# DEVELOPMENT OF FABRIC USING CHEMICALLY-TREATED SISAL FIBRES

**Pinkie E. Zwane**

The Council for Scientific and Industrial Research (CSIR)
National Fibre, Textile and Clothing Centre (Clothing Technology Area),
P.O. Box 1124, Summerstrand, Port Elizabeth, South Africa.
Tel: 041-5083200 /3292 Fax: +27-041-5833277. E-mail: pzwane@csir.co.za

**Rinn M. Cloud**

Department of Textiles and Consumer Sciences
332 Sandels Bldg., Florida State University
Tallahassee, FL 32306-1492
Telephone: 850-644-2498 Fax: 850-645-4673
e-mail: rcloud@garnet.acns.fsu.edu

## Abstract

*The aim of this study was to explore the spinnability of sisal fibres treated with sodium hydroxide (NaOH), and the potential utility of spun yarns in producing a woven fabric for different end uses. Exploratory and experimental approaches were utilised in gathering data for this project. Yarns were spun using a spinning wheel, and subsequently a portable weaving loom was used for weaving the fabric. Fabric softeners were applied on the woven fabric, and later fabrics were evaluated for hand and potential end uses.*

*Major findings revealed that sisal fibres treated with NaOH were successfully spun into yarns using a traditional spinning wheel with the aid of a binding agent. Yarns spun from treated fibres were finer, weaker and highly absorbent. Flexural rigidity was the only significant fabric property that was decreased for fabric made from treated fibres compared to the control fabric. The application of fabric softeners had no significant effect on fabric hand. Subsequently, potential end uses of woven fabric were identified, which included apparel and accessories.*

## Key words:

*sisal yarns, sisal fabrics, softened fabrics, textile product development*

## Introduction

Research into sisal fibres has not made any major breakthrough, as the fibre is believed to be brittle and limited in its pliability for use in fabrics with a softer hand. The most significant and recent end use of sisal fibres as highlighted by Varghese et al.[1] has been in reinforced structures, from which the Daimler Chrysler Automobile company in South Africa has tried making dashboards. However, that initiative was discontinued due to the economic problems experienced by the suppliers of raw material.

Given the limited research on the fibre, chemical treatment of sisal fibres was successfully tried in order to enhance the pliability of fibres[2,3]. The applicability of chemically treated fibres can be in textile production or in the craft industry.

The purpose of the study was to explore the spinnability of fibres using a traditional spinning wheel and the potential utility of spun yarns in producing a woven fabric for different end uses. Attempts have been made in this study to determine some physical properties of yarns and fabric woven from an optimal concentration of NaOH treated fibres, to compare the hand qualities of softened and non-softened woven fabrics and thereby determine possible uses. It was further hypothesised that yarns and fabric made from treated sisal fibres would result in decreased breaking strength, linear density for yarns, and stiffness, but also increased absorbency and apparent elongation. Furthermore, fabrics made from treated fibres and subsequently treated with commercial softeners would have an improved hand compared to non-softened fabrics.

## Materials and methods

### Materials

A traditional spinning wheel was utilised to spin the fibres into yarns with an aid of a liquid-based binding agent, using a ratio of one to two parts of water. Yarn spinning was carried out on a traditional spinning wheel that was manually operated; this method is ideal for job creation. A portable weaving loom was utilised to weave the fabrics, and two cationic fabric softeners were used to soften the fabric. Forty grams per litre of cold water were used to dilute the fabric softeners.

### Methods

The spun yarns had a low twist of eight to 12 tpi, and were made from two plies with each ply consisting of about seven treated fibres. The yarns were later compared for some of their physical properties to a control yarn made from untreated fibres that were manually spun on the ?thighs by rural women. The spun yarns were tested for four different qualities. The yarn breaking strength was tested using the ASTM D 2256-90[4] test method with five replications. A 1000g load cell, 20 cm gauge length and 100 cm/minute strain rate were used for tensile testing. A CRE 8936-EA Houndsfield tensile tester was used in conducting the test. The yarn's apparent elongation was also tested using the ASTM D 2256-90[4] method.

The yarn's linear density was determined using the ASTM D 1577-90[4] test method. Ten yarn bundles, 50 cm long, were weighed to determine yarn fineness and expressed in tex. Option B (Heart Loop) of the ASTM D 1388-96[5] test method was used to determine yarn stiffness. Twenty-centimetre length yarns were used for the test with two replications on each yarn type. For the absorbency test, the bleached textile AATCC 79-1995[6] test method was used to determine the absorption rate after removal of the waxes from the sisal fibres by the NaOH treatment. The yarns were first rinsed in water to remove the binding agent used in the spinning process and then dried. A drop of distilled water was released from 1 cm away onto 10 closely aligned yarns, and the time recorded for the complete absorption of water by yarns.

Plain-woven fabrics were woven using yarns spun from fibres treated with optimal concentration (0.25 normality) on a portable table loom. The warp yarns in the fabric were made from 100%, 3-ply unwaxed cotton with 80 tex, and the weft yarns were made from 100%, 2-ply sisal yarns with fibres treated in optimal NaOH concentration. The experimental fabric was compared with a control fabric, which consisted of the cotton warp yarns and untreated control sisal yarns in the weft direction.

The cotton warp threads were utilised to increase product acceptance and improve the hand, as cotton is an acceptable and versatile natural fibre in textiles. To further enhance the fabric's hand, a polyethylene cationic wax emulsion (which is expensive) and another cationic softener (which is comparatively inexpensive) were used on the fabric with treated fibres. The fabrics were manually soaked in the diluted fabric softening solution for 10 minutes and hung on a clothes line to dry, due to the unavailability of a padding machine.

Five fabric specimens 10 cm in width and 15 cm in length were cut from randomly selected portions of control and treated fabrics. A total of four tests was conducted on the fabrics, which were the ASTM D 5034-90[4] Grab test method for the breaking strength and apparent elongation. An Apex T 1000 Satec Tensile Tester was used, with a load cell of 453.5 kg, 7.5 cm gauge and 3.125 cm/minute tensile rate for the control fabric and a tensile rate of 1.25 cm/minute for the treated fabric. The testing rates were altered to achieve fabric breaks within ±20 seconds as required by the procedure. Option A of the ASTM D 1388-96[5] test method for the fabric stiffness test was conducted using a Cantilever Tester. Fabric strips of 2.5 cm by 26 cm cut along the weft yarns for the control fabric were used for the test, as the 15 cm length strips were too short to measure the bending property. Two replications were done for each sample.
The AATCC 79-1995[6] for the absorbency test method was used. The fabric samples were secured on an embroidery hoop and placed 1 cm away from the nozzle of a pipette with distilled water. Complete absorption of the water droplet was recorded to determine absorption. The subjective hand evaluation was done by a consumer panel of 20 trained female assessors. 20cm² fabric samples were evaluated for their hand according to the AATCC Evaluation Procedure 5-1995[6]. The assessors were further requested to indicate potential fabric uses.

## Results and discussion

### Yarn properties

Yarn breaking strength, absorbency and linear density were significant and inversely correlated to NaOH concentration at $p \leq 0.01$; apparent elongation was also negatively correlated with alkaline concentration, but at $p \leq 0.05$. A Spearman's rho correlation test was used for the $p \leq 0.01$ significance level, given that the distribution of the data was skewed. With a normal bell-shaped distribution of data for apparent elongation and stiffness, a Pearson product-moment correlation test was used[7] as shown in Table 1.

**Table 1.** Correlation coefficients for NaOH concentration and yarn properties

| Yarn property | Type of test | Correlation coefficient |
|---|---|---|
| Breaking strength | Spearman's rho | -0.716** |
| Apparent elongation | Pearson product moment | -0.906* |
| Linear density | Spearman's rho | -0.829** |
| Stiffness | Pearson product moment | -0.152 |
| Absorbency | Spearman's rho | -0.886** |

* Significant at $p < 0.05$ ** Significant at $p < 0.01$

The findings revealed that as the NaOH concentration was increased, the yarn breaking strength, linear density and time for absorbency decreased. The reduction in breaking strength was due to the removal of cementing layers in the fibre structure, resulting in weaker and thinner fibres as shown in Table 2.

**Table 2.** Effects of NaOH concentration on mean yarn properties

| NaOH conc. (N) | Breaking str. (N*/tex) N=5 | Apparent elong. (%) N=5 | Linear density (tex) N=10 | Stiffness (mg.cm) N=4 | Absorbency (seconds) N=5 |
|---|---|---|---|---|---|
| Control | 194.6 | 9.15 | 1042.20 | 420.004 | 45.8 |
| 0.075 | 67.0 | 6.45 | 519.75 | 351.502 | 5.6 |
| 0.088 | 67.6 | 5.95 | 509.60 | 179.278 | 6.0 |
| 0.100 | 59.2 | 5.95 | 608.50 | 416.537 | 3.2 |
| 0.113 | 48.6 | 5.42 | 502.75 | 320.246 | 2.6 |
| 0.125 | 47.2 | 4.20 | 495.50 | 329.925 | 3.0 |

N* Newtons

Apparent elongation decreased significantly due to the increased NaOH concentration. These findings are consistent with Sikdar et al.[8] , who compared treated and untreated jute fibres that were spun into yarns. Yarns made from treated jute fibres showed a decreased apparent elongation compared to yarns made from untreated jute fibres.

Yarn linear density significantly decreased with an increase in alkaline concentration. Finer fibres were expected to produce finer yarns. Given the rudimentary spinning technology that was used in this study, yarn evenness was uncontrollable. Yarn absorbency increased as NaOH concentration increased. High absorbency is attributed to the removal of lignin and hemicellulose, which are responsible for impeding water absorbency on sisal yarns. The degradation of cementing layers between the fibrils increases the internal surface area where absorption takes place[9].

There was no significant correlation between yarn stiffness and increased NaOH concentration. The findings in this study were consistent with those concerning pliable kenaf fibres that had been spun, and resulted in less rigid yarns compared to those made from less pliable kenaf fibres[10]. The insignificant correlation in stiffness may be due to the binding agent used in the yarn spinning process. The first research hypothesis was therefore supported for breaking strength, linear density and absorbency, but not supported for apparent elongation or stiffness.

### Fabric properties

The independent sample t-test results indicate no significant difference in all of the four fabric properties measured, as seen in Table 3. The higher difference in the standard deviation for flexural rigidity between the fabrics necessitated the use of a non-parametric Mann-Whitney U test, which indicated a significant difference at $p \leq 0.05$. See Table 4.

**Table 3.** T test scores on fabric properties between control fabric and degummed fabric

| Fab. prop. | Fabr. typ. | Number | Means | Std. dev. | t value | p value |
|---|---|---|---|---|---|---|
| Breaking strength | Control | 5 | 382.600 | 22.250 | | |
| | Opt. deg. | 5 | 160.190 | 32.686 | 1.905 | .205 |
| Apparent elongat. | Control | 5 | 14.866 | 0.768 | | |
| | Opt. deg. | 5 | 6.796 | 1.241 | 0.834 | .388 |
| Flexural rigidity | Control | 4 | 5691.609 | 1223.787 | | |
| | Opt. deg. | 4 | 877.013 | 289.634 | 4.246 | .085 |
| Absorben. | Control | 5 | 32.200 | 5.020 | | |
| | Opt. deg. | 5 | 29.800 | 7.727 | 0.312 | .592 |

Significant at $p < .05$

**Table 4.** Mann-Whitney U test on stiffness of optimally degummed fabric and control fabric.

| Fabric type | Number | Mean rank | P value |
|---|---|---|---|
| Control fabric | 4 | 6.50 | |
| Optimally degum. | 4 | 2.50 | 0.029 |

The fabric made from alkaline treated fibres was more pliable than the control fabric. This could be attributed to the incorporation of cotton in the fabric structure, which could have masked the effects of NaOH treatment on the sisal fibres. These findings are consistent with the flexible kenaf fabric that was made from chemically treated fibres[10]. The second hypothesis was supported for flexural rigidity, but not for breaking strength, apparent elongation or absorbency.

## Softened fabrics

Three fabric types were evaluated for fabric hand against a control fabric that was made from untreated sisal fibres as weft yarns. The ANOVA results in Table 5 indicate a significant difference for the density hand attribute at p=0.017 on the 95th percentile. A Scheffe's *post hoc* test to determine which fabric was significant revealed that the fabric made from weft-treated fibres and yarns was different from the control fabric at p=0.049.

**Table 5.** ANOVA Table on Fabric Hand Attributes of Woven Fabrics

| Hand attribute | | Sum of squares | df | mean square | f | p |
|---|---|---|---|---|---|---|
| Compress. | between groups | 38.769 | 3 | 12.923 | 2.423 | .068 |
| | within groups | 832.075 | | 156 | 5.334 | |
| | total | 870.844 | | 159 | | |
| Density | between groups | 42.525 | 3 | 14.175 | 3.505 | .017* |
| | within groups | 630.850 | | 156 | 4.044 | |
| | total | 673.375 | | 159 | | |
| Extensibi. | between groups | 6.819 | 3 | 2.273 | .458 | .712 |
| | within groups | 774.375 | | 156 | 4.964 | |
| | total | 781.194 | | 159 | | |
| Flexiblity | between groups | 21.450 | 3 | 7.150 | 1.040 | .377 |
| | within groups | 1072.550 | | 156 | 6.875 | |
| | total | 1094.000 | | 159 | | |
| Resilience | between groups | 28.369 | 3 | 9.456 | 1.812 | .147 |
| | within groups | 814.125 | | 156 | 5.219 | |
| | total | 842.494 | | 159 | | |
| Surf. cont. | between groups | 12.325 | 3 | 4.108 | 1.270 | .287 |
| | within groups | 504.650 | | 156 | 3.235 | |
| | total | 516.975 | | 159 | | |
| Surf. frict. | between groups | 8.350 | 3 | 2.783 | .999 | .395 |
| | within groups | 434.750 | | 156 | 2.787 | |
| | total | 443.100 | | 159 | | |
| Thermal c. | between groups | 7.475 | 3 | 2.492 | .679 | .566 |
| | within groups | 572.500 | | 156 | 3.670 | |
| | total | 579.975 | | 159 | | |

* significant at $p < 0.05$

The degumming or chemical treatment process and use of commercial softeners had no significant effect on the hand attributes as perceived by the assessors who conducted the subjective hand evaluation of fabrics. Since the hand ratings of the softened fabrics were similar to the control, the mean ratings for each fabric type will be discussed as seen in Table 6.

The control fabric was highly rated as being harder, rougher, harsher and more open rather than soft, smooth, slippery and compact compared to all the other fabric types. For flexibility, extensibility, resiliency and thermal character, the control was rated low as being stiff, non-stretchy, limp and warm; but nevertheless the mean scores were higher for the control fabric when compared to the mean scores of the rest of the fabrics. The incorporation of cotton warp yarns in the fabric structure contributed to the improved fabric hand, and may have been sufficient to overshadow the differences resulting from the processing or treatment.

**Table 6.** Mean hand values for the tested fabrics

| Hand attribute | Control fabric | Degum. fabric | Soft. fabric (L) | Soft. fabric (V) |
|---|---|---|---|---|
| Flexibility | 5.1 | 5.2 | 4.5 | 4.3 |
| Compressibility | 6.6 | 6.1 | 6.0 | 5.2 |
| Extensibility | 4.0 | 4.5 | 4.5 | 4.2 |
| Resilience | 4.9 | 4.0 | 4.0 | 4.1 |
| Density | 7.3 | 6.1 | 6.2 | 6.2 |
| Surface Cont. | 7.7 | 7.4 | 7.0 | 7.0 |
| Surface frict. | 7.8 | 7.5 | 7.2 | 7.3 |
| Thermal chara. | 4.4 | 4.1 | 3.8 | 4.2 |

When panellists were requested to indicate or suggest potential end uses for the four fabrics, the majority of respondents perceived the fabrics as being suitable for wall hangings, followed by improved rugs and upholstery. The fabric that was softened in one of the softener was further perceived to have a potential in making table linen. Suggestions for other uses that could be explored with the fabrics included carpets, bags, sunhats, table runners, body scrubbers, seats for garden chairs, hammocks and sandals. The softened fabrics were further suggested for pants and fabric for count thread embroidery.

## Conclusions

Treated sisal fibres were successfully spun into yarns using the traditional spinning frame with the aid of a binding agent. Yarns made from treated fibres were finer and weaker in strength, but highly absorbent. On the other hand, the apparent elongation of yarns was decreased, indicating the brittleness of the fibres, and yarn stiffness was not significantly reduced due to the use of the binding agent in the spinning process. Therefore, the hypothesis on yarns was supported for breaking strength, linear density and absorbency, but not supported for apparent elongation or stiffness. The hypothesis on fabric made from treated sisal fibres was supported only for flexural rigidity. The application of softening finishing agents had no significant effect on fabric hand when compared to non-softened fabric. Therefore, the last hypothesis was not supported by the findings. The potential end uses of fabric that were identified were apparel and accessories.

Future research endeavours may focus on the utilisation of better or mechanised spinning technology to attain better yarn evenness and higher productivity. In addition, the production of 100% sisal fabrics may be explored using a finer yarn than that which was used in this study.

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