyes and pigments. These types of materials are now finding a lot of interest in opto-electronic device application like solar energy, solar cells, diodes etc. The main reason for the current shift of application of organic dyes and pigment is based on factors like cost, electronic property and most important is that the whole technology including processing and functioning is environmentally friendly. This work intent to give a review of some of organic dyes and pigments which have crossed over from coloring textile to become organic electronic materials. Some of the chemical modifications done to improve on optoelectronic properties will be briefly discussed.

Keywords: Dyes, Pigment, opto-electronic materials, electronic properties

1. INTRODUCTION

The impact of climate change is no longer a theory but a reality and many people across the world have experienced difficult times in the recent past. Floods have become a phenomenon in some parts of the world good example in the Philippians, drought and associated food shortage is now common in many parts of Africa, environmental caused diseases are now threatening life in many parts of the world. One major cause of all this suffering is pollution of environment by industrial activities. Concerted efforts are now being taken by various governments and other organizations to minimize the pollution from industries. More than 70% of industries across the world depend on oil to power their production. The use of oil produces a lot of fumes which contribute immensely to environmental deterioration. Not only alternative clean sources of power are currently being highly demanded but also appliances that consume less power. Solar power has been identified as a major source of power and holds a great potential of conserving the environment if it can be efficiently utilized.

The first solar cell was developed in the bell laboratory in USA by Chapin et al in 1954 using silicon material (Chapin et al., 1954). Ever since Chapin discovery various studies have been undertaken by various researchers to improve on the efficiency of the solar cell which has seen to the successful commercialization of silicon based solar cells. However due to the complexity of processing and the cost of silicon, the solar cells overall cost has been very expensive making it unaffordable. Efforts to find alternative materials which can replace silicon so as to overcome its limitation became successful in 1991 when Gratzel et al (O'Regan & Gratzel et al., 1991) invented the first solar cell using ruthenium dye. The dye was used to sensitize the solar cell and thus the technology is called Dye sensitized solar cell (DSSC). However, like the silicone development of ruthenium dye requires complex process which made the solar cell expensive. Efforts to reduce the cost have seen the introduction of organic dyes into the electronic world. Organic electronic dyes are cheap in price and their processing is simple, also other electronic application of these organic materials in areas like sensor, light emitting diodes, among others have been developed. In the last couple of years organic materials have been intensively researched as they are believed to hold the keyto cheap solar cells and other electronic applications (Kim et al., 2004; Liang et al., 2007). Initially general organic dyes which had little or no significance in the textile industry were used however as time went by some important textile dyes both synthetic and natural dyes have joined the band wagon and are now playing a significant role in solar cell generation and electronic devices which use low power. This review is indented to give a brief overview of these dyes. We have also done some work on this dye of which we would like to show case.

2. THE SOLAR CELL TECHNOLOGY AND OPTOELECTRONICS

Conversion of light into electricity requires three distinct processes: light absorption generates an electronically excited state, separation of the excited states into electrons and protons, transfer of electrons. In a DSSC set up, the light absorption is done by the dyes while $TiO_2$is used as a semiconductor to separate the electrons from the excited state and transfer them to the conduction band where they are directed to the load. To increase the surface area and maximize electron transfer, the semiconductor in form of nanoparticles are sintered onto the transparent electrode, then coated with a single monolayer coverage of dye. The thinner the dyes layer the higher the light absorption. Furthermore, every light- absorbing dye molecule is directly attached to the semiconductor to optimize charge separation. Completing the circuit in a DSSC is typically accomplished with a redox electrolyte, almost always iodide/triiodide as illustrated in Fig. 1.

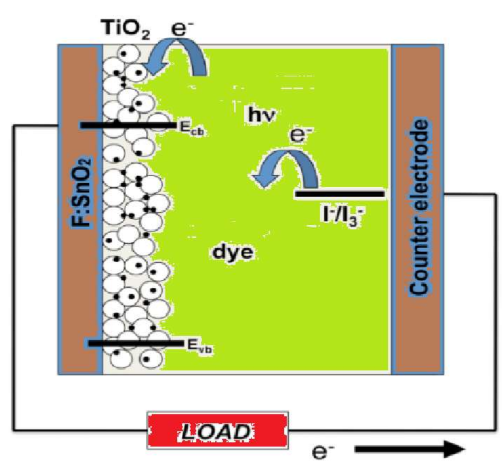

Figure 1 The components and electron transfer processes in a typical dye-sensitized TiO_2 solar cell

One important factor that governs the performance of a solar cell is the absorption spectrum of the organic semiconductors or the dye molecules used for device fabrication. In an ideal situation, the solar cell absorption spectrum should completely cover the region of terrestrial solar irradiation (Winder & Sariciftci, 2004). Therefore, the development of novel dye molecules with appropriate absorptive properties for photon harvesting has become an important area to explore. Dyes which have maximum absorption in the maximum irradiation region of the solar as illustrated in Fig. 2 are highly recommended.

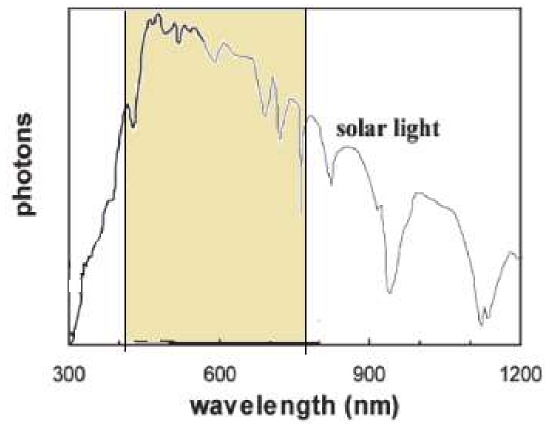

Figure 2 Normalized absorption spectra of typical perylenediimide dyes and the spectrum of solar irradiance

3. DYES FROM TEXTILESUSED FOR DSSC AND OPTOELECTRONIC APPLICATION

There are various textile dyes which in the past few years have found a lot of application in solar cell and other optoelectronic applications. The list is quite long but this report will focus on a few important once which have received a lot of interest among researchers. Some of these dyes include Phthalocyanine, Porphyrines and perylenediimides.

Common characteristics of these classes of dyes used in electronic application is their strong conjugation due to extended π-system, absorption in high wavelength region which make them good light harvesters and good light emission properties. These properties are required both for solar cell and optoelectronic applications. The listed organic dues their good optoelectronic properties now find wide application in solar cell devices, light emmiting diodes, sensors and many other optoelectronic applications.

3.1. Phthalocyanine

Phthalocyanine is an intensely blue-green-coloured aromatic macrocyclic compound that is widely used in dyeing. Phthalocyanines form coordination complexes with most elements of the periodic table as shown in Fig. 3. These complexes are also intensely colored and also are used as dyes or pigments. Phthalocyanine are good materials for solar cell due to their suitable properties which include strong red and near-IR absorbance, high extinction coefficients, good thermal, chemical, and photolytic stability, and easy tuneability through rational design of the macrocyclestructure (Cid et al., 2009; Eu et al., 2008).

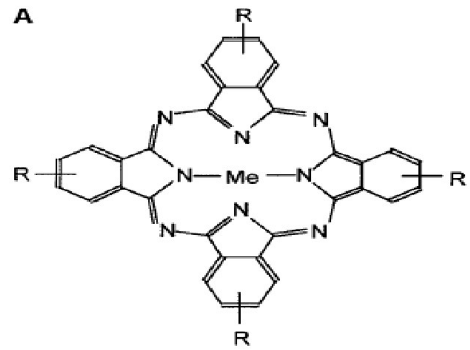

Figure 3 Structure of phthalocyanine dyes; Reactive blue 38: Me = Ni, R = $-SO_3H$ or $-SO_2$-NH-D, D = phenylen unit with reactive group; Reactive Blue 15: Me = Cu, R = $-SO_3Na$ or $-SO_2$-NH-$C_6H_3SO_3Na$-NH-$C_3N_3ClNH_2$.

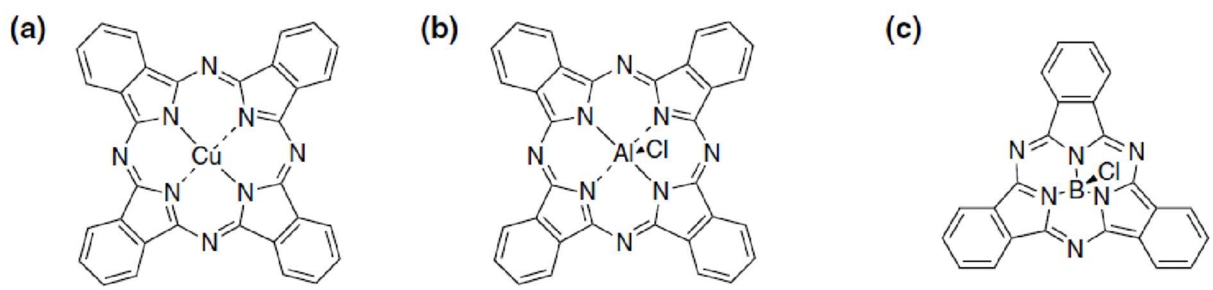

Figure 4 Derivatives of phthalocyanine dyes

The pioneer work of organic solar cell done by Tang (Tang, 1986) reported in 1986 used phthalocyanine with a C60 to make hetero-junction bilayer organic solar cell, the efficiency was very low however over the years continued research has seen significant improvement. Fig. 4 shows some of derivatives which have been studied (Walter et al., 2010).

3.2. Porphyrins

Porphyrins are a group of organic compounds, many naturally occurring. They are highly conjugated systems. As a consequence, they typically have very intense absorption bands in the visible region and may be deeply colored (Gouterman. 1978). Porphyrin dyes are active dyes for polyamide fibers and as cationic dyes for wool, polyamide, polyacrylic, and cellulose fibers.

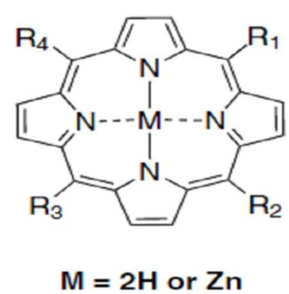

Figure 5 Structure of porphyrins dyes

Porphyrins are one of the first organicdyes that were studied as possible dyes to replace the expensive ruthenium complex dye for

DSSC (Kay et al., 1994) and interest in these dyes has continued to grow. The performance of Porphyrine dyes based DSSC has continually been improved and recently efficiency of up to 11% has been reported making porphyrines a possible alternative for ruthenium dye. Porhyrines have also been widely used in a range of applications, such as molecular electronics (Tsuda et al., 2003; Lash & Chandrasekar, 1996), solar energy conversion (Hasobe et al., 2005), photochemical water splitting (Darwent et al., 1982; Funyu et al., 20030 and donor-acceptor systems.

3.3. Perylenediimide dye

Perylenediimides (PDI) constitute a group of high- performance pigments with red to black shades, depending on the fine details of chemical structure and on molecular packing in the solid state. PDI-based pigments are used predominately in fiber applications and in high- grade industrial paints, particularly in carpet fibers and in the automobile industry, they produce high quality and/or durability of the colors. Perylene imides are well-known as chemically, thermally, and photophysically stable dyes (Ego et al., 2003). Together with phthalocynines they were the first organic dyes which were tested for DSSC. Ever since concerted effort has been made to see the successful utilization of this dye in electronic appliances. Also, PDI have been utilized in various optical devices like organic field-effect transistors (OFETs) and light-emitting diodes (OLEDs). These dyes have also been used in electrophotography (xerographic photoreceptors), fluorescent light collectors, and lasers (Liu et al., 2004, O'Neil et al., 1992).

3.3.1. Our work on PDI

The electronic properties of perylene-3,4;9,10- bis(dicarboximide) chromophores can be tailored by changing substituents on the perylene chromophores, yielding a family of n-type and p-type materials (Zhao et al., 1999; Lukas et al., 2002). Currently PDI is the most researched organic dye for solar cell and other electronic device application, the reason being this is the only organic dye which can be used as electron donor (p-type) and electron acceptor (n-type). As compared to other organic materials which are only p-type, PDI stands a high chance of maximum utilization in many areas of application. However, the dye has inherent stacking problem which has greatly limited its potential applications. Much research has been done to solve this challenge and significant achievement has been reported. Our group has also been involved in studying the self-assembly behavior of aggregation constrained PDI dye. We have used a bulky nanoparticle to sterically hinder the aggregation forces as per the molecular structure in Fig. 6.

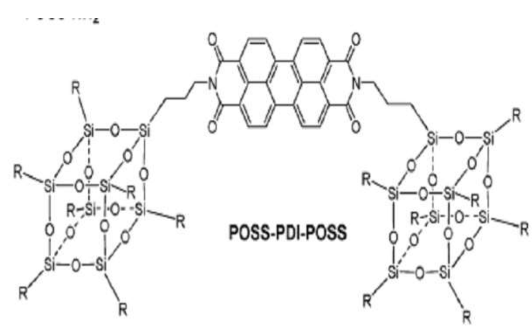

Figure 6 PDI dye modified with bulky nanoparticle POSS

Due to the nodes at the imides nitrogen, the bulky nanoparticle did not have any significant effect on the solution optoelectronic properties as reflected in Fig. 7. Both the absorption and fluorescence spectrum resembled the characteristic PDI chromophore in solution. However, significant straining of aggregation was achieved which enabled development of solid crystal structure with enhanced optoelectronic properties like fluorescence. Our molecular structure is tended to have good properties which are believed to be required for DSSC application and we believe better efficiency will be achieved when applied. Also, the achieved highly ordered crystal can find many other applications in optoelectronics.

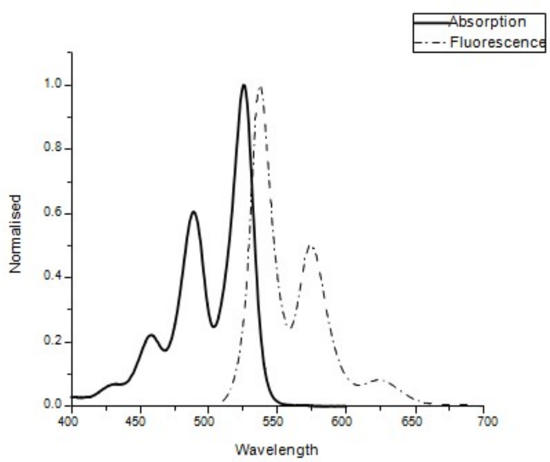

Figure 7 Absorption spectra and emission spectra of PDI dyes in chloroform

4. NATURAL DYES

Natural dyes found in flowers, leaves, and fruits have traditionally been extracted by simple procedures and used to dye textile products for a long time. The advent of synthetic dyes almost saw complete disappearance of natural dyes but due to environmental concerns, natural dyes have been gaining a lot of interest in the textile world. These types of dyes are cheap, non-toxic, and completely biodegradable. Apart from textiles natural dyes have been gaining significant attention in the electronic world, specifically for DSSC application. Already several natural dyes have been investigated for light generation good examples include cyanin (Sirimanne et al., 2006), carotene (Gomez-Ortiz et al., 2010), tannin (Espinosa et al., 2005), and chlorophyll (Kumara et al., 2006). So far, the best DSSC efficiency of 7.6% for natural dyes. This achieved efficiency is very promising to the development of natural dye sensitized DSSC.

5. FUTURE OUTLOOK

It is now clear that both natural and synthetic dyes are set for a major shift in their area of application. It's just a matter of time that the full commercialization of DSSC made from organic dyes will be realized. Since a lot of research is being undertaken, we anticipate more textile dyes to join the electronic world. Already major companies are keen on adapting this emerging technology especially the digital world are already embracing appliances made of organic dyes. Samsung and LG are already in the market and within a short time major shift is expected. The challenge is, textile dyes are now joining a more lucrative field, will we be able to compete favorably?

Reference

Chapin D.M., Fuller C.S., & Pearson G.L., (1954), Journal of Applied Physics, 25, 676.

Cid JJ, Garcia-Iglesias M, Yum JH, Forneli A, Albero J, Martinez-Ferrero E, Vazquez P, Gratzel M, Nazeeruddin MK, Palomares E & Torres T (2009) Chemistry-A European Journal, 15, 5130.

Darwent JR, Harriman PDA, Porter G &Richoux MC (1982) Coordination Chemistry Reviews, 44, 833.

Ego C, Marsitzky D, Becker S, Zhang J, Grimsdale AC, Mullen H, MacKenzie JD, Silva C and Friend RH (2003) Journal of American Chemical Society, 125, 437.

Ehret A, Stuhl L &Spitler MT (2001) Journal of Physical Chemistry B, 105, 9960.

Espinosa R, Zumeta I, Santana JL, Martinez-LuzardoF, Gonzalez B, Docteur S & Vigil E (2005) Solar Energy Material and Solar Cells, 85, 359.

Eu S, Katoh T, Umeyama T, Matano Y &Imahori H (2008) Dalton Transactions, 5476.

Funyu S, Isobe T, Takagi S, Tryk DA & Inoue H (2003) Journal of American Chemical Society, 125, 5734.

Gomez-Ortiz NM, Vazquez-Maldonado IA, Perez-Espadas, AR, Mena-Rejon GJ, Azamar-Barrios JA &Oskam G (2010) Solar Energy Material and Solar Cells, 94, 40.

Gouterman M. (1978) The Porphyrins, Academic Press Inc., London.

Hasobe T, Kamat PV, Troiani V, Solladie N, Ahn TK, Kim SK, Kim D, Kongkan A, Kuwabata S &Fukuzumi S (2005) Journal of Physical Chemistry B, 109, 19.

Kay A, Humphry-Baker R &Gratzel M (1994) Journal of Physical Chemestry, 98, 952.

Kim S, Lee JK, Kang SO, Ko J, Yum JH, Fantacci S, De Angelis F, Di Censo D, Nazeeruddin MK &nd 21.

Kitamura T, Ikeda M, Shigaki K, Inoue T, Anderson NA, Ai X, Lian T &Yanagida S (2004) Chemistry of Materials, 16, 1806.

Koumura N, Wang ZS, Mori S, Miyashita M, Suzuki E & Hara K (2006) Journal of American Chimerical Society, 128, 14256.

Kumara GRA, Kaneko S, Okuya M, Onwona-Agyeman B, Konno A &Tennakone K (2006) Solar Energy Material and Solar Cells, 90,1220.

Lash TD and Chandrasekar P (1996) Journal of American Chemical Society,118, 8767.

Li K, Schuster DI, Guldi DM, Herranz MA &Echegoyen L (2004) Journal of American Chemical Society,126, 3388.

Liang M, Xu W, Cai F, Chen P, Peng B, Chen J & Li Z (2007) J. Phys. Chem. C, 111, 4465.

Liu Y, Li Y, Jiang L, Gan H, Liu H, Li Y, Zhuang J, Lu F & Zhu D (2004) Journal of Organic Chemistry, 69, 9049.

Lukas AS, Zhao Y, Miller SE and Wasielewski MR (2002) Journal of Physical Chemistry B,106, 1299.

Myles AJ and Branda NR (2001) Journal of American Chemical Society,123, 177.

O'Neil MP, Niemczyk MP, Svec WA, Gosztola D, Gaines GL &Wasielewski MR (1992) Science, 1992, 257, 63.

O'Regan B &ndGratzel M (1991) Nature, 353, (6346), 20. Hasobe T, Kamat PV, Troiani V, Solladie N, Ahn TK, Kim SK, Kim D, Kongkan A, Kuwabata S &Fukuzumi S (2005) Journal of Physical Chemistry B, 109, 19. 737.

Silvestri F, Garcia-Iglesias M, Yum JH, Vazquez P, Martinez-Diaz MV, Gratzel M, Nazeeruddin MK and Torres T (2009) Journal of Porphyrins Phthalocyanines, 13, 369.

Sirimanne PM, Senevirathna MKI, Premalal EVA, Pitigala PKDDP, Sivakumar V &Tennakone K (2006), Journal of Photochemistry Photobiology A, 177, 324.

Tang CW (1986) Applied Physics Letter, 48, 183.

Tsuda A, Sakamoto S, Yamaguchi K & Aida T (2003) Journal of American Chemical Society, 125, 15722.

Walter MG., Rudine AB &Wamser CC (2010) Journal of Porphyrins Phthalocyanines, 14, 759.

Winder C and Sariciftci NS (2004) Journal of Material Chemistry, 14, 1077.

Zhao Y &Wasielewski MR (1999) Tetrahedron Letter, 40, 7047.

The Impact of Imported New and Second-Hand Clothing on the Zimbabwe Textile and Clothing Industry

Abraham B Nyoni[1*] Londiwe C. Nkiwane and Peeps Gonde[1]
[1]National University of Science and Technology, Bulawayo, Zimbabwe
([*]Author for correspondence: babsnyoni@hotmail.com)

Abstract: Clothing imports into Zimbabwe has grown steadily since the trade liberalisation measures were introduced in 1991. Asia has grown in importance as the source of imported yarns, fabrics and clothing. In addition, there is growing concern in the clothing sector of the continuous growth in the second-hand clothing market and illegal imports from within the SADC region. All these factors have crippled the textile and clothing industry in Zimbabwe leading to the reduction in the market share of locally manufactured products, factory closures and retrenchments. This paper discusses the work carried out to assess the impact of the imported new and second-hand clothing on the Zimbabwe Textile and Clothing Industry. Results show that most of these cheap imports don't come into the country through the formal borders and pose unfair price competition to local products due to their cheapness and perceived superior quality. The slow recovery of the textile and clothing industry is also due to other contributory factors such as lack of foreign currency, cost of borrowing money, brain drain, power cost and supply, heavy import duty rates, etc. which when all are summed up, together have led to the decline of the textile and clothing industry in Zimbabwe.

Keywords: Zimbabwe, new, second hand, imported, clothing, textiles.

1. INTRODUCTION

The Zimbabwean Clothing and Textile industry has been a major contributor to the growth and development of the Zimbabwean manufacturing sector and created many job opportunities not only in textile industries but also in other related sectors such as cotton growers, spinners, weavers, dyers and finishers, manufacturers of chemicals etc.

In the past few years, there has been a decline in the textile manufacturing sector due to the economic down turn and also due to the importation of cheap new clothing textiles from the Far East especially China (Thorburn, 2002; Baden & Barber, 2005, Nkala, 2008; Kamau et al., 2011) and second-hand products (Thorburn, 2002) from Europe. A study by Moyo (Moyo, 2008) on the clothing and textile sectors performance, challenges, opportunities and its contribution to the countries economic growth between 2003- 2007 indicated that the success of this sector was dependent upon the availability of raw materials, machine spare parts, Government policies, trade agreements, the economic environment and brain drain. Among the top six companies studied by Moyo (Moyo, 2008) three are now closed and the rest operating at between 30-40% capacities. The RBZ annual report of 2004 indicated that clothing exports had gone down from a peak of US$ 139 million in 1994 to an estimated export earnings of US$14million in 2004 (Mukurazita, 2007). The availability of cheaper clothes from the Far East and second-hand clothes from Europe could have filled in a gap for need of clothing when the Zibwabian economy was on its knees, and people had little many to spend. The economic down turn over the last decade can therefore one of the factors that has led to the proliferation of flea markets all over the country popularly known as Khothama (Bend) or "K" Boutiques (Figure 1 and 2).

Figure 1 Shopping For Second Hand Clothes At Khothama (Bend) Boutique

Due to the nature of the shopping sequence where you have to bend to select the desired items and Mpedzanhamo (Poverty Alleviation market) because even those of low income can be decently dressed as a result of the affordability of the second-hand clothes in these markets.

2. METHODOLOGY

Structured questionnaires and direct interviews were used to collect data from second hand clothes vendors, retailers and Zimbawe Revenue Authority (ZIMRA) in four major parts of Zimbabwe i.e. Bulawayo, Harare, Kariba and Mutare. Bulawayo and Harare were chosen since they are the major cities and the border towns of Kariba and Mutare the major, entry points of second-hand clothes. Flea markets selling imported new and second-hand products and retail outlets selling Zimbabwean made products were visited in these target areas and pricing and buying behavior by consumers of the commonly used items gathered. Border entry points were also visited and customs officials were interviewed

Figure 2 Shopping For New Clothes at Khothama (Bend) Boutique

3. RESULTS

Initial investigations revealed that the conduit for most of these products was the northern parts of the country as the terrain presented better opportunities for smuggling. The new products are mostly from China and find their way into the country through countries like Botswana, South Africa, Zambia and Mozambique and the illegal imports of second hand textiles come through Zambia, Mozambique. Some second hand clothes that come through Zimbabwe's neighboring countries originate as far as Kenya, Tanzania, Zaire, Somalia and Rwanda.

Table 1 Prices of Gents Wear-US$

Item	Zim made	Imported New	2nd Hand	Price Range US$
Jean	32.7	12.24 [20.46]	4.33 [28.37] 0.047222	New [9-20] 2nd[3-7] Zim [20-50]
T-shirt	18.3	5.84 [12.46]	1.63 [16.67] 0.049306	New [4-8] 2nd [0.50-3]- Zim [15-21]
Shirt	19.75	7.40 [12.35]	2.57 [17.18] 0.047222	New [5-10] Old [1-4] Zim [15-25]
Trousers	28.1	8.18 [19.92]	3.60 [24.50] 0.047222	New [3-10] 2nd [3-5] Zim [20-45]
Suit	76	37.83 [38.17]	Nil	New [12-50] 2nd [nil] Zim [60-110]
Socks -pair	2.25	0.95 [1.30]	0.33 [1.92] 0.046528	New [0.33-1] 2nd [0.20-0.33] Zim [2-3.50]

Judging by the volumes of products found at the flea markets throughout the country, it was obvious that all those products don't come into the country through the formal borders.

- Cross border transporters-new
- Cross border shoppers-new products
- Cross border truckers-new and old

Individuals on bicycles, donkeys, donkey drawn carts especially through the borders north of the country.- new and old Customs officials at times confiscate new and second hand clothes from smugglers and these followed by the imported new textiles and the Zimbabwean made textiles being the most expensive. Tables 1-4 show the summary of the prices charged by various competitors in the clothing and textile market in the areas that were studied. Results show that the second-hand clothes are the cheapest

Table 2 Prices of Ladies Wear (US$)

Item	Zim made	Imported New	2nd Hand	Price Range US$
Jean	17.14	6.36 [10.78]	1.48 [15.66] 1:12	New [5-9] 2nd [0.20-2] Zim [10-23]
Shorts	14.3	3.53 [10.77]	0.89 [13.41] 0.052778	New [2-6] 2nd [0.10-2] Zim [9-27]
T-shirt	9.11	4.56 [4.55]	1.05 [8.06] 0.047917	New [3-7] 2nd [0.20-2] Zim [3-15]
Shirt	13	3.90 [9.10]	1.25 [11.75] 0.048611	New [2-6] 2nd [0.33-2] Zim [7-20]
Trousers	10.1	4.28 [5.82]	1.62 [8.48] 0.045833	New [2-6] 2nd [0.50-3]

The Clothing and textile manufacturers attribute the high production costs per unit output to factors such:

- Costs and inadequate power supply – The power utility introduced load shedding to try and control the amount of power consumed in the country thus affecting the operational hours of companies.
- High wages as compared to China which has arguably the cheapest labour and one of the strongest textile industries in the world (Moyo, 2008). The issue of a living wage in Zimbabwe was not in competing countries results in the reduction of production costs per unit output.
- Lack of investment- failure by local industry to attract direct foreign investment hinders the upgrading of manufacturing technologies.

In order for their operations to be sustainable, the Zimbabwe textile and clothing manufacturers are forced to pass such costs to the consumer and the consumer show apathy by drifting to the second hand and new imported products markets. Due to the high costs, the made in Zimbabwe products are not able to compete in the market place with finished textile clothing products from Asia.

Table 3 Prices of Child Wear-Boy- US$

Item	Zim made	Imported New	2nd Hand	Price Range US$
Jean	11.2	7.84 [3.36]	1.74 [9.46] 0.045833	New [4-10] 2nd [0.20-5] Zim [7-25]
Dress	8.9	6.24 [2.66]	1.75 [7.15] 0.045139	New [2-10] 2nd [0.20-4] Zim [5.50-17]
Skirt	4.42	4.66 [-0.24]	1.14 [3.28] 0.044444	New [2-6] 2nd [0.20-2] Zim [2.50-10]
Blouse	5.08	3.15 [1.93]	0.97 [4.11] 0.045139	New [1-5] 2nd [0.10-2] Zim [2.50-10]
T -shirt	5.43	3.15 [2.28]	0.74 [4.69] 0.046528	New [0.50-5] 2nd [0.10-2] Zim [4-7]

The factors contributing to consumer shopping behavior were highlighted as:

- Cheap products-affordability: price difference between Zimbabwe made products and second-hand clothing ranged between US$ 1:4-1:16.
- Good quality products: which was determined to be reference to durability (resistance to wear and color fastness), variety of fashion styles and different fabric constructions and fiber types.

Even though the results indicated that the majority of the people interviewed were from the middle to low income groups, it was also gathered that there are now exclusive second-hand shops where the high-income groups go shopping. The difference between the two being that in the exclusive shops most of the items sold are first washed or dry cleaned before they get into the market and also these shops can be operated from home. So, it's not surprising to see a top executive immaculately dressed and think they must have done their shopping during their trip overseas when in actual fact it was during their last trip to "K"-Boutique.

It was noted that, the selling price variations (price range) of the second hand clothing is affected by;

- Proximity to source: Cost incurred by the vendor to land the bale in the market
- Height of bale; when the bale has just been opened prices are high and get less as the bale height drops because the best items will have been selected.
- Period of the month; prices are usually high during month end when people have just been paid.
- Location of the market- Prices in Harare which acts as the wholesale

market of the imported second hand clothing textiles were comparably lower than in Kariba and Bulawayo. In each town prices were lower in high density area markets compared to low density or urban areas.

- Perception of the ability of the customer to pay more i.e. if the vendor judges that the customer might be able to pay more than an average person then the prices go up.

4. CONCLUSION

The Zimbabwe Clothing and Textile industries will continue to struggle against the stiff The Zimbabwe Clothing and Textile industries will continue to struggle against the stiff competition created by imports from the Far East until the high costs of inputs, high cost of finance, power challenges, use of obsolete machinery and lack of control of the high volumes of illegal imports are addressed by all the stake holders.

References

Baden, S. & Barber, C., (2005). The impact of second hand clothing trade on developing countries," Oxfam, 2005.

Moyo, S., (2008). Review of the factors affecting the Zimbabwe Textile Spinning Sector, (2003-7), Final year project, National University of Science and Technology, Bulawayo, Zimbabwe, May 2008.

Mukurazita, A. (2007). The impact of liberalisation of the cotton merchanting on the Zimbabwe textile industry," Final year project, National University of Science and Technology, Bulawayo, Zimbabwe, May 2007.

Nkala,S. (2008). Textiles and Clothing Sector Brief Zimbabwe Last, Zimtradeiso certified 9001, 2008.

P. Kamau, P. & Michuki, G., McCormick, G. & Gatimu, C. (2011). Adjusting to Chinese ascendancy in the global clothing industry: Kenya's experience, International conference for East African Cotton, Textiles and Apparel (CAT) Value Chain, North Coast Beach Hotel, Mombasa, Kenya, 1-4th November 2011.

Schindler, C. (2011). Global textile and apparel industry-Emerging equations and their impact on Africa, International conference for East African Cotton, Textiles and Apparel (CAT) Value Chain, North Coast Beach Hotel, Mombasa, Kenya, 1-4th November 2011.

Thorburn, J., (2002). Globalisation and the South African textile industry, "Trade and Industrial Strategies (TIPS) Workshop on Globalisation, Production and Poverty in South Africa, Johannesburg, 24 June 2002.

An investigation of the concentration and performance of locally produced cotton desizing enzyme

Josphat Igadwa Mwasiagi[1,2*],Winnie Tonui[1],Jacob Ngadia[1],John Lusweti Kituyi[3],Lodrick Wangatia[2]
[1]School of Engineering, Moi University, Eldoret, Kenya
[2]Ethiopian Institute of Textile and Fashion Technology, Bahir Dar University, Bahir Dar, Ethiopia
[3]School of Science, University of Eldoret, Eldoret, Kenya
([*]Author for correspondence: igadwa@gmail.com)

Abstract: The textile industry has had its share of problems in the last decade. One of the remedial actions proposed by the Government is to improve the competitiveness of the textile sector by reducing the cost of doing business. Given that the Kenyan factories have to pay higher rates than their competition, for electricity, transport and labor, any effort taken to reduce the cost of running a textile process will be a boast to the industry. Furthermore vision 2030, envisages an increase in the manufacturing sector in Kenya. Therefore, the local production of cotton desizing enzyme will no doubt be a contribution to the industrialization process. It was with the aforementioned reasons in mind that a study of the performance of a locally produced enzyme during desizing was undertaken. The challenges reported during the use of the locally produced enzyme included the inability to determine the concentration of the enzyme. This paper reports the use of spectrophotometer to study the concentration and performance of the locally produced desizing enzyme. The results obtained in this research work showed that the locally produced enzyme could remove 85% of the starch in a plain weave fabric. The commercial enzyme could remove 98.3% of the starch.

Keywords: cotton, desizing, spectrophotometer, enzyme, potato waste, local production

1. INTRODUCTION

The sizing process is one of the important processes especially for factories dealing with woven cotton fabrics. As shown in Fig. 1, the weaving preparatory process begins with combination of between 300 to 800 yarns to form a layer of yarns. This is called the warpers beam. Several warpers beams are combined together in the subsequent process which is called sizing. During sizing the yarns are coated with synthetic or starch-based material to impart some strength to the yarns so that they can withstand the vigorous tensile forces involved in weaving. Sizing also reduces yarn hairiness which could adversely affect the efficiency of the subsequent processes. The sizing material could range from 8 to 14% (by weight) of the yarn and its efficiency is affected by the size and type of the starch used (Xu et al., 2011; Hussein, 2007). Some oil may also be added to the sizing ingredients to reduce yarn to yarn abrasion. While the sizing process is important, after weaving the size material is of no further use. Sizing material imparts poor water absorption to the yarn. This is not good, and will be detrimental to the subsequent pre-coloration, coloration and post coloration processes needed to make the fabric acceptable for human and industrial use. The size material can be removed from the fabric in a process called desizing, which involves breaking down the insoluble complex sugars found in the size material into simple soluble sugars. One of the main disadvantage of the desizing process is that it can contribute up to 50% of the total pollution load of a mills waste water (Achwal et al., 1990). Therefore, the optimization of the desizing process will go a long way in cutting down the cost of cotton processing.

Some of the desizing methods used in the textile industry include oxidative, acid and enzymatic desizing. Enzymes are biodegradable and are therefore be an attractive option for most textile factories. Furthermore the enzymatic desizing process produces less adverse effects to the quality of the fabrics (Hussein, 2007). The enzymatic desizing process may be divided into three processes; (i) impregnation (ii) incubation and (iii) after-wash. During the impregnation process the enzyme solution is absorbed by the fabric, at optimum temperature and pH to cause the gelatinization of the size (starch) (Qi et al., 2011; Li et al., 2012). Once the enzyme has been absorbed by the fabric the enzyme breaks-down the size. The control of the incubation period will affect the efficiency of the desizing process. The final process involves the washing away of the broken down complex sugars and hence the removal of the size. This should be down using a detergent and optimum washing temperature. Recent research into the improvement of desizing process, include the use of ultrasonic and plasma treatment methods (Qi et al., 2011, Sahinbaskan, 2011; Mori et al., 1999). The traditional desizing process is however still being widely applied in the textile industry because the new methods are expensive and tend to reduce fabric strength.

Another line of research in the enzymatic desizing process has been undertaken by Anis et al (Bedi, 2003) who used other types of enzymes commonly used in the food industry.

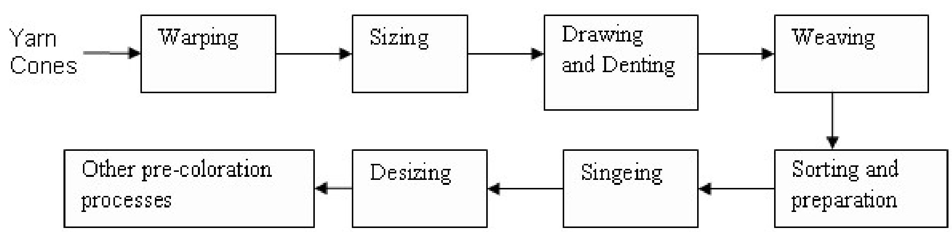

Figure 1 The Sequence of weaving preparatory, weaving and pre-coloration processes

The results of the aforementioned research are encouraging and produced well desized fabric in a shorter period of time. The study has however been limited at the laboratory level. It is hoped that industrial scale research will be undertaken to popularize the new types of enzymes. While the desizing process is mandatory for cotton woven fabric, the desizing chemicals used in the Kenyan textile factories have to be imported from Europe or Asia. This strains the scarce foreign exchange apart from holding up the factory finance due to the fact that the factory has to order higher stocks of desizing chemicals. The textile industry has had its share of problems in the last decade. One of the remedial actions proposed by Kenya Associations of Manufacturers (KAM) is to improve the competitiveness of the textile sector by reducing the cost of doing business (Ikiara & Ndirangu, 2003). Given that the Kenyan factories have to pay higher rates than their competition, for electricity, transport and labor (Government of Kenya, 2007), any effort taken to reduce the cost of running a textile process will be a boast to the industry. Furthermore vision 2030 (Mwasiagi et al., 2011) envisages an increase in the manufacturing industry in Kenya. The manufacturing of cotton desizing enzyme locally will no doubt be a contribution of the industrialization process. It was with the aforementioned reasons in mind that a study of the performance of a locally produced enzyme (Teli et al., 2008) was undertaken. The challenges reported during the use of the locally produced enzyme included the inability to determine the concentration of the enzyme. This paper reports the use of spectrophotometer to study the concentration of the locally produced desizing enzyme. The optimization of the performance of the locally produced enzyme was also undertaken.

2. EXPERIMENTAL

The desizing enzyme was harvested from a bacteria obtained from the soil, by using potato waste as a bait. The potato waste was collected from the Eldoret municipal market. The harvested bacteria amylase was cultured, concentrated and used for the experiments. The experiments carried out included; determination of concentration of extracted enzymes, effect of temperature and pH on enzyme activity during desizing of a plain weave fabric of Nm 8 warps and Nm 14 weft counts, with a size pick-up of 12%.

To determine the concentration of extracted concentration of commercial enzymes, was drawn. By using different concentrations and corresponding absorbance as measured by the A range of 0.03 to 13 g/l of the commercial enzyme was prepared and used to draw a standard curve. The standard curve was used to study the concentration of the locally made enzyme.

The absorbance of the enzymes was determined using the iodine test method. As reported by Anis et al (Bedi, 2003), when starch is mixed with an enzyme solution, the enzyme will break down the starch, up to a point where all the enzyme with be consumed. A measure of the amount of residual can be used to study the activity of the enzyme. If iodine solution is added to the mixture of enzyme and starch, the iodine will react with the residual starch producing a blue color. The intensity of the blue color will depend on the amount of the residual starch which is inversely proportional to the amount of enzyme present before the start of the experiment. The intensity of the blue color was measured using the spectrophotometer.

To study the efficiency of the enzymes, the desizing efficiency was monitored during the desizing of a plain weave fabric using the following parameters; (i) Bath Temp: 60ºC, (ii) Enzyme Concentration: (0.015-4.6 (varied), (ii) Wetting agent : 0.75 g/l (iii) Acetic acid to adjust pH : 7, (iv) Washing: done using detergent. The efficiency of the desizing process was calculated using the weight loss method suggested by Teli and Chakrabart .

3. RESULTS AND DISCUSSIONS

3.1. Standard Curve

The standard curve was drawn as explained earlier. The absorbence of the different concentrations of the commercial enzyme were recorded, and the results are given in Fig. 2.

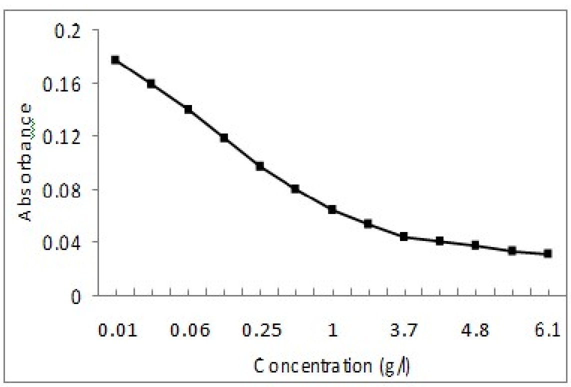

Figure 2 The standard curve obtained by using the commercial enzyme

The curve slopes downwards showing that absorbance is inversely proportional to concentration. As explained earlier when a solution which is highly concentrated with enzymes is reacted with starch solution, there would be a higher percentage of starch degraded than in a solution containing less enzymes. The amount of starch not degraded is free to react with iodine to form the blue color, whose intensity can be measured by the spectrophotometer. Higher absorbance shows that a larger amount of starch was not degraded meaning that there was lower concentration of enzymes. The standard curve was used to study the concentration and performance of the locally produced enzyme.

Different samples of the locally produced enzyme were prepared. The concentration of the locally produced enzyme was determined using the standard curve. The range of the concentration of the locally produced enzyme was from 0.015 to 4.6 g/l. While the study of the factors which influenced the concentration of the enzyme was beyond the scope of this study, it was however noted that the number of days the bait stayed in the soil and the general conditions of the soil (moisture, temperature etc) affected the amount of bacteria harvested.

3.2. The Effects of pH on Enzyme Activity

By preparing a solution of enzyme from the locally produced enzyme a study of the effect of pH on the performance of the enzyme was undertaken and the activity of the enzyme measured using the iodine method. As shown in Fig. 3 the absorbance of the enzyme solution is sensitive to pH. At neutral pH (7) the absorption of the enzyme was at its lowest. This was an indication of maximum activity of the enzyme. Acid and alkali pH do not promote the activity of the locally produced enzyme, and should therefore be avoided. For optimum performance the recommended working pH for the enzyme as indicated by this research work was 7.

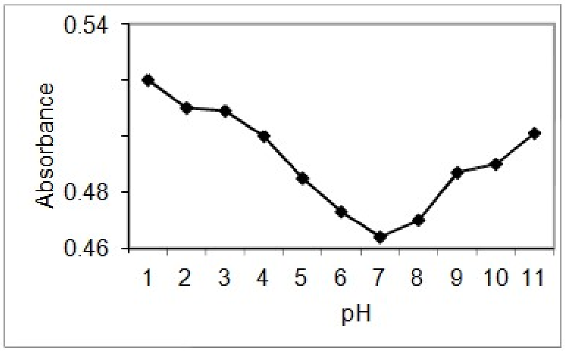

Figure 3 Effect of pH on Enzyme Activity

3.3. The Effects of Temperature on Enzyme Activity

A study of the effect of temperature on the enzyme activity was performed by subjecting the enzyme to different temperatures and by using the iodine test, the activity of the enzyme was monitored. The results are given in Fig. 4. The effect of temperature on the enzyme activity showed similar trend as that of the pH, with an optimum temperature of 70ºC.

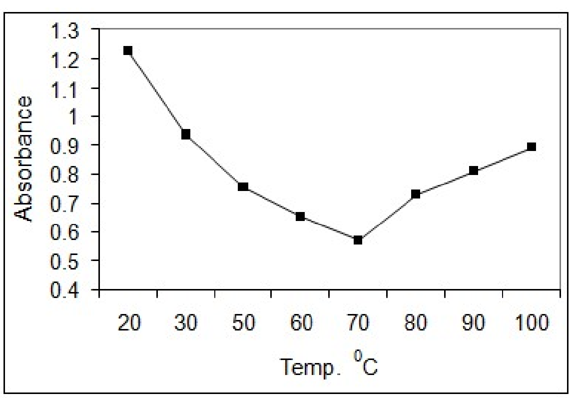

Figure 4 Effect of Temperature on Enzyme activity

At lower temperatures the enzymes were inactive therefore less starch was degraded in the solution. Increase in temperature beyond optimum temperature lead to the denaturing of enzymes leading to less degradation of starch.

3.4. The Effect of Storage on Enzyme Activity

One of the important properties for an industrial product is it's shelf life. The locally made enzyme is in a liquid media. A study of the effect of storage time for the locally produced enzyme was performed by storing the enzyme solution for a given number of days and then studying the activity of the enzyme using the iodine method.

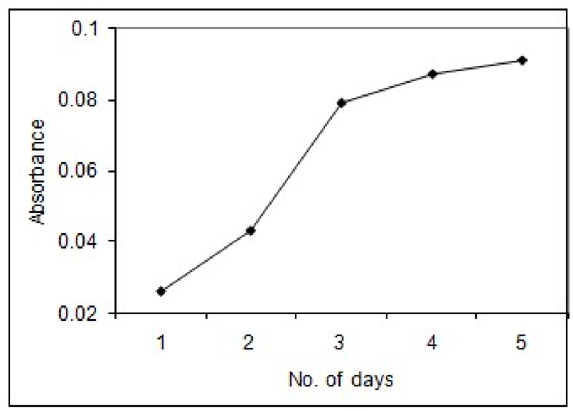

Figure 5 Effect of Storage on Enzyme activity

As shown in Fig. 5 the efficiency of the enzyme decreased with time. The enzyme gets deactivated when stored at room temperatures for longer periods. Enzymes stored for a longer periods are less active in degrading starch. The activity of enzymes was higher when stored for one day and lower when stored for five days as shown in Fig. 5. In fact after 72 hours (3 days) the concentration of the enzyme is drastically reduced. From performance point of view, the enzyme should be used as soon as possible.

3.5. The Performance of the Locally Produced Enzyme during Desizing

Having established optimum performance parameters for the locally produced enzyme, an enzyme solution was prepared and used for desizing. The conditions were; (i) pH: 7; (ii) Temperature: 70°C, storage: freshly prepared. Desizing of a plain weave fabric with a size of 12% was done and the results are given in Fig. 6. From the results obtained, the rate of desizing increased with the increase of the concentration of the enzyme. This is expected. Higher concentration avails more enzymes hence more desizing occurs.

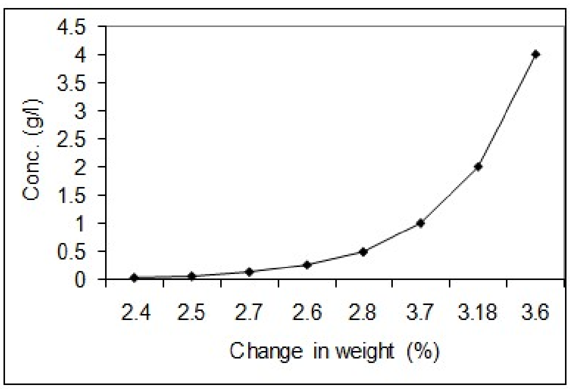

Figure 6 Effect of Enzyme Concentration on Desizing

A comparative study of the performance of the commercial and locally produced enzyme was done and it indicated that the maximum starch removed from a fabric with size of 12% by the locally produced enzyme was 10.2%, while the commercial enzyme removed 11.8%. The performance can therefore be adjudged to be 85% and 98.3% for the local and commercial enzyme respectively.

4. CONCLUSIONS

A locally produced enzyme, harvested from the soil by using potato waste was produced and its concentration and performance investigated using a spectrophotometer. The results obtained from the experiments carried out in this research work, indicated that; (i) The concentration of the extracted enzyme varied from 0.015 g/l to 4.6 g/l, (ii) The optimum performance conditions for the locally produced enzyme during the desizing of cotton fabric was; pH of 7 and temperature of 60°C (iii) The locally produced enzyme was able to remove 85% of the size material. The results are acceptable although lower than that of the commercial enzyme which stood at 98.3%. There is need for further research so as to improve the performance of the locally produced enzyme. Research should also be done to improve its shelf life.

References

Achwal, W.B., (1990). Colourage 37 (9 September) 40-42.

Anis, P., Davulcu, A., & Eren, H. A. (2008). Fibres & Textiles in Eastern Europe, 16(4(69)), 100-103.

Bedi, J. (2003, November 27). Textile/Apparel Sector in Kenya. Textile Sector in Kenya. Retrieved April 22, 2010, from http://www.epzakenya.com/UserFiles/File/

Government of Kenya. (2007, October). A Globally Competitive and Prosperous Kenya, Vision 2030, Nairobi, Government Printers.

Hussein T. (2007, October 29). Common problems in Desizing and their counter measures. Textile Science. Retrieved July 14, 2010, from http http://textilescience.blogspot.com/2007/10/common-problems-in-desizing-their.html

Ikiara, M., & Ndirangu, L. (2003). Developing a revival strategy for Kenya's cotton-textile industry: a value chain approach. Nairobi, Kenya, KIPRA.

J. I. Mwasiagi, S. Ayabei, W. S. Shikoshi, 2010, Performance of a locally produced st Cotton Desizing Enzyme, 1 Engineering, Science and Technology Conference at Masinde Muliro University of Science and Technology, Kakamega, Kenya, 9th-11th June, 2010.

Li, X., Lin, J., & Qiu, Y. P. (2012). Applied Surface Science, 258(7), 2332-2338Qi, M. Z., & Shan, Y. Z. (2011). Advanced Materials Research, 331, 261-264. 1098.

Sahinbaskan, B. Y., & Kahraman, M. V. (2011). Starch – Starke, 63(3), 154–159.

Teli, M. D., & Chakrabarti, C. (2008). Fibers and Textiles in Eastern Europe, 16(2(67)), 95-100.

Xu, M. M., Wang, J. K., & Shi, R. G. (2011). China Textile Science, 3, 25-27.

Polyester Microfibres for Production of a Comfortable and Affordable Sanitary Pad

Londiwe Nkiwane[1*] Christopher Chakwana[1]
[1]National University of Science and Technology, Department of Textile Technology P.O. Box AC 939, Ascot, Bulawayo, Zimbabwe
([*]Author for correspondence: londiwe.nkiwane@nust.ac.zw)

Abstract: The widespread ignorance on how menstrual hygiene negatively impacts on the well-being of girls and women, and contributes to their marginalisation in some societies is a cause for concern in many poor countries. These poor countries are characterized by poor sanitary facilities, among other issues. These, together with lack of sanitary supplies can impact negatively on girls especially when at school, affecting their performance. Sanitary pads prove expensive for the poor. An average pack of 8-10 pads costs $US1.50 and a woman needs two to three packets in one menstrual cycle. This has caused women to resort to unhealthy ways of menstrual management. For instance they use crude materials such as grass and cow dung, which could bruise them and expose them to infections. The aim of the study was to use polyester microfibres for development of a re-usable sanitary pad because polyester has desired properties such as high absorbency, comfort when worn, pose no health risk and are affordable. A polyester pad was produced and synthetic blood used to test for its absorbency and wicking ability, comparing it to the commercial disposable pads. The new pad exhibited improved properties and was ten times less in cost than the cheapest commercial pad hence suitable for the poor communities.

Keywords: sanitary pad, polyester microfibre, menstrual hygiene, absorbency, wicking

1. INTRODUCTION

The natural process of menstruation comes as a big problem for women and girls in Zimbabwe since commercially produced disposable sanitary pads are too expensive. These sanitary napkins or pads classified as absorbent articles are designed to be worn by females to absorb menstrual fluids and other excrements discharged by the body during a menstrual period. A lot of these absorbent articles (both disposable and re-usable) such as diapers, napkins and sanitary pads, can be used for menstrual collection (Serbiak et al., 1993). In Zimbabwe, an average pack of ten disposable sanitary pads costs about $US1.50, which is significantly expensive for poor females, taking into account that the female will need two to three packets per month. A re-usable sanitary pad would be cost effective for the poor as there would not be any need to purchase pads every moth. The pad should have ease of maintenance, thus should wash clean easily leaving no stain. Commercially developed re-usable sanitary pads are not readily available. The cost attached to these disposable sanitary pads makes them too expensive for most rural women. This has led them to resorting to crude means of collecting menstrual blood, which include using pieces of rags, newspapers, cow dung and tissues as sanitary ware.

When re-usable pieces of cloth (which are usually cotton) are used, they tend to remain with permanent stains after wash. This could be a suitable breeding environment for microbes that can be hazardous to health. In most cases the methods used for collecting menstrual blood are very unhygienic and expose women to vaginal infections which can affect their reproductive health (House et al., 2012). The water, sanitation and hygiene (WASH) programmes in Zimbabwe advocate for improved sanitary facilities and resources. Poor sanitary facilities, inadequate provision of sanitary supplies and educational facilities can impact negatively on girls in terms of school access, performance and success.

2. AVAILABILITY OF SANITARY PADS

2.1. Disposable pad

The commercially available sanitary pads are made from conventional fibres cotton and paper. These take into account the weight of the menstrual flow that differs from woman to woman (Jacek, 2002). As much as cotton is used in the making of disposable sanitary pads, it is common knowledge that modern disposable and re-usable articles for personal and health care should offer excellent absorbency and comfort. Materials used for the absorption of menstrual blood should combine all the necessary functions such as; fluid acquisition, distribution and retention (Jacek, 2002).

Available sanitary pads are manufactured locally (e.g. Farai) and also imported (e.g. Johnson and Johnson, Always, Kotex just to mention a few). The difference between these sanitary pads implies that the method of manufacture is different as noted by their different level of performance. The common types of pads include:

The Cotton type: with an absorbent polymers, wings, special dry soft covers that enhance softness and freshness. The absorbent polymer keeps the surface dry so as to avoid leakages and,

The Soft and dry type: with a soft and comfortable surface, made from absorbent polymer and natural wood pulp that absorb moisture quickly and are soft. These however expire after three years on the shelve (Rodrigues et al., 2012).

Disposable sanitary pads made from cellulosic material such as wood pulp fluff have relatively good absorbency and some shape recovery when dry but unfortunately not when wet. The cellulosic material collapses when wet resulting in loss of shape, thus leading discomfort (Rodrigues et al., 2012). Besides, disposable sanitary pads also pose environmental concerns as some of the materials used in the pads are non- biodegradable. Disposal through incineration contributes to pollution, while burying the used pads in the ground is not environmentally friendly either as some of the materials in the pad are non-biodegrade and will remain in the environment unchanged for hundreds of years (Carr et al., 2009). The main components of a disposable pad are as in Fig 1.

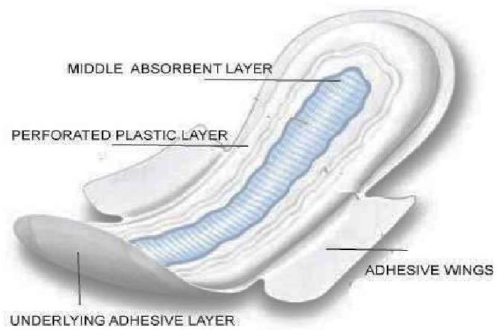

Figure 1 The main components of a disposable sanitary padn (Pinho, et al., 2010).

2.2. Re-usable pad

Re-usable sanitary pads are made of different materials such as cotton, silk, bamboo and hemp that offer a good absorbency (Pinho et al., 2010). Most designs are similar to those of disposable pads, with a bottom layer, a top layer and an absorbent core. New designs may be made with wings that secure around the underpants or without, and just held in place between the body and the underpants with the help of only an underlying adhesive on its bottom layer, whilst the older styles are available in belted styles.

Washable menstrual pads do not need to be disposed of after use and therefore offer a more economical alternative for women. They have become a popular alternative and gaining popularity among women, because they are perfume free, and can be more comfortable for women who suffer from irritations as a result of using disposable pads (Mazgaj et al., 2006). Different types of microfibers such as polyacrylonitrile, polypropylene, cellulose, acetate, and rayon can be used for the production of the re-usable sanitary pads. However, these differ in absorption, wicking and comfort properties. Mixtures of polymers such as polyester-nylon and polyester-polypropylene are also used. Polyester microfiber materials were used due to their ease of availability in Zimbabwe.

The aim of the study was to use polyester microfibres to develop an affordable and re-usable sanitary pad with good performance properties. In order to fulfil the aim of the project the objectives of were set as follows;

i. Design an affordable but reliable sanitary pad from polyester microfibre that provides easy management of menstrual hygiene
ii. Determine functional properties of the polyester pad and compare to those for the pads on the market.

3. METHODOLOGY

3.1. Designing a polyester sanitary pad

The pad was designed using measurements of the Johnson and Johnson re-usable pad design. Polyester microfibre materials were used for pad sample (Kimiran et al., 2008). The polyester microfibre sanitary pad was developed as follows [Fig 3]:

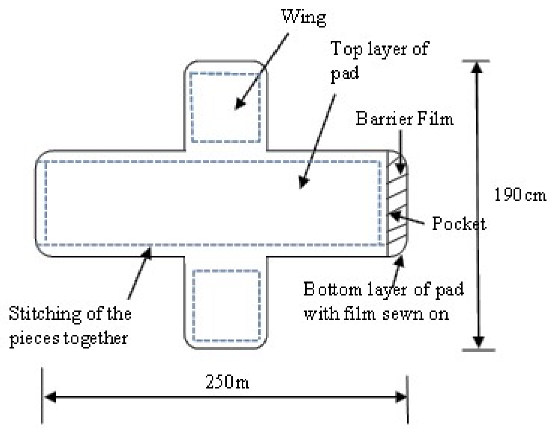

Figure 2 Measurements of the newly designed polyester microfibre pad (Christopher et al., 2014)

The bottom cover and top cover of 250 mm x 60 mm, with wings (65 mm x 40 mm) on each side, were cut to shape from a woven polyester microfibre materials plain and pile respectively (Christopher et al., 2014). The polyester microfibre material was chosen because it is comfortable to wear close to the skin. The woven structure makes it, strong and yet porous thus enhancing breathability of the sanitary pad (Christopher et al., 2014; Sandip et al., 2007). The same measurement was used to cut a piece of polyethylene film to create water proof layer of the pad (cut without wings). The film material was attached to the bottom layer. The polyethylene material is cheap, less bulky, flexible, light and strong enough to withstand forces experienced during normal usage (Mazgaj et al., 2006; Christopher et al., 2014). The pile loops on the top cover will increase the absorption capacity of the fluid and transport it into the inner absorbent core. The top layer is sewn onto the previous two, with the polyethylene film in between, forming a pocket between the top layer and the polyethylene film. The pocket created is where the insert material that absorbs the fluid will be placed.

An insert was cut out from a compactly woven polyester microfibre cloth. The compactness of the weave coupled with the nature of the fibre should allow gradual flow and uniform distribution of the fluid (Kimiran et al., 2008) Non-compact structures infringe on fluid retention. An adhesive material was then sewn onto the wing and the same adhesive material used to fasten the pad to the underwear (Fig 3).

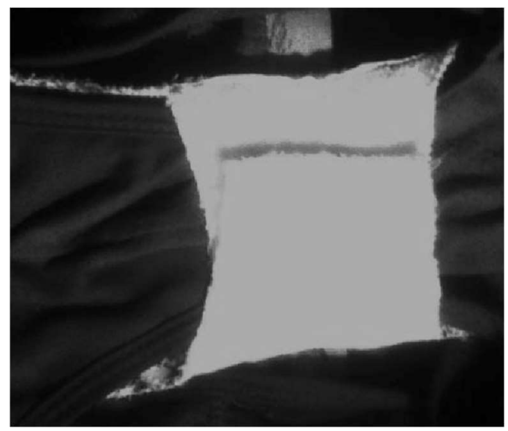

Figure 3 Fastening of pad onto the under wear

3.2. Functional properties of the sanitary pad

The absorbency, leakage, wicking and strike through experiments were conducted on five different thicknesses (ultra-thin which is 2 mm thick; light which is 4 mm thick; regular which is 6 mm thick; medium which is 8 mm thick; and supper which is 10 mm thick) of three different types of sanitary pads which were: imported commercial sanitary pad; locally manufactured commercial sanitary pad; and the newly designed polyester sanitary pad in order to compare their functional properties. This resulted in 15 tests being conducted per experiment.

Synthetic blood used for experiments was made using the following ingredients (Joanne, 2004):

1. Plain flour 10g
2. Distilled water 200ml
3. Scarlet food colouring 2ml

This homogeneous constituency imitates real blood (Christopher et al., 2014, Joanne, 2004).

3.3. Absorbency experiments

Absorbency experiments were conducted according to EAS 96:2008-Annex C, as laid out in the Ugandan Standard Tests for Sanitary Towels Document. A balance was used to determine the amount of uptake of fluid by the pad. Its weight was measured before and after saturating it with the synthetic blood (Joanne, 2004). On reaching saturation point the pad had a 1 kg weight placed on it so as to remove the excess fluid within it. More liquid was blotted from the pad using filter paper and the pad weighed. The purpose of the load was to simulate the weight of the woman as she sits on the pad during menstruation. The load also helps to measure the extent to which the protective barrier prevents leakage in the pad (EAC, 2008).

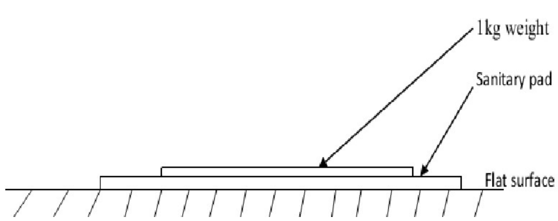

Figure 4 Pad subjected to pressure through of a 1kg weight (Christopher et al., 2014).

Fluid absorbency was calculated using the following formula;

Change in mass in grams (Z)= (X-W)g

Where

W is the initial dry weight of the pad expressed in grams.

X is the final weight of the pad expressed in grams, after absorption of the test liquid.

Z is the change in mass of the pad after absorption of test liquid.

3.4. Leakage experiments

To test the efficiency of the protective barrier used in newly designed sanitary pad, leakage experiments were conducted using the Cone Method Test according to EAS 96:2008-Annex B as laid out in the Ugandan Standards Tests for Sanitary Towels Document (EAC, 2008). Pieces of the protective barrier (polyethylene material) were cut into a square of approximately 6.5 cm per side, and folded into a cone without creasing; These were placed in a filter funnel which was mounted over an empty beaker (Fig 5).

Figure 5 Set up for leakage experiment to assess the effectiveness of the polyethylene barrier material

The funnel was then filled with the test liquid and left to stand for 48 hours after which it was check if any liquid had passed through (EAC, 2008).

3.5. Wicking experiments

The polyester microfibre pad was tested for its wicking property and compared with the available commercial pads. Test were conducted according to BS3424 Method 21(1973) 'Determination resistance to wicking' (EAC, 2008) which is a vertical strip experiment meant to test the ability of the material to take up fluid. The pads were dipped 10 mm in the blood substitute and fluid absorption along the pad was measured in millimetres after 30 minutes (EAC, 2008).

3.6. Strike through experiments

Strike through was determined by dropping the test liquid on the pad sample. A small volume (2.0 ml) of blood substitute test liquid was used and its penetration though the pad was measured (Justinger et al., 2009). Strike through was evaluated by measuring the time taken for the blood substitute to be absorbed from the upper layer of the pad to the inner layer. The drop was closely monitored until the bright red drop of the test liquid appeared like a dull spot on the pad sample, the pads being observed over the same period of time (Justinger, et al., 2009).

4. RESULTS AND DISCUSSION

Absorption capacity of the polyester microfibre pad The results from Fig 6 show sanitary pads absorption capacity (amount of liquid taken up) when subjected to 1 kg pressure. The polyester microfibre pad was compared to each of the five thickness of either the locally or the imported pad (which were classified according to their thicknesses from ultra-thin to the thickest super-size).

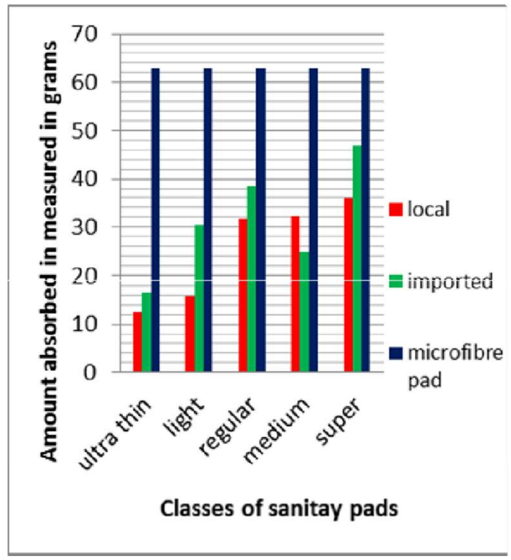

Figure 6 Absorption of test fluid by three different sanitary pads

The results indicate that the polyester microfibre pad had a higher absorption capacity than both (locally and imported) commercially available pads, and its absorbency was higher than that for all thickness. The new polyester microfibre pad could absorb 62 grams of fluid, while the imported pads absorbed more than the locally made (Fig 6). This is because the polyester microfibres have very high absorption capacity as compared to natural fibres that are found in some parts of commercial pads and also used in most re-usable pads. The commercial pads' absorption is a result of super-absorbent gels which form the core that is able to absorb and retain liquid under slight mechanical pressure (Christopher et al., 2014). These gels swell up holding the absorbed liquid in a solid, rubbery state and preventing any leakage, thus helping in making the pad remain feeling dry during usage. Results show that the absorption capacity of the commercial pads, both imported and locally made, is directly related to the thickness of the pads (Christopher et al., 2014).

The thinner the pad, the less absorbent it was and the imported pads performed better than the local brand. It was also observed that the imported pads possessed more gelatinous granules within their structures as compared to locally manufactured sanitary pads, which could have contributed to their better performance. In general the best wet comfort is provided by sanitary pads with higher absorption capacity, and low re-wet. The polyester microfibre pad with its desirable properties such as the high absorbency as compared to its commercial counterparts, also has an advantage of being re-usable. This makes the microfibre pad cheaper as each re-usable pad can be used for at least two years, because the polyester microfibres pads will be stronger and more durable than the cotton fibres pads that can be used for up to two years

4.1. Leakage

The polyethylene material sewn onto bottom layer was tested to determine its ability to prevent blood from passing through. Results showed that the polyethylene protective barrier was liquid proof. This is because polyethylene is an impervious continuous film, hence no liquid was collected in the beaker after 48 hours.

4.2. Wicking rate of the pads

Results (Fig 7) show that the polyester microfibre pad exhibited good wicking properties. The wicking tests also showed that both the local and imported pads exhibited comparable wicking rate. The polyester pad however, performed better than the best of the commercial pads, the ultra-thin. For the locally made pads wicking increases from a regular (6mm thick) to ultra-thin (2mm thick) and increases again from regular to medium (8 mm thick) and super(10mm thick). For the imported pad wicking increased as the pad got thinner. Varying wicking for these pads could be the result of the way the super absorbent gels are distributed within the pad. These super absorbent gels were responsible for the transportation of the fluid within the pad. Different types of gels absorb and distribute the fluids at different rates (Pinho et al., 2010, Christopher et al., 2014).

The high wicking values obtained in polyester microfibres are due to their super-absorbency, absorbing over 7 times their weight (Jacek, 2002; Christopher et al., 2014). The polyester also dries quickly, in one-third of the time of natural fibres (Jacek, 2002). Wicking in sanitary pads allows the blood to be distributed along the entire structure, and the pad to retain and distribute the collected blood in the pad, leading to reduction in leaking (Christopher et al., 2014).

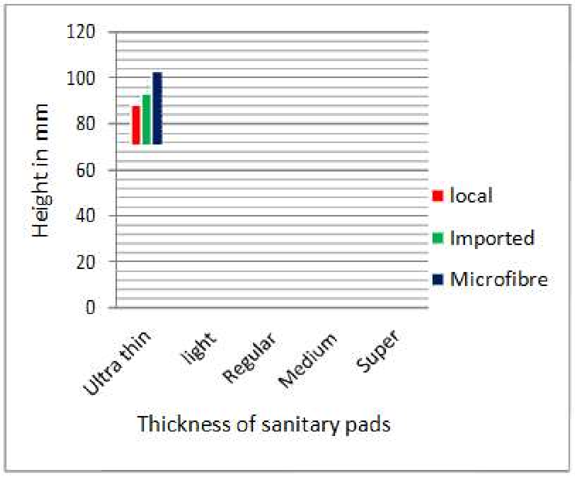

Figure 7 Vertical wicking for different sanitary pads

4.3. Liquid strike through of the sanitary pads

The strike through results shows the rate of fluid transportation from the top part of the pad to the inner collector layer of the pad.

Fig 8 shows that polyester microfibres have better strike through as compared to the local and imported commercial sanitary pads. The commercial locally made sanitary pads exhibited poor strike through properties as compared to imported pads, which also performed poorer than the re-usable designed polyester pad. In an ideal situation, the strike through results in this case indicates the rate at which the liquid was transported from the surface to the interior of the pad.

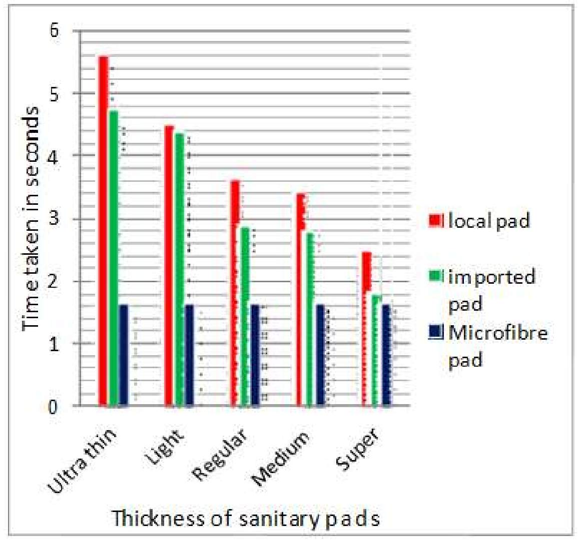

Figure 8 Liquid strike through for three different sanitary pads with varying thicknesses

Good resistance to strike through for polyester microfibres sanitary pad was a result of the high wicking behaviour of the polyester fibres. Wicking properties of the commercial pads increased with increase in thickness, from the ultra-thin type to super-size due to the increase in the quantity of the super absorbent granules that increased within the pad as the its thickness also increased (Christopher et al., 2014). When a pad has good strike through properties; it means that its upper surface readily takes up the blood and transports it to the next layer. The top layer should not cause discomfort to the wearer which means that it should have good wicking properties and yet not leak (Christopher et al., 2014).

4.4. Maintenance of the polyester microfibre pad

The newly designed sanitary pad is made from 100% polyester microfibre in all its components, top cover, bottom cover and insert. The insert is placed in the pocket between the covers. The pad is then fastened round the underwear using a sewn on adhesive material on the wings of the pad. The used insert material can be removed from the pad opening and together with the pad, socked in cold and mild salty water. Soaking in cold water minimizes the chances of staining so that the blood does not leave permanent stains. After soaking the pad is washed using detergent or soap to ensure that microbes are eliminated. Both the insert and outer shell are then dried in the sun, and sterilized using ultraviolet (UV) light and stored for future use.

Sun rays are natural sterilisers that kill germs and bacteria (Shanmugasundaram & Gowda, 2010). The polyester fibre, being synthetic will not attract microbes (Christopher et al., 2014).

4.5. Economics of using the polyester microfibre pad compared to the commercial brands

Table 1 Cost of producing one home-made polyester microfibre sanitary pad (Christopher et al., 2014)

Details	US$
Polyester microfiber material used on each pad (four pieces measuring 250X190mm at$2.00 (enough for one bottom cover, one top cover and at least two inserts)	2
Cost of washing soap ($0.20 worth of soap is required for 5 litres)	0.08
Polyethylene film-60mmX250mm (a1metreX1.5metre material cost $4.00)	0.06
Total cost of Velcro strips used-4cm (100cmofVelcroth at cost$1)	0.04
Total cost of materials and maintenance	1.18
Labour at 20% of total cost	0.24
Total cost of pad	2.40

4.6. Cost of production per sanitary pad

Production of one polyester microfibre sanitary pad is calculated taking into consideration cost of the materials used, and labour costs calculated as 20% percentage of total cost of materials (Table 1) (Christopher et al., 2014).

Re-usable baby diapers and sanitary pads made from a blend of bamboo and cotton fibres can last up to two years (Christopher et al., 2014; Huang et al., 2004; Martin et al., 2007). As cellulosic fibres they are prone to bacterial attacks, which means that the pads from polyester microfibres will last longer as polyester is resistant to bacterial attacks. Table 1 shows that the total cost of one re- usable polyester microfibre sanitary will be $2.40 and one would need at least three re- usable polyester sanitary pads per month will enable her to wear one pad while the second one is drying and the third on stand-by. This will cost the woman $7.20 for three pads that will last more than two years. Generally, for commercially available disposable pads, most women can spend $3.38(£2.25) to $7.5 (£5) per month on disposable sanitary pads (Christopher et al., 2014), which will amount to between $40.50 and $90.00 per year. The minimum amount spent in Zimbabwe will be $36.00 ($1.50 X 2 packets/month X 12) per year for locally manufactures and up to $86.40 to ($3.6 X2packets/month X12) for imported pads. The polyester microfbre sanitary pad is cheaper than the lowest priced disposable sanitary pads. The microfibre pad could be the most suitable as compared to available pads as it is not just cheaper than the disposable pads, but also washes easily and dries quickly as compared to re-usable pads made from cotton. The polyester microfibre is also comfortable close to the skin (Huang et al., 2004).

The re-usable microfibre sanitary pad also has an advantage of being highly absorbent with the capacity to quickly distribute the liquid within the pad coupled with minimum leakage (Martin et al., 2007). The microfibre pad offers the user a pad with performance properties similar to those found in the commercially available disposable brands, and yet affordable. The pad also offers easy maintenance and reduced straining, which are important in cultures where menstruation is associated with social stigma because women and girls can manage their menstruation without being noticed. The ease of washing also helps to eliminate the blood from the pad pieces. Blood remnants in pads can trigger the development of bacteria that may cause an odour in women with poor menstrual hygiene management. Besides the polyester microfibre pad will be more durable than the cotton pad because of its resistance to microbial attack. The developed pad is easy to wear as it sticks to underwear, thus reducing the risk of the pad falling during use.

The nature of materials used for making re-usable pads has an effect on the drying time and subsequently the cost of the product. In this case the cost covers the drying time, pad maintenance and the durability. The amount of time required for a pad to dry, combined with the frequency of replacing a soiled pad with a fresh pad, dictates the number of pads needed to get through an average menstrual cycle. The number of pads included in a package is directly proportional to the retail cost of the product. This is an important consideration, also given that the average consumer has very limited purchasing power. The faster the pads dry, the fewer pieces needed to be included in a package and therefore the cheaper the total cost of the package. Consequently, the re-usable pad is made from polyester rather than cotton due to the significant variance in drying time (Christopher et al., 2014, Shanmugasundaram & Gowda, 2010).

5. CONCLUSION

The re-usable polyester microfibre pad could be a solution to most poor women's need (especially those from rural areas where there are very few or even none, shops that sell pads). Menstrual hygiene management becomes a challenge. The designed polyester microfibre pads are easy to make as they can be produced in a rural or urban setting. A pack of three re-usable polyester microfibre pads will cost $7.20, and no other purchase could be made for the next two or more years. For women with heavy flows, a pack of five pads may be required and still this will cost them $12 in two or more years which is $24 cheaper than the lowest priced disposable pads required in a year. Given the fact that most of the cotton based re-usable sanitary pads have a lifespan of up to two years, the assumption is that the re-usable microfibre sanitary pad will last much longer due to the higher strength of the polyester microfibres, as well their non- susceptibility to microfibres (Christopher Chakwana, et al., 2014). Polyester microfibres possess more properties required in sanitary pads, such as absorbency, wicking and easy wash. The pad can be used over and over again, making it a cheaper option for poor women.

References

Carr, D. J., A. G. Heward, R. M. Laing and B. E. Niven (2009). Journal of the Textile Institute 100(1): 51-56.

Christopher Chakwana and L. Nkiwane (2014). Textiles and Light Industrial Science and Technology 3(TLIST): 48-56.

EAC (2008). Uganda Standard for sanitary towels specification. Tanzania, EAC

House .S, Mahon .T and C. .S (2012). "Part of Menstrual hygiene matters; A resource for improving menstrual hygiene around the world, Module 3." Retrieved 5 January, 2013, from www.wateraid.org/mhm

Huang, M.-H., S. Li and M. Vert (2004). Polymer 45(26): 8675-8681.

Jacek .D (2002). AUTEX Research Journal 2(3): 153-165.

Joanne, M (2004). "Development of a synthetic blood substitute for use in Forensic science teaching", London Metropolitan University. Msc.

Justinger, C., M. R. Moussavian, C. Schlueter, B. Kopp, O. Kollmar and M. K. Schilling (2009). Surgery 145(3): 330-334.

Kimiran Erdem, A*. , Sanli Yurudu, N.O.(2008). IUFS Journal of Biology 67(2): 115-122.

Martin, T. P., S. E. Kooi, S. H. Chang, K. L. Sedransk and K. K. Gleason (2007). Biomaterials 28(6): 909-915.

Mazgaj, M., K. Yaramenka and O. Malovana (2006). "Comparative Life Cycle Assessment of Sanitary Pads and Tampons". Stockholm, Royal Institute of Technology.

Pinho, E., L. Magalhães, M. Henriques and R. Oliveira (2010). Annals of Microbiology 61(3): 493-498.

Rodrigues, M. T., A. Martins, I. R. Dias, C. A. Viegas, N. M. Neves, M. E. Gomes and R. L. Reis (2012). Journal of Tissue Engineering and Regenerative Medicine 6(10): e24-e30.

Sandip V.,P. Narsingh and R. Panigrahi (2007). AUTEX Research Journal 7(3):148-158.

Serbiak, P. J. A., WI), Cesco-cancian, Annamaria (Appleton, WI), Fredrick, Julie K. (Larsen, WI), Peerenboom, Robert J. (Little Chute, WI) (1993). "Sanitary napkin with a faster transverse wicking absorbent layer to indicate the approach of maximum fluid capacity". United States, Kimberly-Clark Corporation (Neenah, WI).

Shanmugasundaram, O. L. and R. V. M. Gowda (2010). Indian Journal of Fibre & Textile Research 35: 201-205.

A study of the antimicrobial efficancy of silk suture

Sibanda Pethile[1*] Ncube Sizo and Ndlovu Lloyd[1]
[1]National University of Science and Technology, Bulawayo, Zimbabwe
([*]Author for correspondence: pethile@gmail.com)

Abstract: In recent years many antimicrobial sutures have been developed in a quest to deal with the problem of surgical site infections in the medical world. This study was done to find out the effects of pre-treating the braided suture materials before applying the antibacterial coating agent. 0.1N sodium hydroxide (NaOH) solution was used to pre-treat / pre scour the sutures to remove impurities and also to open the structure of the silk sutures so as to allow the coating agent to penetrate into the suture structure. A biodegradable polymer and an antibacterial drug, that is, polycaprolactone (PCL) and Sulphamethoxazole trimethropm (SMZ) were used as the coating agent. The polymer PCL was made into a solution of 10% whilst the drug SMZ was made into a solution of 2500µg/ml. 5cm pieces of silk braided sutures were first cut aseptically and then washed in 0.1N NaOH solution and dried. After this pretreatment, they were coated with the antimicrobial coating agent and then dried. The pretreated sutures were then evaluated and compared, with non-treated sutures acting as the control. Antimicrobial tests were then carried out to find out the effects of pre-treated and non-pre-treated sutures on the antimicrobial properties of the sutures. Through this study it was found that the pre-treated sutures exerted a better sustained efficacy assay compared to those that are not pretreated, however mechanical properties were lowered but were still within the required standards for antimicrobial sutures.

Keywords: Silk suture, antimicrobial, scouring, tenacity, surface morphological analysis

1. INTRODUCTION

The development of infection oozing and scar at the incision site following suturing is among the main concerns that surgeons, physicians and patients have in the medical field (Farid et al., 2008). The role of suture material in the development of wound surgical site infections has been the subject of speculation among surgeons since the 1960s (Alexander et al., 1967). A numerous number of bacteria may contaminate the suture material and once tissue material becomes contaminated, wound healing may become very difficult (Rodeheaver et al., 1983; Uff et al., 1995).Therefore sutures impregnated or coated with antibacterial agents have been developed in an attempt to reduce bacterial adherence and colonization of suture materials (Liu, et al., 2010).

Silk fibers in the form of sutures have been used for centuries due to their ability to offer a wide range of properties and their use as a material for wound ligation (Altman et al., 2003). Silk fibers as a suture material are well known for their impressive mechanical properties, biocompatibility, environmental stability and morphological flexibility (Vepari & Kaplan, 2007). Any suture product of natural or synthetic composition and of mono or multi-filament construction is susceptible to bacterial attachment and colonization.

Polycaprolactone (PCL) is a widely used polymer in the field of medical research due to its appealing properties as linear aliphatic polyester that is biodegradable whose biocomaptibilty, low melting and elastomeric properties make it even more appealing for use in tissue engineering. To date, biodegradable polymers have been successful in the development of antimicrobial sutures as shown by a considerable decrease in the bacterial adherence to triclosan-coated sutures invitro. Therefore, a continued research in the development of sutures with antimicrobial properties would be worthwhile to further lay a foundation in their development (Vila et al., 2008; Gao et al., 2011).

This research was done so as to find out the effects of pre-scouring sutures with sodium hydroxide solution on the resultant antimicrobial coated silk sutures. Suture pre-treatment with sodium hydroxide (NaOH) is therefore very important in exploring the methods of producing antimicrobial coated silk sutures which can posses the properties that match the ones of the current ones used in the medical field.

2. MATERIALS AND METHODS

2.1. Suture material

The silk suture material that was used was procured from Jiangsu Medical Supplies Ltd Co. in China. It was a size 2-0 silk suture of 0.320-0.331 mm diameter. This suture was cut into 5 cm pieces for antimicrobial testing and this was done inside a laminar air floor to create an aseptic condition.

2.2. Coating agent

The suture coating agent consisted of an antimicrobial agent mixed with a drug coating carrier. Compound Sulphamethoxazole (SMZ) tablets where purchased and used as the antimicrobial agent. A biodegradable polymer, Polycaprolactone (PCL) of 80, 000 molecular weight was chosen to act as the drug carrier or polymer add on for the suture. This was dissolved together with the drug in aqueous acetic acid. 2500 µg/ml antibacterial agent was first suspended in acetic acid and homogenized at high speed for 10 minutes to reduce the gathering of particles. Then, PCL was added into the resulting suspension and stirred for 1 hr at high speed to build up a drug concentration of 10% PCL/SMZ solution (Viju, et al., 2013).

2.3. Test organisms

To test the antimicrobial properties of the prototype sutures , two test strains where used , that is, Staphylococcus Aureus (ATCC25923) and Escherichia coli (ATCC25922) as they are the most common enteric pathogens (Ming et al., 2008). All the strains were cultured to late logarithmic growth phase on agar plates at 37˚C for 18 hrs before conducting tests under aseptic conditions in a laminar airflow (Janiga et al., 2012). The colonies were touched with a loop and then transferred to a tryptone soy broth (TSB) and incubated at 37˚C until the growth reached turbidity equal to or greater than that of 0.5 McFarland standard. The culture was then diluted using broth to give a turbidity of 1 x 108 (CFU)/ml bacterium concentration.

2.4. Suture pretreatment

The silk suture was cut into 5cm pieces and sterilized in autoclave at 121˚C. After this, sutures were divided into two, whereby the first batch was to be coated without pre-treatment and then the other batch was scoured first before antimicrobial coating using 0.1N Sodium hydroxide solution (NaOH) and then washed in distilled water (Lou et al., 2008; Janiga et al., 2012).

2.5. Coating process

A uniform coating along the length of the suture was done through the use of a roller drying system thus coating the sutures with the drug polymer combination using a dip coating method (Masini et al., 2011).

2.6. Antibacterial activity

2.6.1. Zone of inhibition Assay

A qualitative agar diffusion test was carried out on the coated silk sutures of 5 cm in length (Elayarajah et al., 2011). It was done according to the Antimicrobial Performance Evaluation (Zone of inhibition assay) Standard (ISO 20645:2004) Textiles Evaluation of antibacterial properties - Part 1: agar diffusion method (Singh et al., 2005; Pinho et al., 2011). The antimicrobial braided silk sutures with and without pre-treatment with sodium hydroxide solution were challenged in vitro with indicator strains of the selected test organisms. The zone of inhibition diameter was done according to the Fig.1. The inhibition zone diameter was calculated according to the following formula (KimiranErdem et al., 2008): -

$H = (D-d)/2$

Where:

H is inhibition zone (mm);

D is the total diameter of specimen and inhibition zone (mm);

d is the total diameter of specimen (mm)

2.7. Sustained efficacy Assay

After 24 hrs of incubation at 37°C, suture samples were evaluated by zone of inhibition assays, as described above and then transferred daily onto new Petri plates growing a similar number of bacteria. This assay was terminated when the sutures ceased to inhibit bacterial growth similar (Ming et al., 2007).

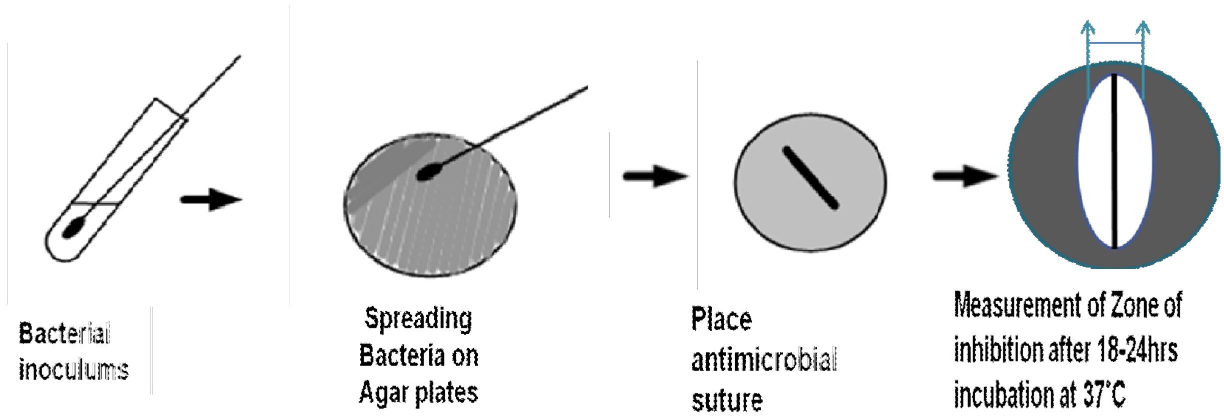

Figure 1 Measuring the Zone of inhibition

2.8. Surface morphological analysis

To observe the effect of scouring sutures before antimicrobial coating on the suture, the scanning electron microscope (SEM) was used. SEM images of sutures pre-treated with NaOH and none pre-treated sutures where obtained and then compared with SEM images of sutures without antibacterial agent.

2.9. Mechanical evaluation

2.9.1. Measurement of diameter

The diameters of the treated sutures were measured after coating and drying at five different positions along the length of the suture using an electronic thickness gauge CH-10-AT. The average diameter of each suture was calculated and expressed in millimeters. The change in diameter was calculated using the following relationship.

Change in diameter = (D1-D2) / D1

Where

D1 is the diameter of suture before coating and

D2 is the diameter of suture after coating.

3. TENSILE PROPERTIES

The tensile properties were measured using the universal testing system (YG-B026G, China). According to ASTM D2256 Standard Test Method for Tensile Properties of Yarns by the Single Strand Method, the sutures were tested for breaking tenacity, elongation at break, initial modulus and fracture strain, stress and work. The gauge length used was 50 mm and extension rate was 200 mm/min. The tests were done under a standard atmosphere for textile testing which involved a temperature of 20 ± 2 ˚C and relative humidity of 65±2% RH.

3.1. Results and discussion Antibacterial activity Zone of inhibition Assay

All the sutures pretreated by washing with NaOH (scouring) showed larger zones of inhibition diameters. This shows that the scouring treatment opens up the polymeric braided structure of the silk sutures, therefore enlarging the diameter of the suture and at the same time allowing more antibacterial agent particles to penetrate the braided suture structure. This explains as to why a scoured suture is able to retain more antibacterial agent than non-scoured suture as illustrated by Fig. 2.

Table 1 Zone of inhibition diameter for scoured and not scoured sutures

Suture Treatment	Zone of inhibition (mm) (mm)	
	S. aureus	E. coli
Scoured	9.8±0.86	11.1±0.78
Not scoured	8.5±0.74	9.2±0.70

3.2. Sustained efficacy assay

The sutures that were scoured first by pre-treatement with 0.1N NaOH showed longer lasting antimicrobial activity as compared to the non-scoured sutures. Zones of inhibition of pre-scoured sutures where observed against both the test strains, E. Coli and SA with antimicrobial activity lasting for up to 5 days whereas the non-scoured sutures lasted only 4 days as shown in Table 2. Table 2 also shows that pre-treated sutures had larger zone diameters accounting for greater penetration of antibacterial agent into the suture braided structure.

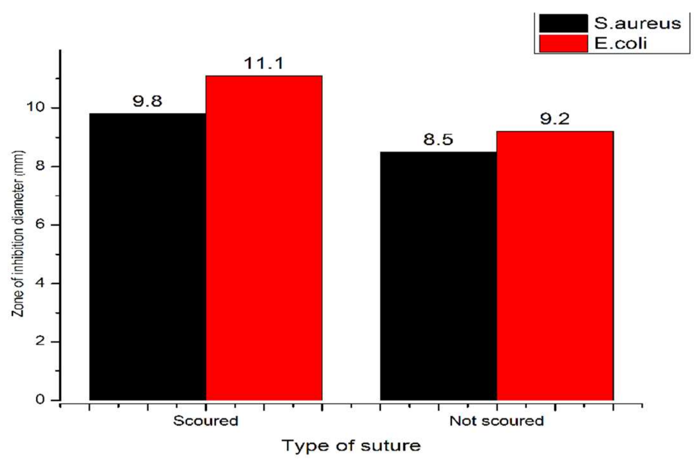

Figure 2 Zone of inhibition Assay

Table 2 Sustained efficacy assay of sutures against S.aureus and E.coli

	Zone of inhibition (mm)			
	S.aureus		E.coli	
Time (Days)	Scoured	Not scoured	Scoured	Not scoured
1	11.1±0.78	8.5±0.74	9.8±0.86	9.2±0.70
2	9.8±0.86	7.1±0.69	8.8±0.65	7.82±0.74
3	6.3±0.62	3.8±0.51	5.4±0.51	3.97±0.67
4	4.1±0.55	2.77±0.46	3.8±0.47	3.32±0.41
5	2.60±0.47	0	1.5±0.34	0
6	0	0	0	0

3.3. Surface morphological analysis

Figure 3 above shows a rougher surface on the suture pre-treated with NaOH (c) as compared to suture (b) which was not pre-treated. The SEM images show that a stable and regular coating was applied on the surface of the suture after the addition of PCL into the coating agent. This shows relatively good properties for sutures as it prevents friction during suturing process. However according to the results observed in picture (c) it is seen that the polymeric structure of the silk fibers is relatively destroyed when a suture is scoured with NaOH.

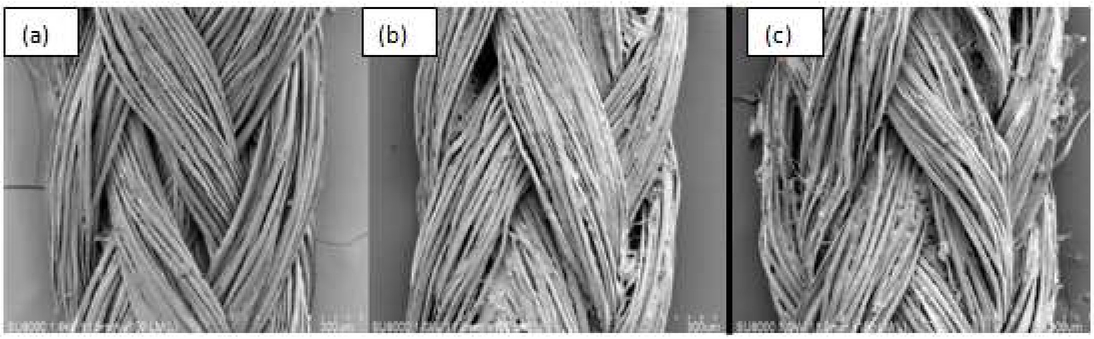

Figure 3 Scanning Electon Microscope (SEM) images showing the effects on the physical appearance of the antibacterial treated and untreated suture (a) untreated suture , (b) SMZ +PCL treated suture and (c) NaOH pretreated suture.

Therefore, as much as sutures pretreated with NaOH showed relatively good results on antimicrobial activity, its effects on the physical properties of the suture were not very good.

4. MECHANICAL EVALUATION

4.1. Measurement of diameter

The results showed that pre-treating the suture by scouring before coating the silk sutures with antimicrobial agent had a large effect on the diameter of the suture. As it is shown by the graph in Fig.4, diameter of the scoured suture is larger than that of the non-scoured suture. However, the increase observed was still within the required diameter of (0.30-0.39) experimental reference Chinese standard (YY0167-2005) for a 2-0 suture.

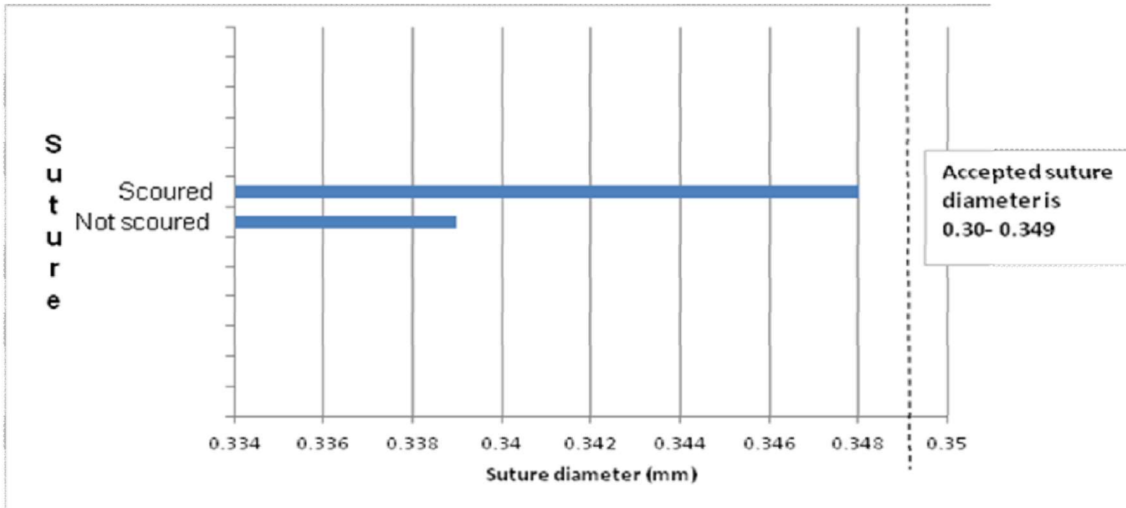

Figure 4 Effects of scouring on suture diameter

4.2. Tensile Properties

A decrease in both suture tensile properties was observed as the suture was subjected to treatment with coating agent. However more decrease was observed for sutures that had been pretreated with NaOH. The decrease in the overall strength was probably due to the suture losing some of its mechanical properties during suture pre-treatment, as shown by the surface morphological results of the suture.

Table 3 Suture Tensile properties

Property tested	Not coated	Type of suture	
		No Pre- treatment	Pre- treated with NaOH
Breaking strength (N)	27.4±1.5	24.8±1.4	20.51±2.3
Elongation at break (mm)	8.94±2.6	8.66±0.6	10.57±1.8
Initial modulus (N/mm)	94.69±2.3	92.28±0.8	90.04±0.4
Fracture stress (N/mm)	97.45±0.8	92.35±2.6	95.61±1.9
Fracture strain (%)	17.4±1.7	19.1±1.9	23.13±2.5
Fracture work (N Ÿ/mm)	100.43±1.1	104.14±2.3	104.14±2.7

5. CONCLUSIONS

A number of researchers in this field have used this method of scouring the silk sutures with NaOH first before antimicrobial treatment. This is relatively common method as observed by the author, but however through the results obtained from this study, it shows that, this can be a disadvantage when used for medical silk sutures. The antimicrobial results observed for suture pretreated with NaOH where relatively good, with all of them surpassing the non-pretreated sutures. However, when observed in the SEM, it was seen that the NaOH destroys the silk suture surface fibers as the sutures pretreated with NaOH had a rougher surface compared to those not scoured.

References

Alexander,J. W., J. Z. Kaplan and W. A. Altemeier (1967). Annals of surgery 165(2): 192-199.

Altman, G. H., F. Diaz, C. Jakuba, T. Calabro, R. L. Horan, J. S. Chen, H. Lu, J. Richmond and D. L. Kaplan (2003). Biomaterials 24(3): 401-416.

Elayarajah B, Rajendran R and Venkatrajah B (2011). International Journal of Pharmaceutical Sciences Review and Research 7(2): 336–343.

Farid Saleh, B. P., Danielle Lodi,and Khalid Al-Sebeih (2008). International Journal of Medical Sciences 5(6): 354-360.

Gao, G., D. Lange, K. Hilpert, J. Kindrachuk, Y. Zou, J. T. J. Cheng, M. Kazemzadeh-Narbat, K. Yu, R. Wang, S. K. Straus, D. E. Brooks, B. H. Chew, R. E. W. Hancock and J. N. Kizhakkedathu (2011). Biomaterials 32(16): 3899-3909.

Janiga, P. K., B. Elayarajah, R. Rajendran, R. Rammohan, B. Venkatrajah and S. Asa (2012). Journal of Industrial Textiles 42(2): 176-190.

KimiranErdem, A., SanliYurudu, N. O. (2008). IUFS Journal of Biology 67(2): 115-122.

Liu, H., K. K. Leonas and Y. Zhao (2010). Journal of Engineered Fibers and Fabrics 5(4): 10-19.

Lou, C.-W., C.-H. Yao, Y.-S. Chen, T.-C. Hsieh, J.-H. Lin and W.-H. Hsing (2008). Textile Research Journal 78(11): 958-965.

Masini, B. D., D. J. Stinner, S. M. Waterman and J. C. Wenke (2011). Journal of Surgical Education 68(2): 101-104.

Ming, X., S. Rothenburger and D. Yang (2007). Surgical Infections 8(2): 201-208.

Ming, X., S. Rothenburger and M. M. Nichols (2008). Surgical Infections 9(4): 451-457.

Pinho, E., L. Magalhaes, M. Henriques and R. Oliveira (2011). Annals of Microbiology 61(3): 493-498.

Rodeheaver, G. T., L. D. Kurtz, W. T. Bellamy, S. L. Smith, H. Farris and R. F. Edlich (1983). "Biocidal braided sutures." Archives of surgery (Chicago, Ill. : 1960) 118(3): 322-327.

Singh, R., A. Jain, S. Panwar, D. Gupta and S. K. Khare (2005). Dyes and Pigments 66(2): 99-102.

Uff, C. R., A. D. Scott, A. G. Pockley and R. K. S. Phillips (1995). Biomaterials 16(5): 355-360.

Vepari, C. and D. L. Kaplan (2007). Progress in Polymer Science 32(8-9): 991-1007.

Viju, S. and G. Thilagavathi (2013). Journal of Industrial Textiles 42(3): 256-268.

Vila, J., A. Soriano and J. Mensa (2008). EnfermedadesInfecciosas y MicrobiologíaClínica 26(1): 48-55.

Tensile properties of PET fibers incorporated with bacteria spores

Lucy Ciera[1*], Fredrick Nzioka[1], Wangari Njuguna[2]
[1]Technical University of Kenya, Nairobi, Kenya
[2]Bahir Dar University, Bahir Dar, Ethiopia
([*]Author for correspondence: lucyciera2@gmail.com)

Abstract: The demand for high-tech textiles with special functionalities is currently increasing. This has led to the continuous effort to modify conventional polymeric textile materials like Polyethylene terephthalate (PET). Previous studies have proved that bacteria spores can be incorporated in PET fibers during melt extrusion. However, the effects of extruding spores in the fibers on the resulting fiber`s tensile properties have not been studied deeply. In this work, tensile tester, scanning electron microscopy (SEM), transmission electron microscopy (TEM) and optical microscopy (OM) were used to study the tensile properties of PET/spores fibers. Results indicated that tensile strength, Young's modulus and elongation at break were dependent on spore concentration. Nevertheless, the properties of the resulting fibers were found to be as of same tensile quality as normal PET fibers.

Keywords: Bacteria spores, PET fibers, extrusion, tensile properties

1. INTRODUCTION

With the current switch from conventional use of textile to use of textile with additional superior functionalities, the textile industry has witnessed a tremendous increase in demand for functional textile materials which can basically be defined as materials tailored and engineered to give specific properties that are suitable for a given application (Coman et al., 2010). Due to this current demand, efforts have been made to transform the traditional textile materials by incorporating different additives to add new values or functionalities or to improve the chemical, physical and biological properties. This has resulted to production of innovative high-performance textile materials for various specific end use which include personal protective equipment (PPE), medical applications and packaging (Coman et al., 2010; Gupta, 2011). One of the traditional textile materials that are being transformed into functional textiles is Poly Ethylene Terephthalate (PET) popularly known as polyester (Oerlikon, 2010). Polyester is a long-chain semi-crystalline thermoplastic polymer that is widely produced worldwide due to its superior mechanical properties like high tensile strength, low cost and ease of production as well as its ability to be recycled (Broda et al., 2007; Zeng et al., 2012). Up to date, many functional additives have been incorporated into PET polymer among them being nucleating and antimicrobial additives, enzymes, colorants, cross-linking as well as matting agents (Gao & Cranston, 2008, Park et al., 2010). In most cases, functionalizing additives are usually applied on the material surface as a post- treatment process. This means that the additives are physically or chemically bound on the material surface (Park et al., 2010, Vihodceva et al., 2011). The disadvantage with this technique is that resistance to abrasion and washing is never guaranteed as well as some finishing methods like spraying can be detrimental to the environment due to spills during spraying (Vihodceva et al., 2011; Kusuktham, 2012). Additionally, poorly applied coatings may lead to partial loss during use, care and storage (Kusuktham, 2012). On the contrary, applying functionalizing additives during fiber production can entrap the additive in the polymer matrix during solidification of the fiber forming polymer and may take part in the crystallization process resulting in a strong bond between the polymer and additives as well as providing high resistance to abrasion (Broda et al., 2007, Vihodceva et al., 2011). Moreover, due to the porous nature of the fibers, the functionalizing additive can slowly migrate to the surface acting as a slow release mechanism that can result to an extended period of additive activity (Hong et al., 2006). This means that the release rate will be influenced by the physical and chemical characteristics of the polymer in relation to the characteristics of the additive (Williams et al., 2005; Shao-Yun et al., 2008). A recent study demonstrated that bacteria spores can be incorporated in PET fibers during extrusion (Ciera et al., 2014). However, the extent to which the spores can be incorporated without fundamentally changing the properties of PET fibers needs further investigation. The present study looks into the tensile properties of PET fibers with incorporated spores. This is aimed at checking if the produced fibers will be different from normal PET fibers in terms of their tensile properties. The PET fibers incorporated with spores (0%, 2%, 4% and 6%) were extruded in a single screw extruder. The survival of PET was first tested and later spores-PET interaction and dispersion was studied with Scanning electron microscopy (SEM), Transmission electron microscopy (TEM) and optical microscopy (OM). Afterwards, the tensile properties like tensile strength, Young's modulus and elongation at break were studied on Favimat tensile fiber testing machine.

2. MATERIALS AND METHOD

2.1. Extrusion

The PET pellets were initially dried in an oven for two days at 70°C (Doudou et al., 2005) after which pure bacteria spores were added by gravimetric dosing during spinning to obtain a 0 (control), 2, 4 and 6% concentration of spores to PET polymer. This mixture was then extruded into multi-filament fibers by a single screw extruder (General extrusion technology, China). The three-barrel heating zones were set to 270°C for the feed stock (transport of material), 270°C for plasticizing (compression) and 275°C for pumping (metering). The die was heated at 275°C, the pressure was around 6.5 Mpa while the average residence time was approximately 4 minutes. The resulting fibers had an average linear density of about 7.5dtex.

2.2. Characterization methods

2.2.1. Survival tests

The resistance of the extruded spores was determined by the growth/germination biological assay as explained by Ciera et al (Ciera, 2014). The samples were sterilized by subsequently soaking first in a sodium hypochlorite solution, followed by a Dettol solution and finally in an ethanol solution for 10 minutes each, where after they were inoculated on Nutrient Agar plates and incubated at 40°C for 24 hours. Finally, the plates were visually checked for colony forming spots (Ciera, 2014).

2.3. Tensile testing

The tensile properties, like tensile strength, modulus and elongation at break of the resulting extruded spores/PET fibers were determined with the FAVIMAT-ROBOT (Textechno, Germany). All samples were kept in a conditioned room of 55% humidity and a temperature of 20°C for 24 hours before testing. An average of 50 single filaments was tested for each spore concentration level. The two-sample Kolmogorov-Smirnov statistical test was used to determine how significantly the spores affected the tensile properties at all the spore concentration level (0%, 2%, 4% and 6%).

3. RESULTS AND DISCUSSION

3.1. Survival tests

Dormant bacteria spores are more resistant to extreme environmental conditions than their vegetative cell counterparts. Among the factors that contributes to the spores resistant includes saturation of the spore chromosome with a group of small, acid-soluble proteins (SASP) of the a/b type, low water content in the spore protoplast/core, decreased spore permeability, high levels of minerals in the spore core, etc. (Popham et al., 1995).

The survival test results of spores extruded in PET fibers is shown in Fig. 1. The control sample of pure PET fibers with no spores (Fig. 1a) shows no growth around the fibers, while the PET fibers extruded with 4% spores shows bacterial growth all around the fibers (Fig. 1b). The growth observed in Figure 1b confirms that spores survived the extreme melt extrusion parameters (High temperature, pressure, shear stress and residence time). As explained by previous studies, the resistance of spores to extreme melt extrusion conditions could have been due to low operating pressure, short residence time and possible agglomeration of spores in the extruder (Ciera et al., 2014; Boesel & Reis, 2008).

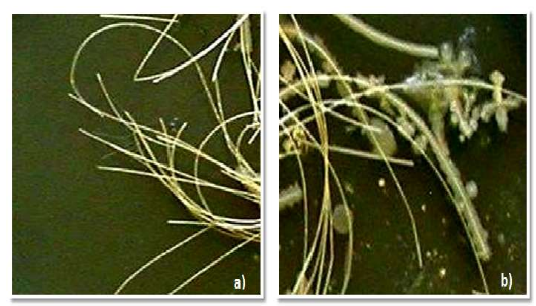

Figure 1 Viability tests (PET fibers inoculated in nutrient medium and incubated for 24 h at 40°C. a) Control PET fibers with no spores showing no growth, b) PET fibers extruded with 4% spores showing bacterial growth

3.2. Morphological structure of PET incorporated with bacteria spores

The morphological properties of the fibers were studied using an optical microscope, a scanning electron microscope and a transmission electron microscope.

3.3. Scanning electron microscopy (SEM)

The SEM micrograph of PET fibers incorporated with 4% spores showed visible spore agglomerates on the surface (Fig. 2). Two main factors may have caused the agglomeration of spores in the polymer matrix. Firstly, the high temperature and shear stress which are the main process parameters during extrusion. Spores can form agglomerates in suspensions during heat treatment due to increased surface hydrophobicity caused by denaturing of the protein coats (Furukawa et al., 2005; Wiencek et al., 1990). On the other hand, force originating from shear stress possibly impacted a higher energy on the spores which overcame the spores' electrostatic repulsive force leading to formation of agglomerates. The second factor that possibly caused the agglomeration of spores in the fibers is poor dispersion bond between the spores and the polymer matrix influenced by spore size and loading. In most cases, small sized particles tend to agglomerate more than larger particles while chances of forming agglomerates increases with loading (Williams et al., 2005; Supova, 2009).

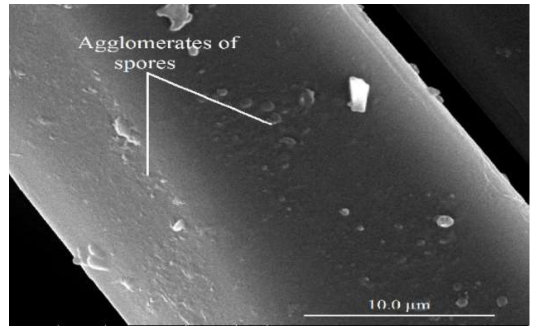

Figure 2 SEM micrographs for PET incorporated with 4% spores characterized with agglomerates of spores on the fiber surface (arrow showing)

3.4. Optical microscopy (OM)

The optical micrographs of PET-fibers extruded with 4% spores are characterized by cracks parallel to the fiber axis (Fig. 3). These cracks suggest that spores may have been heterogeneously distributed throughout the fiber. These cracks could have been caused by the observed agglomerates of spores that formed in the polymer matrix (Fig. 2).

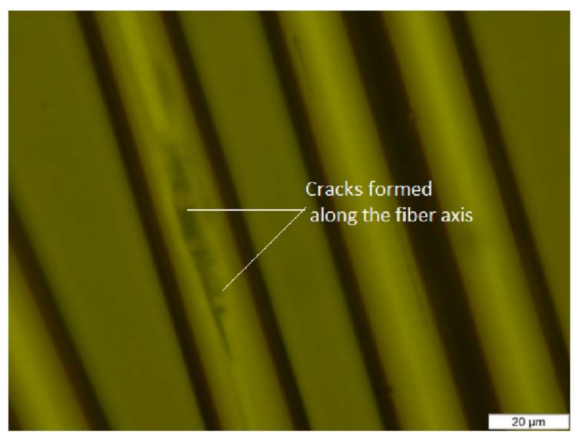

Figure 3 Representative optical micrographs of PET Fibers extruded with 4% spores showing cracks parallel to the fiber length (arrow showing)

Additionally, the cracks can also be associated with decreased macromolecule arrangement of PET along the fiber axis possibly caused by incorporating the spores in the structure (Zupin & Dimitrovski, 2010;

Lee & Yeea, 2000). This suggests poor dispersion of spores in the polymer matrix and poor spore-matrix interface adhesion bonding (Lee & Yeea, 2000).

3.5. Transmission electron microscopy (TEM)

The TEM microscopy confirmed the presence of spores in the PET fibers. The spores seem to have no preferential orientation in the fibers suggesting a heterogeneous distribution. Moreover, there seems to be a good adhesion bond between the spores and the polymer matrix (Fig. 4).

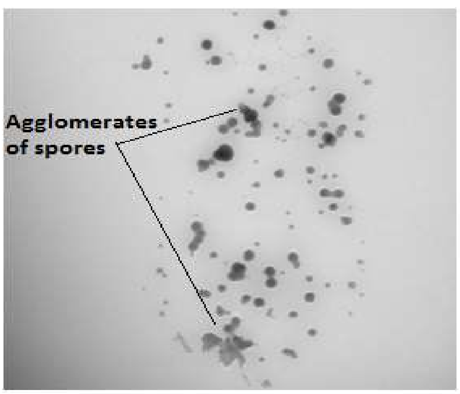

Figure 4 TEM micrographs for PET fibers incorporated with 4% spores showing agglomerates of spores in the polymer matrix

The tensile properties of PET fibers incorporated with bacteria spores

The tensile properties of a textile fiber like the strength, elongation and Young`s modulus greatly determines its applications. For this reason, it is important to develop fibers of a specific quality for a given application. The fibers tensile properties are generally influenced by the processing technique used, type of polymer, additives incorporated, size and distribution of the additives, etc.

A negative trend on the tensile properties can be noted whereby an increase in spore concentration results in a decrease in tensile strength and elongation at break. However, the Young’s modulus increased with spore concentration (Table 1). This trend can be attributed to the observed spore agglomerates in the polymer matrix.

Table 1 The tensile properties of PET fibers incorporated with bacteria spores

Spore	Tensile properties		
content (% w/w)	Tensile strength (cN/dtex)	Young’s modulus (cN/dtex)	Elongation at break (%)
0	4.86±0.3	87.74±7.	50.24±6.9
2	4.26±0.4	88.88±5.	46.99±5.2
4	4.0±0.1	89.36±6.	42.90±2.5
		90.97±7.	
6	3.76±0.3	2	40.72±5.2

Spore agglomerates could have induced cracks on the fiber surface, obstructing stress transfer between the spores and the polymer matrix creating weak points in the fibers which resulted in earlier failure (Shao-Yun et al., 2008; Zi-Kang, et al., 1999; Fan et al., 2007). The mechanical properties of the PET fibers extruded with 2-6% spores were compared with the mechanical properties of blank PET fibers (Control). The p- values presented in Table 1b indicates that incorporating the bacteria spores in the PET fibers shows a significant effect on tensile strength and Young’s modulus at all concentration levels. However, incorporating spores didn’t have a significant effect on the young’s modulus at all spores concentrations ($p > 0.05$).

Table 2 P-values for the tensile properties of PET fibers incorporated with bacteria spores

Spore content (% w/w)	P-Values		
	Tensile strength (cN/dtex)	Young's modulus (cN/dtex)	Elongation at break (%)
2 vs. control	0.001	0.0001	0.527
4 vs. control	0.0001	0.0001	0.182
6 vs. control	0.0001	0.0001	0.177

Generally, fibers normally have a tensile strength of around 3-7 cN/dtex, elongation of about 20-50% and Young's modulus of 77-87 cN/dtex (Boesel & Reis, 2008; Lee & Yeea, 2000). Taking these values as the standard, the properties of PET fibers produced in this study are within the acceptable range. However, our fibers have an additional advantage in that functionalizing additives have been incorporated that can give them special properties.

4. CONCLUSIONS

The tensile strength, modulus and elongation at break were dependent on the spore concentration. The study shows that incorporating spores in PET fibers resulted in decrease of the tensile properties. This decrease in the tensile properties of the resulting PET/spore fibers was associated with the observed spore agglomerates and formed cracks along the fiber axis. However, the resulting properties of the produced fibers were within the acceptable range thus they are of equal quality as normal PET fibers.

5. RECOMMENDATIONS FOR FUTURE RESEARCH

Agglomeration of spores and inhomogeneous distribution of spores in the polymer matrix lead to the decrease in the tensile properties of the resulting PET/spore fibers. Therefore, it is important to identify good techniques that can promote homogenous dispersion of spores and that can prevent spores from forming agglomerates. By solving these two problems, the cracks observed along the fiber axis will be eliminated and there will be efficient load transfer between the spore and the polymer matrix resulting in improved quality of the functionalized fibers.

Reference

Bang H., Kim H., Jin F., Woo J. & Park S. (2011) Bulletin of the Korean chemical society, 32, 542 - 546.

Beaman T.& Gerhardt P. (1986) Appl. Environ. Microbiol. 52, 1242–1246.

Boesel L.& Reis R. (2008) Progress in polymer science, 33, 180 - 190.

Broda J., Gawlowski A., Fabia J., Slusarczyk C., Fibers and textiles in Eastern Europe, 2007, 15, 30 - 33.

Ciera L., Beladjal L., Gheysens T., Almeras X., Nierstrasz V. Van Langenhove L.& Mertens J. (2014) Fibers and Textiles in Eastern Europe, 22, 102 -107.

Coman D., Oancea S. & Vrinceanu N., (2010) Romanian Biotechnological Letters,15, 4913 - 4921.

Deshmukh S., Rao A., Gaval V., Seena J & Mahanwar P. (2010) Journal of Minerals & Materials Characterization & Engineering, 9, 831 - 844.

Doudou B., Dargenty E. & Grenet J. (2005). Journal of Plastic Film & Sheeting. 21, 233- 251.

Espigares I., Elvira C., Mano J., Vazquez B., San Roman J. & Reis R. (2003) Biomaterials, 23, 1883 - 1895.

Furukawa S., Narisawa N., Watanabe T., Kawarai T., Myozen K., Okazaki S., Ogihara H. & Yamasaki M. (2005) International Journal of Food Science and Technology, 102, 107 - 111.

Gao Y.& Cranston R., Textile Research Journal (2008) 78, 60 - 72.

Gashti M. & Moradian S. (2012) Journal of Applied Polymer Science, 125, 4109 - 4120.

Gerhardt P.& Marquis R. (1989) Spore thermoresistance mechanisms, p. 17–63. In I. Smith, R. Slepecky, and P. Setlow (ed.), Regulation of prokaryotic development. American Society for Microbiology, Washington, D.C.

Gupta D., Indian journal of fiber and textile research. (2011) 36, 321 - 326.

Hong K., Park J., Sul I., Youk J. & Kang T. (2006) Journal of Polymer Science Part B: Polymer Physics, 44, 2468 - 2474.

Kusuktham B. (2012) Journal of applied polymer science, 124, 699 - 705.

Lee J. & Yeea A. (2000) Polymer, 41, 8363– 8373

Li G., Helms J., Pang S. & Schulz K. (2001) Polymer Composites, 22, 593 - 603.

Oerlikon. (2010). A world survey on textile and nonwovens industry, Remscheid, Oerlikon textile GmbH & CO. KG, Volume 9.

Park S., Kim H., Jin F. & Park S. (2010) Bulletin of the Korean chemical society, 31, 2637 - 2643.

Popham D., Sengupta S. & Setlow P. (1995) Applied and environmental microbiology. 3633–3638.

Reynaud E., Jouen T., Gauthier C., Vigier G. & Varlet J. (2001) Polymer, 42, 8759 - 68.

Ristic T., Zemljic L., Novak M., Kuncic M., Sonjak S., Cimerman N. & Strnad S. (2011) communicating current research and technological advances, 6, 36 – 51.Zeng X., Lin D., Cai X., Zhang X., Tan S. & Xu Y. (2012) Journal of Applied Polymer Science, 126, 601 - 607.

Zi-Kang Z., Yong Y., Jie Y. & Zong-Neng Q. (1999) Journal of Applied Polymer Science, 73, 2977 - 2984.

Zupin Z.& Dimitrovski K. (2010) Woven Fabric Engineering, Polona Dobnik Dubrovski (Ed.).

Internal environmental factors influencing the implementation of marketing strategies by garment- making micro-enterprises in Kenya

Lydia N. Kinuthia[1*], Keren G. Mburugu[2], Milcah Mulu-Mutuku[1]
[1]Department of Applied Community Development Studies, Egerton University, Kenya
[2]Department Fashion Design and Marketing, Kenyatta University, Kenya
([*]Author for correspondence: lydiankatha@yahoo.com)

Abstract: Marketing is important in any organization that aims at gaining a competitive edge. In Kenya, the clothing industry is characterized by a very dynamic environment and intense competition caused mainly by enlarging globalization, trade liberalization and the second-hand (mitumba) clothes. In such an environment, it is difficult for an enterprise to maintain long-term success. Thus, a sound marketing strategy is critical to the survival and growth of micro-enterprises in the garment making sector. Numerous studies acknowledge that strategies frequently fail because of ineffective implementation. This research aimed at determining the Internal Environmental (IE) factors that enable or impede effective strategy implementation in the garment making micro-enterprises. Ex-post facto design was used and data collected using an interview guide and a questionnaire from a randomly selected sample of 265 respondents for the survey and 40 respondents for the interview. Data was analyzed both quantitatively and qualitatively using exploratory factor analysis and multiple regression analysis to identify and determine the IE factors influencing strategy implementation. Business organizational structure and Culture; and Record Keeping and Financial Management were found to have the greatest influence on the marketing strategy implementation. Further research is recommended to explore the impact of the internal environment factors on the enterprise performance and growth.

Keywords: Marketing strategies, garment-making, micro-enterprises, implementation

1. INTRODUCTION

In general, many manufacturing micro-enterprises in Kenya have stagnated in terms of growth (Mulu et al., 2004). Micro-enterprises in both developed and developing countries are faced by similar constraints though to different extents (Ngoze, 2006). Among these constraints, marketing is seen as one of the major issues that need to be addressed by the entrepreneurs if their enterprises are to survive (Ngoze 2006; Gakure, 2006) indicates that in a developing economy, many principles of marketing (formulated mainly in the developed economies) are inappropriate for micro-enterprises. It is apparent that marketing in micro-enterprises is fundamentally different from that of large firms (Bjork, et al., 2004; Simpson, et al., 2005; Stokes, 2003; Wagar, et al., 2007)). Hills and Hultman (Hills & Hultman, 2006), argue that the difference between marketing in large firms and micro- enterprises is partly because of the way marketing is implemented.

Successful marketing strategy implementation (especially in fashion), is faced with many challenges that are on the increase due to resource constraints, inflationary tendencies, changing lifestyles, rapid technological advancement and increased competition both at local and international levels. This indicates that many garment making micro-enterprises operate in a very turbulent environment of increased risks. Stokes and Wendy (Stpkes & Wendy, 2008). argue that marketing plays an essential role in micro-enterprises and it is an important factor in business growth. In addition, a good strategy helps an enterprise to develop a long-range plan to ensure its survival, profitability, growth, and perpetuity (Schiffman & Kanuk, 1992, Cohen et al., 2007; Ahmed & Rafiq, 1995), posit that one of the pertinent areas in the field of marketing is the strategy implementation. (Zarvnik & Mumel, 2007), indicate that the key success factor for any business in the clothing industry is the implementation of the marketing strategies. Strategy implementation effectiveness requires the planned execution of the appropriate activities. (Pearce & Robinson, 2005; White, et al., 2008), indicate that marketing strategies are only beneficial to a firm when they are successfully implemented and specific functional tactics are identified. Implementation is critical to the success of any firm because it is responsible for putting the marketing strategy into action. According to Pearce and Robinson, implementation is the cause for the difference between intended marketing strategy (what the firm wants to happen) and realized marketing strategy (the strategy that actually takes place).

According to Thomson (Thomson, 2002), there are many factors that affect the implementation of the marketing strategies. These include factors related to the strategy itself, the entrepreneur orientation, the market environment (internal and external) and the target market characteristics. (Gakure, 2006) argues that sales are the life blood of any business. (Bjork et al., 2004, Stokes, 2003; Cohen et al., 2007), all indicate that if an enterprise has to survive and grow, it has to find a competitive edge. However, securing sales and gaining a competitive edge largely depend on identifying, researching and addressing the existing and potential markets correctly in such a way as to differentiate oneself from the competitors. According to a study by (Lewa, 2003), on strategic management practices in Kenya's small and micro-enterprises, only 13% implemented their strategies and they performed better than those which did not. Though the marketing function is important (Bjork et al., 2004), the internal environment has an impact on the way marketing strategies are implemented, (Thelma & Whittaker, 2003; Kruger, 2004; Foss & Klein, 2004). According to (Wilson & Wong, 2003), implementation is critical to marketing effectiveness and an area of weakness in many businesses.

In view of the importance of a sound marketing strategy, this paper focuses on the internal environment forces that influence the implementation of the marketing strategies in garment making micro-enterprises.

2. METHODS

The purpose of this paper was to identify the internal environmental factors that influence the implementation of marketing strategies by garment making micro enterprises in Nakuru, Kenya. It was hypothesized that internal environmental factors do not have any influence on the implementation of the marketing strategies. An ex-post facto research design was adopted since the independent variables (factors) were already in existence. The research started with determining the dependent variables (marketing strategies) with the view of establishing the influence of the independent on the dependent variables. (Foss & Klein, 2004), maintain that ex-post facto design involve a systematic empirical study whereby the researcher does not manipulate or control the variables being studied. According to (Cohen et al., 2007), ex-post facto is a valuable exploratory tool because it yields useful information with regard to the nature of a phenomenon in terms of what goes on and under what conditions. It tests the influence (negative or positive) of the classification variable. Based on a total target population of 385 garment-making micro- enterprises, confidence level of 0.05 and confidence interval of 3, a sample of 295 respondents was selected and used for the survey and 40 respondents for the interviews (10% of total target population). The sample size figures were rounded off to the higher multiple of five. 30 respondents participated in the pre-testing of the questionnaires and 10 in the pre-testing of the interview guide. A preliminary survey was conducted to confirm the physical locations and whether there were some that had moved or new ones who joined the business by the time of the study.

Data were collected by use of a questionnaire and an interview guide. The primary method used for data collection was the questionnaires that comprised questions on a 5-Point likert scale ranging from “all the time” to “never” in relation to the types of marketing strategies that were implemented (30 items), while the internal environmental factors that influenced their implementation ranged from “strongly agree” to “strongly disagree”. Some items were positively worded while others were negatively worded (reverse scored) to reduce response bias. For the sake of data analysis, all the scored items were reversed so that a higher response on the likert would represent the same scale. To ascertain the reliability and validity level of the instruments used, a pre-test was conducted. According to (Mugenda & Mugenda, 2003), a sample size of 1% to 10% of the population may be selected for the purpose of pre-testing the research instrument. A sample of 30 respondents was thus used for the survey while 10 respondents were used for the interview.

Reliability for the questionnaire was measured using Cronbach’s Alpha coefficient. This alpha was used to test the reliability since it required only a single administration to provide unique estimate of the reliability for the given test. It also gave the average value of the reliability coefficients one would obtain for all possible combinations of items when split into two half-tests. The pre-tested questionnaire had a reliability coefficient of .795. To ascertain content validity, the research instruments were reviewed by three experts in research methodologies in social sciences, marketing and entrepreneurship. Exploratory Factor Analysis was conducted to determine the internal environmental factors that influence the implementation of the marketing strategies. The rationale for conducting factor analysis was to reduce the data by summarizing the important information contained in the variables by a fewer number of factors. (Fraenkel & Wallen, 2009), posit that with factor analysis, variables that are highly correlated with one another can be condensed into factors. It was also used to determine which of the variables contained in these factors were the most important when it came to the implementation of marketing strategies by garment- making micro-enterprises. Only the variables with factor loading above 0.5 were used for further analysis. Factor loadings are parameter estimates that indicate the correlation between the observed variables and the factors extracted. Factor analysis produced descriptive summaries of data matrices which aided in the control for the extraneous variables. It also yielded regression factor scores that were used for further analysis.

Using the mean scores for the strategies and the regression factor scores for the independent factors, multiple regression analysis was conducted to determine which among the independent factors influenced the dependent variables and determine the nature of the influence. The multiple regression procedure was used because it provided a way of analyzing the influence by more than one independent variable. Regression factor scores obtained from factor analysis were used for the multiple regression analysis in order to eliminate the multi-collinearity problem.

The coefficient of determination (R-square) was used to indicate the percentage of variability of the marketing strategy implemented that was accounted for by all the factors under analysis. The standardized beta (β) coefficients were used to indicate the direction (positive or negative) and magnitude of influence as well as compare the relative contribution of each independent factor in the implementation of the marketing strategies. The regression model summary indicated whether or not there are internal environmental factors influencing the implementation of the marketing strategies while the beta coefficients were used to single out the specific factors influencing the implementation of each strategy at a significance level of $p \leq 0.05$. The interview results were used for triangulation and clarification of information as well as convergence among the results. The analysis involved extracting issues that clarified or supported aspects that arose during the discussion.

3. RESULTS AND DISCUSSIONS

Eight marketing strategies that were being implemented by the garment making micro enterprises were identified using Varimax rotation method (ref. Table 1). These include Interactive Marketing (66%), Branding and Cost Reduction Strategy (61%), Customer Focus (57%), Market Penetration (56%), Product Differentiation (55%), Pricing (46%), Product Quality Strategy (37%) and E-marketing (21%). Four internal environmental factors influencing the implementation of marketing strategies were identified as Culture and Structure (62%); Resources (56%); Record Keeping and Financial Management (46%); and Flexibility of Implementation (38%) (ref. Table 2). Branding and Cost Reduction was 0.596 (p-value =.000); Customer Focus was 0.082 (p-value = .000); Pricing was 0.253 (p-value = .000); Product Differentiation was 0.125 (p-value = .000); Product Quality was 0.140 (p-value = .000); and for Interactive Marketing was 0.046 (p-value = .019). For all the strategies the influence was statistically significant at 0.05. This was an indication that some of the internal environmental factors had influence on those strategies.

Culture and Structure had a positive statistically significant influence on Market Penetration strategy (β= .227, sig.000), Branding and Cost Reduction strategy (β= .771, sig. 0.000), Interactive Marketing strategy (β= .151, sig. 0.015) and Product Differentiation strategy (β= .124, sig. 0.036). However, it had no significant influence on E-marketing strategy (β= .051, sig. 0.411) and Product Quality (β= .047, sig. 0.424). It is worth noting that respondents who said Culture and Structure influenced how they market their products were those with employees and those who indicated it does not were enterprises without employees. The typical structure found in the garment making enterprises was the entrepreneurial organization, where the owner-manager has full central control of the activities and decisions in the enterprise including delegation of responsibilities, communication and involvement of employees in organizational activities as described by (Stpkes & Wendy, 2008). The culture that emerged from this study was characterized by employees being responsible for their own work. However, when there was much work, they assisted one another. It also emerged that work was given based on capabilities and experience; and incase modifications were needed; the person who was involved did the changes.

Table 1 Implementation of the Marketing Strategies by the Micro-enterprises

Strategy	Implemented	Didn't Implement	Ranking
Interactive Marketing	170(66%)	86(34%)	1
Branding and Cost Reduction	155(61%)	101(39%)	2
Customer Focus	146(57%)	110(43%)	3
Market Penetration	144(56%)	112(44%)	4
Product Differentiation	141(55%)	115(45%)	5
Pricing	119(46%)	137(54%)	6
Product Quality	96(37%)	160(63%)	7
E-marketing	54(21%)	202(79%)	8

Culture and Structure, as a factor positively influenced Market Penetration; Branding and Cost Reduction; and Product Differentiation while negatively influenced Interactive Marketing. This implies that the structure and culture of an enterprise is an important factor to consider in the implementation of marketing strategies. As indicated by (Le & Eppler, 2008), culture influences the perception of the employees and this has impact on how they handle customers. As structures and culture gets formal and complicated, the enterprise loses the personal touch with the customers. On the contrary, they are able to penetrate the market more. Resources had a positive statistically significant influence on Market Penetration (β= .182, sig.001) and Customer Focus (β= .268, sig. 0.000). There was a negative influence which was statistically significant on E-marketing (β= -.166, sig. 0.008) and Product Quality (β= -.259, sig. 0.000). A positive statistically insignificant influence was on Pricing (β= .051, sig. 0.352) while there was a negative statistically insignificant influence on Branding and Cost Reduction (β= -.035, sig. 0.390), Interactive Marketing (β= -.005, sig. 0.939) and Product Differentiation (β= -.093, sig. 0.115). According to (Ferreira & Azevedo, 2007), the resource factor is very critical in any entrepreneurial decisions. The results of this study indicated that many garment making enterprises lacked finances; personnel in marketing; and marketing skills and knowledge. Most of the entrepreneurs indicated inability to access loans, lack of capital, high costs of electricity and high rent as major resource factors that had great influence on marketing their businesses. This confirms (Dinning, 2010), remarks that micro-entrepreneurs in Kenya lack sufficient resources and capital to run their enterprises. This therefore implied that the garment making entrepreneurs were inhibited in terms of marketing and for any marketing efforts to bear fruits these issues will need to be addressed.

Table 2 Internal Environmental Factors

IE factor	Influencing	Not influencing
Culture and Structure	158 (62%)	98 (38%)
Resources	144 (56%)	112 (44%)
Record Keeping and Financial Management	118 (46%)	138 (54%)
Flexibility of Implementation	98 (38%)	158 (62%)

The R-square for Market Penetration was 0.207 (p-value = .000) (ref. Table 3);

Record Keeping and Financial Management had a positive influence which was statistically significant on Market Penetration (β= .332, sig. 0.000), Interactive Marketing (β= .141, sig. 0.023), Pricing (β= .450, sig. 0.000), Product Differentiation (β= .225, sig. 0.000) and Product Quality (β= .210, sig. 0.000). This factor also had a positive influence which was not statistically significant on E- marketing (β= .007, sig. 0.905) and Branding and Cost Reduction (β= .003, sig. 0.948). However, the influence on Customer Focus (β= -.097, sig. 0.111) was negative and not statistically significant. Record keeping is important because an entrepreneur is able to monitor the progress of the business; keep track of income and expenditure; and be able to prepare financial statements. If an enterprise is able to keep daily records, then managing finances is easy. However, garment making micro enterprise found it difficult to keep record hence managing the finance also become difficult. As indicated by (Atieno, 2009), record keeping is necessary for a growth-oriented enterprise. Based on the results of this study, record keeping and financial management was a challenge for many entrepreneurs because most of them relied on the daily collections to cater for immediate family needs or to cover daily transport costs.

Table 3 Regression Model Summary for Internal Environmental Factors

Marketing strategy	R	RSquare	Adjusted R Square	Std.Error of the Estimate	Sig.
Market Penetration	.454[a]	.207	.194	.945	.000*
Branding and Cost Reduction	.772[a]	.596	.589	.900	.000*
Customer Focus	.287[a]	.082	.068	.610	.000*
Pricing	.503[a]	.253	.242	.990	.000*
Product Differentiation	.354[a]	.125	.111	.659	.000*
Product Quality	.374	.140	.126	.958	.000*
Interactive Marketing	.214[a]	.046	.031	.438	.019*
E-marketing	.176[a]	.031	.015	.440	.095

This therefore meant they were not able to tell how much money they collected per day or per week. Lack of proper record keeping had an impact on the enterprises especially when accessing credit. Most of the respondents indicated that keeping records required high discipline which was hard to maintain. However, they mentioned they were keen in keeping records related to customer orders. These included customers' personal measurements, sketches for garment construction and receipts indicating how much deposit had been paid and the balance yet to be cleared. From the findings, record keeping and financial management had a positive influence on Market Penetration; Customer Focus; Pricing; Product Differentiation and Product Quality strategies. This means the success of these strategies rely much on how an enterprise is able to keep records and manage its finances. Flexibility of Implementation had a positive influence which was statistically significant on Pricing (β= .206, sig. 0.000) and Product Quality (β= .162, sig. 0.006). On Product Differentiation (β= -.224, sig. 0.000), the influence was negative but statistically significant. E-marketing (β= .026, sig. 0.676), Market Penetration (β= .109, sig. 0.054) and Customer Focus (β= .013, sig. 0.826) were influenced positively though this was found to be insignificant. The influence on Branding and Cost Reduction (β= -.017, sig. 0.671) and Interactive Marketing (β= -.055, sig. 0.378) was negative and statistically insignificant.

Flexibility of Implementation was in terms of ability to adjust to changes in prices and accommodate customer complaints within one's schedule. This implied that there was latitude for making adjustments allowing the entrepreneur to act proactively paving way for a customization in the marketing approach as well as cope with environment uncertainties. These results are consistent with arguments by (Stpkes & Wendy, 2008), that most entrepreneurs in micro-enterprises have the advantage of acting quickly and opportunistically more than those in large firms because they rely mostly on their own judgment. They are also able to adapt to customers' needs due to the nature and size of their enterprises; and have ability to effect changes in a timely manner. Many scholars hold the opinion that flexibility is a function of the structure and considered as a competitive priority that must be given priority if an enterprise is seeking competitive advantage. However, as indicated in this study, it was a factor that stood on its own as far as the garment making micro- enterprises were concerned. This meant that garment-making micro-enterprises were able to adjust swiftly based on customer needs.

Only two strategies, Pricing and Product Quality, were influenced positively by flexibility of strategy implementation in a significant way. This implied that Pricing and Product quality strategies are dependent on how flexible the enterprise was in the implementation of decisions.

4. CONCLUSION

Structure and Culture, Record Keeping and Financial Management were the only factors that had a positive significant influence on the implementation of all the marketing strategies studied. This implies that micro-enterprises need to focus on how records are kept, finances are managed, communication is done and the enterprise is structured in order to effectively implement the marketing strategies. The hypothesis that internal environment did not significantly influence the implementation of marketing strategies by garment-making micro-enterprises was rejected. Internal environmental factors play a role in implementation of marketing strategies in garment making micro-enterprises. Therefore, successful implementation of marketing strategies in garment making micro enterprises is dependent on the internal factors though the influence will differ based on the type of strategy being implemented.

References

Ahmed PK& Rafiq M (1995), Journal of marketing practice: Applied Marketing Sciences. 1 (4), 32-51. Retrieved October 6, 2008, from http://www.emeraldinsight.co./insightlviewcontentservlet>filename=publjshed/Ernerald fullText/Articles/1 550010402.html

Atieno R (2009), Institutional Arrangements and the Performance of Micro and Small-Scale Clothing Enterprises in Kenya. Retrieved July 17, 2010 from http://www.csae.ox.ac.uk/conferences/2009-EDiA/papers/305-Atieno.pd

Bjork P, Lindquist L J, Poukkula K, Ravald A, West B and Ahman (2004), A theory of marketing-in-use in micro firms - preliminary findings. Finland. Retrieved December 15, 2007, from http://web.bi.no/forskninglncsb2004.nst76ef4dJ$FILE/Bj%C3%B6rk&al.pdf

Cohen L et al. (2007), Research methods in education. New York, Routledge: Taylor & Francis grp., 2007

Dinning R (2010), Micro Enterprise in Kenya. Retrieved July 17, 2010, from http://www.slideshare.net/fhk/micro-enterprise- in-Kenya

Ferreira J & Azevedo SG (2007), Entrepreneurial Orientation as a main Resource and Capacity on small firms' growth. Retrieved July 22, 2008, from http://204.19.44.91/FondationlEntrepreneurial%20 0rientation.pdf.

Foss NJ & Klein PG (2004), Entrepreneurship and the economic gain of the firm: Any gains from trade? Retrieved December 14, 2007, from www.mises.org

Fraenkel JR & Wallen NE (2009), How to design and evaluate research in education (Seventh Edition). New York: McGraw-Hill.

Gakure RW (2006), Factors affecting growth of small and medium hand craft enterprises in Nairobi, Kenya. Paper presented during the 3rd International Entrepreneurship conference held at USIU 29th to 30th May 2006.

Hills IE and Hultman CM (2006), Entrepreneurial marketing. in Stefan Lagrosen & Goran Svensson (eds), Marketing — Broadening the Horizons (pp. 219-223). Retrieved November 11, 2007, from http://www.kmu.unisg.ch/rencontres/RENC2006/Topics06/C/Rencontres2006Hultman_Hills.pdf

Kruger, ME (2004), Entrepreneurship theory and creativity. Retrieved January, 2008, from www.upetd.up.ac.za

Lewa PM (2003), Strategic practices in Kenya 's small and Micro enterprises. Paper presented during the lst International Entrepreneurship conference held at USIU 15th to 25th April, 2003.

Li Y, Guohui S & Eppler MJ (2008). ICA Working Paper 2/2008. Retrieved May 14, 2010, from http://www.knowledge-communication.org/pdf/making-strategy- work.pdf

Mulu-Mutuku M, Namusonge GS & Odhuno A. (2004), Effects of Training on Manufacturing Micro-enterprises' Growth in Nakuru, Kenya. Paper presented during the 2nd International Entrepreneurship conference held at USIU 12th to 14th May 2004.

Mugenda D & Mugenda A (2003), Quantitative and Qualitative Approaches: Research Methods. Kenya Act Press.

Ngoze ML (2006), Barriers inhibiting growth of small enterprises in Kenya. Paper presented in the Second Annual 2006 San Francisco-Silicon Valley Global Entrepreneurship Research Conference on March 22-25, 2006 San Francisco, California. Retrieved July 16, 2008, from http://www.usfca.edu

Pearce II JA & Robinson RB (2005), Strategic Management. (Ninth Edition) New Delhi: McGraw-Hill

Schiffman LG & Kanuk LL (1992), Consumer Behavior. New Delhi: Prentice-Hall of India

Simpson M, Padmore J & Taylor N (2005), Marketing in SMEs Session paper No. 2005.08, University of Linneolin. Retrieved November 13, 2007, from www.shef.ac.uk/managementlresearchl2005- 08.pdf

Stokes D (2003), Thomas learning small business management. Retrieved November 20, 2007, from www.mhlw.go.jp

Stokes D & Wendy L (2008), Marketing: A brief introduction. Thomson Learning.

Thelma Q & Whittaker H (2003). Entrepreneurial Orientation and Entrepreneurs' Intentions and Objectives. ESRC Centre for Business Research, University of Cambridge, Working paper No. 271. Retrieved May 26, 2008, from http://www.cbr.cam.ac.uk/pdf/wp27 1.pdf.

Thomson L (2002) Chapter 10: Marketing implementation. Retrieved March 28, 2009, from http://people.senecac.on.ea/angela.zigras/mkm 8O6wO4/chl 0.ppt

Wagar K, Bjork, P, Ravald, A & West B (2007), Exploring marketing in micro firms. Retrieved July 22, 2008, from http://www.openax.shh.fimarketing.pdf

White JC, Conant JS & Echambandi R (n.d), Marketing strategy development styles, implementation capacity and firm performance: Investing the curvilinear impact of multiple strategy-making styles. Retrieved July 22, 2008, from http://www.bus.ucf.edu/eehambadi/Review/Planning.pdf.

Wilson K & Wong SM (2003), Key determinants of successful marketing strategy implementation. Retrieved November 28, 2008, from http://smib.vuw.ac.nz.808/WWW/ANCMAC2003/papers/STO6_wilsonk.pdf

Zarvnik B& Mumel D (2007), Fibers and Textiles in Eastern Europe. January/March 2007, 15 (60) 11-15. Retrieved October 11, 2008, from http://www.fibtex.lodz.p1160_06_1 1 .pdf.

Consumer Attitude and Involvement Towards Pet Clothes: A comparative Study of Chinese and Non-Chinese

Magdalene Curic[2] Josphat Igadwa Mwasiagi[1,2 *]
[1]Donghua University, Shanghai, China
[2]Ethiopian Institute of Textile and Fashion Technology, Bahir Dar University, Bahir Dar, Ethiopia
([*]Author for correspondence: igadwa@gmail.com)

Abstract: A rising number of pets and the increasing market for pet products in China has necessitated a study into the consumer attitude and involvement towards pet apparel. A survey on the consumer attitude and involvement towards pet apparel was carried out. A total of 166 Chinese, 69 Americans and 114 other foreigners respondents were involved in the study. The other foreigners were of several nationalities which included Romania, Canada, Italy, Australia, Japan, Singapore and Zambia. The data collected in this research indicated that for the non-Chinese consumers, gender, age and income did not affect the purchase of pet apparel. For the Chinese consumers, the results showed that while gender and income did not affect the purchase of pet apparel, age of the consumer however affected the purchase of pet apparel. The results of the research indicated that the attitude of the Chinese consumer towards pet apparel is driven by fashion and aesthetic properties (fun) while that of the non-Chinese especially the Americans placed more emphasize on the functionality of the pet apparel.

Keywords: Slaughterhouse waste; cationization; cotton; reactive dyes; proteinous products

1. INTRODUCTION

The behavior of a consumer towards a given product can be influenced by several factors which include attitude, involvement, culture, lifestyles and product attributes. The consumer's attitude can be divided into three main components; effect, behavior and cognition (Schutte & Ciarlante, 1998, Solomon & Rabolt, 2004). A person's attitude represents a psychological tendency that is expressed by evaluating a particular object, and can serve various motivations (Eagly & Chaiken, 1993). According to functional theory, since attitudes may serve various motivations depending on the purpose, behavior is therefore a function of attitude toward that behavior (O'Keefe, et al., 2002). On the other hand, according to dual attitudes perspective, people may possess (simultaneously) both an implicit and an explicit attitude, even opposite in valence, toward the objects, people, and issues that are important in their lives (Schooler, et al., 2000).Based on the above-mentioned considerations, it may be important to study if the consumers attitudes toward pet apparel is greatly affected by the importance of human being place on pets. An extension of such a study will be to consider whether the consumers attitude can be measured by the amount of money spend on pets, pet products and services.

The ownership of pets and the amount of money spent on pets and pet products is on the rise.

The "humanization" of pets is a continuing trend, whereby pets (particularly dogs and cats) are increasingly cared for according to human patterns and human aesthetic standards (Tashiro & Rowley, 2007). According to Tanikawa (Tanikawa, et al., 2004), any generation that has failed in raising their children, pets serve as a filler to cover up the void. This could explain the drastic increase of pets in Asia. The economy of most of Asian nations have recorded high growth, while at the same time aggressive government policies have let to fewer children being born. These factors could add up to give rise to an increase in pet ownership. Pets are considered as friends and companions that provide psychological comfort. In increasingly hectic and stressful societies, pets represent security and comfort and have long been recognized as a source of emotional support. Animal companions are more popular with empty-nesters, single professionals and couples who delay having children. People who do not have children find comfort and emotional satisfaction dressing pets instead (Roberts, et al., 2010). As people get to a point of finding companionship in pets (Zhuang, 2005), the needs of the pets come to the fore. Some pets like dogs are given shelter and clothing to protect them from extreme cold or hot weather. Pet clothes may include items to cover the pet and hence keep it warm, or to shield the pet from the hot sun. Although pet clothing has been around since 1950 in big cities such as New York, Los Angeles, Paris and London, it was mostly regarded by the general public as a peculiarity or extravaganza in celebrity, fashion and rich peoples' life. The overall statistics for spending on pets' related products and services in general are on the increase. In the U.S.A, where the pet industry was worth $32.4 billion in 2003, there are more pets than human beings. The market that combines the sale of live animals, pet care and supplies and veterinary services grew to its current size from about half that level 10 years ago, and it serves about 378 million pets, most of them cats and dogs, compared with 290 million human beings. According to the American Pet Products Manufacturers Association, which compiled the statistics, American pet owners are expected to spend $34.3 billion on pets in 2008 (Tanikawa, et al., 2004). In China the pet population has grown by a 20% in five years, from 240.8 million in 1999 to 291.4 million in 2004 (Wines, 2010) and attitudes towards pets are changing in China's fast-paced economy.

2. RESEARCH METHODOLOGY

The purpose of this study was to examine the attitude and involvement of consumers toward pet apparel in general, consumer attitudes toward pet apparel shopping, individual differences, cultural differences and demographic factors for consumers of pet apparel in China and other countries. A questionnaire was developed to collect data on the attitude and involvement of consumers towards pet apparel both in English and Chinese. Two strategies, on-site and online, were employed for gathering data in China and other countries. In

Shanghai, China and Birmingham, Alabama, U.S.A, questionnaires aimed at both pet owners and non-owners were distributed. The questionnaire was also posted on the web. The website address was popularized through different social networks. The web link was active for a two-month period; April to May 2007. The questionnaire was designed with two sections; the first section introduced the research being done to the participants through a cover letter which asked for their contribution. The second section was subdivided into two sections A and B. Section A, part 1, to be completed by all participants, covered the attitudes, knowledge and opinions of consumers, pet owners or not, towards pet clothing. Twenty-two questions were included in this section to provide a better understanding of new life trends and attitudes towards pet apparel. Part 2 of section A was specifically geared towards pet owners aiming at investigating their purchasing behavior: actual as well as intended apparel purchase, degree of satisfaction and evaluation of pet apparel. Participants having completed section A, part 1 and did not own a pet were invited to go straight to section B. This last section, B, required socio-demographic data and included questions on education, household income, age and gender. Sections A, part 1 and 2 required participants to indicate their agreement or disagreement with the statements developed on a five-level Likert scale which had the following levels; 1: Strongly disagree, 2: Disagree, 3: Neither agree nor disagree, 4: Agree and 5: Strongly agree. The data collected was analyzed using the Statistical Package for the Social Sciences 15.0 (SPSS).

3. RESULTS AND DISCUSSIONS

3.1. Sample Characteristics

The sample population consisted of 166, 69 and 114 Chinese, Americans and other foreigners respectively. The other foreigners were from Romania 32, Canada 12, Italy 7, England 6, Russia 6, Turkey 5, Germany 5, Sweden 5, Holland 4, Austria 4, Spain 4, Australia 4, Singapore 3, Korea 3, Japan 3, India 3 and Zambia 2. Statistical analysis was conducted using cross tabulation and Chi-square to study if there existed any significant difference between pet apparel purchasers/ non-purchasers across countries and gender, age, income. The chi- square test should indicate whether or not the variables depend on each other and the extent to which they do. A statistically significant p- value of 0.05 was used in this study. Table 1 presents the descriptive statistics for Chinese and non-Chinese consumers' purchasers and non-purchasers of pet apparel. As seen in the Table 1 a higher percentage of the Americans purchased pet apparel, followed by the Chinese.

Table 1 Descriptive Statistics for respondents

Purchase	Chinese		Americans		Others	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
No	107	64.5	41	59.4	82	71.9
Yes	59	35.5	28	40.6	32	28.1
Total	166	100	69	100	114	100

After cross tabulation and chi square was conducted the results (Table 2) showed that there was no significant relationship between the purchasing frequency of pet apparel on one hand and gender, income and age on the other hand for non-Chinese consumers. That means gender; age and income did not affect purchasing of pet apparel. The same case applied for the Chinese consumers concerning gender and income. For the Chinese consumer age and frequency of purchasing pet clothes showed a correlation. The younger Chinese tend to more, while the older Chinese recorded lower levels of purchasing pet clothes. The young adults between the age of 21-30 years with a monthly income of C¥12,000 - C¥60,000 (US$2000 - US$10000) recorded a very high purchase frequency when compared to the older people (over 60 years old). That is to say the purchasing frequency showed a drastic reduction as the ages increased.

Less than 20 years ago, Chinese consumers could only satisfy their most basic needs. Being affected by traditional Confucianism, older people wanted to be modest and did not like to stand out from the crowd. The drastic change in the Chinese economy has brought in a lot of changes. The close family unity is no longer

Consumer Attitude and Perceptions toward pet apparel A study of the consumer attitude toward pet apparel was undertaken using a questionnaire. Some of the keys points captured in the questionnaire and response are given in Table 3.

The results indicated that Chinese consumers and non-Chinese consumers both had a positive perception of pet apparel. All the respondents maintained due to the fact the young find themselves in new cities far from family members. Coupled with the stress of work and the availability of disposable income, the young adults are more prone to indulge in new ideas (like pet ownership) which might give them emotional satisfaction (Jeanne, 2009). For the non- Chinese, the people who embrace the pet culture seem to carry it from Childhood to old age. Parents buy pets to keep the kids occupied when they (parents) are always away at work. As the kids grow up and leave home, the parents buy pets to fill the emotional void left. In old age the pets become some of the closest companions.

Table 2 Chi-Square tests for gender, age, income

	Factor	Nationality	Value	Degree of freedom	Sign
Pearson Chi – Square	Gender	Chinese	1.605	1	0.205
		Americans	2.914	1	0.088
		Others	0.422	1	0.516
	Age	Chinese	13.5	4	0.009
		Americans	1.935	5	0.858
		Others	3.86	5	0.57
	Income	Chinese	3.728	3	0.292
		Americans	2.111	3	0.55
		Others	7.341	3	0.062

(Chinese and Non-Chinese) felt that pets should be treated as family members. Out of seventeen key issues considered in this study, the response of four issues was not significant, which means that there was no major difference among the three different groups. The four issues were (i) Whether pets should be treated as members of the family (ii) The source of the information about pet clothes being from the media (iii) Natural fibers are more preferable for use in pet clothes and (iv) The importance of price while buying pet clothes. The other thirteen issues as listed in Table 3 were adjudged to have registered significant differences among the groups and can therefore be used to explain the consumer attitude and involvement towards pet apparel. The attitude of the Chinese consumers is much higher than that of the Non-Chinese in the following areas (i) The importance of the dressing pets (More Chinese believe dressing pets is important) (ii) Pet clothing are for fun (iii) A desire to buy pet clothes after seeing other peoples' pets wearing clothes.

Table 3 Differences in perception and consumer attitude toward pet apparel

SN	Questionnaire statement	Mean Chinese	Mean Americans	Mean others	Chi-Square value	Sign
1	Clothing for pets is important.	3.27	2.54	2.66	36.286	0.00
2	Pet clothing should be for protection against the weather.	3.01	3.93	3.9	50.39	0.00
3	Pets clothing should be for fun and dressing up.	3.68	2.38	2.64	67.615	0.00
4	Pets should be treated as members of the family.	3.94	3.9	3.94	0.19	0.091
5	Purchasing pet clothing is extravagant.	2.93	3.9	3.25	16.413	0.00
6	Pets should wear clothes in any season.	3.2	3.52	2.5	27.149	0.00
7	My knowledge about pet clothing comes from many different media.	2.92	2.84	3	0.975	0.614
8	Seeing other people's pets wearing	3.57	2.65	2.38	86.218	0.00

	clothes makes me want to buy pet clothes					
9	Natural fibers are preferable for pet apparel.	3.45	3.14	3.38	3.031	0.22
10	Pet clothing should be marketed in the same way as clothing for people.	3.49	1.97	2.81	50.019	0.00
11	Style and color are important for pets.	3.69	2.38	2.68	56.954	0.00
12	Functionality is important in pet clothing.	3.69	4	3.84	6.068	0.048
13	Design and quality are important in pet clothing.	3.78	3.22	3.32	8.048	0.018
14	Pet apparel should be viewed as fashion.	3.3	3.43	2.54	33.23	0.00
15	Pet apparel should have the same variety in style and size as clothing for humans.	3.87	2.49	2.74	72.576	0.00
16	I would be willing to visit an exhibition for pet apparel	3.53	2.38	2.81	50.018	0.00
17	I would be interested in purchasing a magazine about pet apparel.	3.07	2.54	2.32	67.095	0.00

The aforementioned attitudes could have lead to other attitudes and perceptions where the Chinese consumers are more strongly convinced than the Non-Chinese. More Chinese than Non-Chinese feel that style and color are important for pets hence pet clothing should be marketed like human clothing. The Chinese respondents also believe that pet clothing should have the same variety in style and size as cloths for humans. This could be due to the fact pet clothes are for fun and an occasion for the pet owners to show off. Therefore, it should not come as a surprise when more Chinese were reported to have responded that design and quality are important for pet clothes. The Chinese seem to have a strong desire to dress up their pets to a point that they are ready to learn more about pets by visiting exhibitions and buying magazine about pet clothes. In China, pet apparel is a newly emerged trend and it has to do with considerable pet ownership increase in China and other Asian countries in the last two decades. Despite the fact that it is a new trend in China, the consumers here have a positive perception of pet apparel and are very open to more information and knowledge. Also, Chinese consumers are much more influenced by other consumers' behavior and social reflection when buying apparel for their pets. Most non-Chinese consider pet apparel should be functional first and foremost. When not intended for protective purposes, they consider pet apparel as a fashion and extravagant item. Pet Apparel Consumer Involvement The consumer involvement with pet apparel was captured using questionnaires. The responses to some of the key issues in consumer involvement with pet apparel are given in Table 4.

All the respondents showed strong agreement with the two facts (i) Pet clothes are for functional purposes (ii) Purchase of pet clothes is easier done in a store rather than online.

Chinese consumers' involvement with pet clothes is higher than non-Chinese consumers' involvement in pet apparel. This could be due to the economic changes in the Chinese economy, and the one child policy implemented by the Chinese government.

Table 4 Differences in pet apparel consumer involvement

SN	Questionnaire statement	Mean Americans	Mean others	Mean Chinese	Chi-Square value	Sign.
1	I enjoy dressing up my pet in fashionable	2.29	2.16	3.49	34.586	0.00
2	I take as much care in picking out clothing for	2.17	2.24	3.7	44.377	0.00
3	The main reason my pet wears clothes is for warmth and/or protection from the weather.	3.51	3.57	3.26	5.02	0.081
4	For me, dressing my pet is a kind of hobby.	2.17	1.84	3.43	46.828	0.00
5	I buy many articles of clothing for my pet.	2.12	1.9	2.9	26.172	0.00
6	When people complement me on my pet's clothes, it makes me feel good.	2.95	2.6	4	35.619	0.00
7	Price is not important to me when buying clothes for my pet	2.1	2.25	3.08	26.135	0.00
8	My pet wears special clothes for different holidays.	2.33	2.18	3.33	26.479	0.00
9	When I purchase clothes for my pet, I take my	2.73	2.82	3.41	8.027	0.018
10	I frequently buy accessories to go with the outfits I buy for my pet. (Hats, footwear, etc.)	1.68	2.06	3.09	46.7	0.00
11	I consider myself a picky shopper when it comes to clothes for my pet.	2.44	2.35	3.24	14.996	0.001
12	I buy name-brand clothing for my pet.	1.93	1.88	2.59	18.454	0.00
13	When buying clothing for my pet, I prefer plain, functional clothing over clothing that is more elaborate	3.2	3.06	3.21	0.275	0.872
14	I prefer shopping for pet apparel in a pet store rather than online.	3.51	3.38	3.41	0.701	0.704
15	Clothes that I have bought for my pets influence my friends to buy clothes for their pets.	2.43	2.6	3.14	13.427	0.001

The Chinese were more interested in pet apparel and bought more articles for their pets, including special accessories and special clothes for holidays. They were more open to knowledge, information and they enjoyed dressing up their pet as a hobby. Also, for the Chinese consumers, having a pet and dressing up a pet is very much a social experience, something they would like to share with others in the community. In summary the term "Dressing dogs is more of the person than the dog" can be aptly applied (Serpell, 2009).

The harsh economic situations the USA and the western economies could have lead to less involvement between humans and pets in the non-Chinese study group (Lawinski, 2008). As people find themselves in dire financial situations other luxuries like pets have to be shed off. This could explain the less involvement for the non-Chinese with pets (Taylor, 2008). Just as a decreased human involvement with pets and pets items like clothes could be due to harsh economic times for the non-Chinese (Hansen, 2011), the increased involvement of the Chinese in pets and pets items like clothes could be due to the booming economy in China.

4. CONCLUSION

A survey on the consumer attitude towards pet apparel was carried out among 166 Chinese, 69 Americans and 114 other foreigners. The other foreigners were of several Nationalities which included Romania, Canada, Italy Australia, Japan, Singapore and Zambia. The data collected in this research indicated that for the non-Chinese consumers; gender, age and income did not affect the purchase of pet apparel. For the Chinese consumers, the results showed while gender and income does not affect the purchase of pet apparel, age of the consumer affected the purchase of pet apparel. The results of this research indicated that the attitude of the Chinese consumer towards pet apparel is driven by fashion and aesthetic properties (fun) while the non-Chinese especially the Americans tend to place more emphasize on the functionality of the pet apparel.

References

Eagly, A. A., & Chaiken, S. (1993). The psychology of attitudes. Fort Worth, TX: Harcourt Brace Jovanovich.

Hansen, A. (2011, July 3). Pets increasingly abandoned, surrendered due to economy. MagicValley. Retrieved February 14, 2011, http://magicvalley.com/lifestyles/relationship s-and-special-occasions/article_718e08e8- a36b-11e0-b5ad-001cc4c03286.html

Jeanne B. (2009, January 27). Designer Dog Clothes . Lots About Dogs. Retrieved February 14, 2010, http://www.lotsaboutdogs.com/tag/designer- dog-clothes/

Lawinski, J., (2008, December 11). Left Behind: The Economy's Toll on Man's Best Friend. Fox News, retrieved March 10, 2009, http://www.foxnews.com/story/0,2933,46482 4,00.html#ixzz1mKtr5Dc6

O'Keefe, D. J. (2002). Persuasion: Theory & Research (2 ed.). Thousand Oaks, CA: Sage Publications.

Roberts, A. (2010, September 20). Now the Kids Can Wear Designer Outfits - BusinessWeek. Businessweek . Retrieved February 10, 2011, http://www.businessweek.com/magazine/

Schooler, T. Y., Samuel, L., & Wilson, T. D. (2000). A Model of Dual Attitudes. Psychological Review, 107(1), 101-126.

Schutte, H., & Ciarlante, D. (1998). Consumer Behaviour in Asia. Beijing: Macmillan Press Limited.

Serpell J. (2009). Animals, the economy and your health, Bellweather Fall. 2 , 22-23

Solomon, M., & Rabolt, N. (2004). Consumer Behavior in Fashion. New Jersey: Prentice Hall.

Tanikawa, M. (2004, October 28). The unleashing of the pet industry - The New York Times. The New York Times - Breaking News, World News & Multimedia. Retrieved February 10, 2007,http://www.iht.com/articles/2004/10/23/your money/mpets.php

content/10_39/b4196027867917.htm

Tashiro, H., & Rowley, I. (2007, June 8). Japan's Pampered Pet Set. Businessweek. Retrieved September 15, 2008, http://www.businessweek.com/globalbiz/ content/jun2007/gb20070608_699714.htm

Taylor, J. (2008, May 20). Abandoned! Are Britain's pets the latest victims of the credit crunch? The Independent. Retrieved February 14, 2012,http://www.independent.co.uk/news/uk/hom e-news/abandoned-are-britains-pets-the- latest-victims-of-the-credit-crunch- 831010.html

Wines, M. , (2010, October 28). Once Banned, Dogs Reflect China's Rise, The New York Times, retrieved on Jan 20, 2011, http://www.cnbc.com/id/39826766/Once_Ba nned_Dogs_Reflect _China_s_Rise

Zhuang, J. (2005, March 16). China: changing attitudes to pet ownership drive pet food sales - Analyst Insight from Euromonitor International. Global Market Research and Analysis for Industries, Countries, and Consumers. Retrieved October 5, 2007, http://www.euromonitor .com/China_changing_attitudes_to_pet_own ership_drive_pet_food_sales