Chemical Science International Journal

28(2): 1-13, 2019; Article no.CSIJ.52137
ISSN: 2456-706X
(Past name: American Chemical Science Journal, Past ISSN: 2249-0205)

Impact of Esterification on Physicochemical Properties of Cellulosic Fabric using *Balanites Aegyptiaca* Seed Oil

F. I. Omizegba[1*], K. A. Bello[2], H. M. Adamu[1], D. E. A. Boryo[1], J. O. Abayeh[3] and H. Akanang[1]

[1]Department of Chemistry, Abubakar Tafawa Balewa University, Bauchi, Nigeria.
[2]Department of Textile Science and Technology, Ahmadu Bello University, Zaria, Nigeria.
[3]Department of Pure and Industrial Chemistry, University of Port Harcourt, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. Author FIO designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors KAB, HMA, DEAB and JOA managed the analyses of the study. Author HA managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CSJI/2019/v28i230136
Editor(s):
(1) Dr. Francisco Marquez-Linares, Professor, Department of Chemistry, Nanomaterials Research Group, School of Science and Technology, Universidad Ana G. Méndez-Gurabo Campus, USA.
Reviewers:
(1) Uzoma Paul Chinonso, Federal University of Technology Owerri, Nigeria.
(2) Mariana-Atena Poiana, Banat's University of Agricultural Sciences and Veterinary Medicine, Romania.
Complete Peer review History: http://www.sdiarticle4.com/review-history/52137

Original Research Article

Received 14 August 2019
Accepted 17 October 2019
Published 31 October 2019

ABSTRACT

This paper presents the results of some physicochemical properties of cellulosic fabric obtained by esterification using 50 cm^3 of oil extracted from the seed of *Balanites aegyptiaca*.
The oil was extracted under reflux with hexane which gave 40% yield and 0.22% moisture content. The identified cellulosic materials 10 cm and 21 cm x 2.5 cm) were subjected to purification process of scouring, bleaching and mercerization to obtain cleaner, whiter and stronger fabric that could withstand esterification treatment.
The yarn crimp was 25% and 15% for warp and weft direction respectively, while the grey fabric gave the lowest of 5% and 8% for warp and weft directions. The linear density (45 tex) was recorded for the esterified fabric compared to 37 tex for the grey fabric along warp direction. The fabric sett increased from 24 thd/cm for grey to 27 thd/cm for esterified along warp direction and 16 thd/cm to

**Corresponding author: E-mail: fiomizegba2013@gmail.com;*

23 thd/cm along weft direction. There was an obvious reduction in shrinkage from 31 for mercerized fabric to 28 along warp direction after esterification and 21 to 19 along weft direction. The tensile parameter was 262.60 N and 166.24 N with extension of 13.92 mm and 12.23 mm along warp and weft directions respectively while the grey fabric recorded 223.87 N and 109.39 N with extensions of 3.64 mm and 3.56 mm in warp and weft direction respectively. There was a remarkable improvement in the dry and wet crease recovery angles after esterification (105º dry and 65º wet, 102º dry and 59º wet) along warp and weft direction respectively. The grey fabric gave the lowest crease recovery (50º dry and 37º wet, 45º dry and 35º wet) along warp and weft directions respectively.

The esterified fabric recorded lower water absorption. The improvements in the investigated properties may be due to dimensional stability, flexibility and fineness due to esterification. This research is commendable because biodegradable organic seed oil is used to modify the physicochemical properties of cellulosic fabric for the first time. These incredible effects of the seed oil on cellulose is an immense contribution to knowledge, hence the oil is recommended for replacement of the present day toxic chemicals used in textile finishing of cellulosic fabrics.

Keywords: Esterification; Balanites aegyptiaca; seed oil; cellulosic fabric physicochemical properties.

1. INTRODUCTION

Cellulose is the most abundant polymer in nature formed by glucose units linked through a B-1, 4 glycosidic-linkage. The linear chains of this polymer are bound together forming micro-fibrils which structure the cell wall in most plants [1,2].

Cellulose fibre is known for some properties of immense importance which include linearity of the polymer chain, crystallinity and orientation of the fibre structure as well as high temperature stability to mention but a few [3]. The high moisture absorption characteristics due to the presence of 3 –OH groups afford cellulose good dyeability and the formation of numerous cellulose derivatives [4,5]. Apart from effective absorption of liquid and being easily dyed, its fabrics also drapes well, smooth in texture and ideal for making comfortable clothing. There are many uses of cellulose fabrics, from bed sheets to baby wipes. Cellulose fabrics are everywhere and it would be difficult to imagine life without them [6]. Chemical finishing such as scouring, bleaching, mercerization and resignation has been used to improve the physicochemical properties of cellulosic fabric. The focus in recent time is to do away with the use of toxic chemical and to embrace environmentally friendly and biodegradable substances that would achieve the same or better effect in durable press finish of cellulosic fabric [7,8]. Apart from being toxic and contribution to environmental degradation, amino resins give formation of yellow discoloration on cellulosic fabric during storage, releases hydrochloric acid during ironing leading to lose of strength in such fabric [9]. The very high cost of the chemicals and the finished products is discouraging and unaffordable in the present economic realities. Hence the reason for the paradigm shifts to cheaper, natural and biodegradable substances.

Ester linkage is a covalent bond that can cross-link and stabilize different materials. Structurally, esters are flexible functional groups due to the free rotation about the C-O-C bonds [10]. This characteristic is evident in their physical properties such as less rigidity due to low melting temperature and more volatility because of low boiling temperature [11].

Chemical modification of cellulose by esterification has the potential to improve cellulose properties such as dimensional stability, resistant to fungal attack and decay as well as fastness properties.

Balanites aegyptiaca is chosen for this research because every part of the plant is very useful for various ethnobotanical purposes which include fibre, oil, food, fermented drinks or beverages, medicine and biodiesel [12,13,14,15].

Balanites aegyptiaca as a rich source of quality and non-toxic oil has proved potent for structural modification of cellulose fabric by esterification as revealed by x-ray diffraction crystallography [5]. Under suitable conditions, such as heating and drying, esterification reaction occurred between one hydroxyl group in cellulose and carboxylic group within the oil sample to form cellulose monoester [5,8]. The general purpose of the study is to investigate the physicochemical properties of cellulosic fabric by means of esterification using *Balanites aegyptiaca* seed oil

to replace the use of toxic chemicals in textile processing.

2. MATERIALS AND METHODS

Materials: all chemicals were analytical grades supplied by BDH chemical Ltd. Poole, England. They are sodium hydroxide, acetic acid, sodium silicate, magnesium sulphate, hydrogen peroxide, sulphuric acid, sodium carbonate, and methanol. The equipment include: Oven (Memmert 854 Schwabach and Gallenkamp size on BS), Digital weighing Balance (Model UJ07932 Florham Park USA). Heating mantle (Cliffon), Shirley Crease Recovery Tester (Model No. 308), Shirley Crease Loading Device (Model 308), Stop clock (Raffin), Hook's Travelling Microscope (Serial No. 901879).

2.1 Methods

2.1.1 Extraction of oils

Extraction of the oil was according to Pearson [15]. The fruits were decoated, soaked in water for about 6 hours to dissolve the sticky pulp then sun dried. The seeds were removed from the hard shells through cracking. The kernels obtained were air dried and then ground to fine powder ready for extraction. The ground seeds (50.0 g) was placed in a pre-weighed thimble and then placed in the barrel of the Soxhlet Apparatus. Hexane (200 cm^3) was poured into the flask and the apparatus set for extraction and allowed to run for 6 hours.

2.1.2 Percentage yield

Ground sample (50 g) was placed into the pre-weighed empty thimble (w_1). Weight of sample plus that of thimble was recorded (w_2). The thimble was removed after extraction and dried in an oven to a constant weight (w_3). The percentage yield was calculated using;

$$Percentage\ yield = \frac{w_2 - w_3}{w_2 - w_1} \times 100 \quad (1)$$

2.1.3 Moisture content

A 3 g of oil sample was weighed into an empty crucible (w_1), so that the weights of the crucible and oil sample were recorded as (w_2). The crucible and its content were then placed in an oven at 105º C for 4 hours after which it was removed, cooled in a desiccator and reweighed (w_3). The process of heating and cooling was repeated until a constant weight was obtained [15]. Percentage of moisture content is calculated as:

$$Percentage\ moisture\ content = \frac{W_2 - W_3}{W_2 - W_1} \times 100 \quad (2)$$

2.2 Identification Test of Fabric

In this section, Standard method according to BS 11 [16] was employed.

2.2.1 Burning test

Yarns were unraveled from the fabric along the warp and weft directions. These were introduced separately into the Bunsen burner flame with the aid of forceps.

2.2.2 Alkali and acid test

The fabric sample (1 g) was immersed into 25 % concentrated solution of sodium hydroxide at room temperature and allowed to stand for 1 hour, and then heated at 80º C for 10 minutes. A fresh sample of the same size was also immersed into 25 % concentrated solution of sulphuric acid and allowed to stand at room temperature for an hour.

2.3 Purification of Fabric

Standard method based on BS 11 [16], ASTM [17] and ASTM [18] was employed.

2.3.1 Scouring of grey fabric

10 cm × 10 cm of the grey fabric was immersed in 2 % NaOH solution and boiled for 1 hour. It was rinsed severally in overflowing water followed by washing in detergent solution, after which it was neutralized with 5 % acetic acid then rinsed with water and dried at room temperature.

2.3.2 Bleaching of scoured fabric

The scoured sample was boiled for 45 minutes in a bleaching liquor containing 5 % of H_2O_2, 0.1 g $NaSiO_3$, 10 cm^3 of 1 % NaOH solution and 0.5 g $MgSO_4$, then rinsed severally in tap water for 10 minutes and neutralized with 5 % acetic acid and dried at room temperature.

2.3.3 Mercerization of bleached fabric

The bleached fabric was immersed in 20 % solution of NaOH at 5º C with occasional turning

with a glass rod for 20 minutes, after which it was washed in detergent solution for 10 minutes, rinsed with tap water for 5 minutes, neutralized with 5 % acetic acid, rinsed with distilled water and dried at room temperature.

2.4 Esterification of Mercerized Fabric

Methanol (100 cm^3) and the oil (50 cm^3) were mixed; 0.5 cm^3 of concentrated H_2SO_4 was added and refluxed for 1 hour at 60º C. The mercerized sample was weighed (1 g) and then immersed into the flask and refluxed for 3 hours at 60º C with occasional shaking. The fabric was removed and neutralized in 2 % solution of Na_2CO_3 in order to destroy any acid residue that remained in the sample, while the residual oil was removed by immersing the fabric in a very dilute detergent solution. The sample was rinsed in distilled water and dried in the oven at 60º C for 20 minutes then weighed again.

2.5 Determination of Physical and Mechanical Properties

Standard method according to BS11 [16] was employed.

2.5.1 Yarn crimp

The original length of the sample was taken as L_o, and the unraveled yarn was subsequently straightened to remove the wavy curves on the thread. The length of the straightened yarn recorded as L_c. the entire procedure was carried out in both weft and warp directions for the grey, scoured, bleached, mercerized and esterified fabrics and the yarn crimp calculated using;

$$Yarn\ Crimp\ \% = \frac{Lc-Lo}{Lo} \times 100 \quad (3)$$

2.5.2 Yarn linear density (Tex)

The mean weight of 10 threads was taken in g for both weft and warp directions. The length of the sample is 10 cm × 10 threads which gives 1 m. The Yarn Linear Density is calculated using;

$$Yarn\ Linear\ Density(Tex) = \frac{Weight\ in\ gram}{Length\ in\ meter} \times 1000 \quad (4)$$

This procedure was carried out for the grey, scoured, bleached, mercerized and esterified samples.

2.5.3 Yarn sett or thread count

The Hook's Travelling Microscope instrument (Serial No. 901879) was used to determine the threads per cm of the fabric samples. This was done for the grey, scoured, bleached, mercerized and esterified samples.

2.5.4 Fabric shrinkage

The dimension of the fabric was measured for weft and warp directions as Lo. After scouring, bleaching, mercerizing and esterifying, the new dimensions was measured in each case for both weft and warp directions as Ls.

The fabric shrinkage is determined using;

$$Fabric\ Shrinkage\% = \frac{Lo-Ls}{Lo} \times 100 \quad (5)$$

Standard methods according to BS11 [16] was employed.

2.5.5 Fabric tensile strength

The sample dimension 10 cm × 5 cm was mounted on the Tensile Strength Tester. The gauge length of the Tester adjusted to accommodate the sample then the instrument operated at the speed of 350 mm/min and the breaking load/extension characteristics of the sample recorded automatically while the load cell was 5000 N. This was carried out on the grey, mercerized and esterified samples in both weft and warp directions.

2.5.6 Crease recovery

Dry crease recovery: The Shirley Crease Recovery Tester was calibrated by adjusting the knobs to face 0^o mark. The fabric sample was cut using the template dimensions along the warp and weft directions for grey, scoured, bleached, mercerized and esterified fabrics. The samples were folded end to end and placed on the Shirley loading device for 5 minutes. The load was removed and the samples allowed recovering for another 5 minutes, after which they were transferred to the Crease Recovery Tester to measure the angle of crease recovery.

Wet crease recovery: The samples were immersed in water and the excess water on the samples drained with filter paper without pressing. The test procedure was repeated as in dry crease recovery angle measurement.

2.6 Water Imbibition

The esterified fabrics were weighed and soaked in 250 cm^3 of distilled water in a beaker for 5 minutes. They were removed and mopped with filter paper gently to remove excess water and

then reweighed again immediately. This was followed by progressive drying at 80º C in an oven for 5, 10, 15, 20, 25 and 30 minutes. At each of these intervals, the weights of the samples were recorded using analytical balance. The temperature of the laboratory was maintained at 25º C during the experiment. The experiment was repeated for the control sample.

$$Water\ imbibition\ (regain)\% = \frac{mass\ of\ water\ retained}{mass\ of\ dry\ sample} \times 100 \quad (6)$$

3. RESULTS AND DISCUSSION

3.1 Percentage Yield of Oil

The percentage oil obtained after extraction with hexane was 40 % [5,8]. The oil is light yellow in colour and liquid at room temperature which implies that it is made up of predominantly unsaturated acids of low molecular weight [19]. The oil is tasteless and odourless therefore is suitable for cellulose esterification.

3.2 Moisture Content

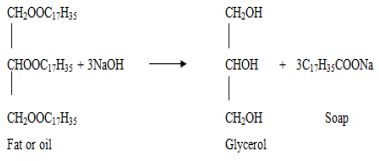
Balanites aegyptiaca seed oil contained 0.22 % moisture which is well below the 0.55 % standard of moisture content recommended by ASTM [18] for edible oil. This is to say that the low moisture content of the oil will not interfere with esterification.

3.3 Fabric Identification and Fabric Purification

The results for fibre identification and fabric purification are presented in Tables 1 and 2 respectively.

The burning test showed that fibre burned rapidly with a yellow flame, giving a powdery ash residue which smells like that of burned paper. The solubility test showed that the material was soluble in concentrated sulphuric acid solution but insoluble in concentrated solution of sodium hydroxide, implying that the fabric was made of 100 % cotton as shown in Table 1.

Table 2 shows the changes in physical properties of fabrics as a result of purification processes. The equation for the scouring treatment is shown in equation 7.



(7)

The soap produced served as the cleaning agent resulted to a material that is cleaner, softer and absorbent. This is as a result of emulsification of the insoluble fats and waxes, degradation of proteins and nitrogenous compounds into soluble salts and the loosening of mechanically adhered dirt.

The whiteness of the fabric was due to the removal of coloring matters, achieved because of the decomposition of the hydrogen peroxide into perhydroxyl ion which is the active bleaching specie as shown in equation 8.

$$H_2O_2 \longrightarrow H^+ + HO_2^- \quad (8)$$

The resulting fabric obtained after mercerization is hydrated cellulose (alkali cellulose or cellulose alcoholate) which is different from the original fabric by its physical properties [20]. The fabric shrank longitudinally, swelled laterally, more lustrous, more absorbent and creased very badly [8, 9,14].

3.4 Esterification of Mercerized Fabrics

The fabric was esterified with 50 cm^3 of *Balanites aegyptiaca* seed oil. The results revealed that there was bond formation between the OH of cellulose and the COOH of the oil to give a new cellulose mono ester with structural modification and an increase in weight [5]. The esterified fabric is expected to absorb less water due to the presence of a more hydrophobic ester group in the molecular structure of the cellulose. The improvements in the properties investigated may be attributed to the structural modification due to esterification.

3.5 Effect of Treatment on Yarn Crimp

Generally, there was increase in percentage crimp due to purification, mercerization and esterification compared to the grey (control) sample. Crimp plays an important role in yarn extensibility, compressibility, fabric extensibility and improves the quality of fabric in smoothness, fullness and softness [21,22]. Yarn crimp is defined as the waviness of a yarn owing to interlacing in the fabric during yarn construction.

Table 1. Results of fibre identification

Test	Observation	Inference
Burning	Yellow flame and white ash residue which smells like burnt paper	Fibre is Cellulosic
Alkali Test	Fibre insoluble	Fibre is Cellulose
Acid Test	Fibre degraded	Fibre is Cellulose

Table 2. Results of fabric purification

Test	Observation	Inference
Scouring	Fabric became cleaner and softer.	Fat waxes, protein and nitrogenous compounds degraded, mechanically adhering dirt are loosened.
Bleaching	Fabric became white.	Removal of colouring matter.
Mercerization	Fabric shrank longitudinally and swelled laterally, increase in luster, wrinkled very badly.	Formation of cellulose alkali.

The percentage yarn crimp for grey, scoured, bleached, mercerized and Balanites esterified samples are 5, 16, 17, 30, 25 for warp directions and 8, 12, 11, 21, 15 for weft direction, respectively as depicted in Fig 1. Obviously, the grey fabric had the lowest crimp, implying that the grey fabric will have very poor draping quality and lowest dimensional stability. However, it is obvious from the result that *Balanites aegyptiaca* seed oil helped to relax a bit the crimping effect caused by mercerization but with significant improvement with respect to the grey fabric. Hence, the esterified fabrics may have a better spinning performance due to better dimensional stability [8].

3.6 Effect of Treatments on Linear Density (Tex)

Linear density is the parameter for assessing the fineness or coarseness of a textile fabric. It is defined as the weight in grams per unit length of 1000 m of yarns [23]. According to Fig. 2, the yarn linear density for grey, scoured, bleached, mercerized and esterified fabrics are 37, 33, 30, 38, 45 along warp direction and 31, 30, 28, 33 and 32 along weft direction respectively. The esterified fabric gave the highest tex value along warp direction. This may be attributed to fibre consolidation and the presence of a more bulky ester bond in the cellulose chain [5,8]. The observed lower values of tex for scoured and bleached fabrics may be due to the removal of all impurities and colouring matters during the purification process. Hence, the esterified fabrics appeared finer and smoother to handle.

3.7 Effect of Treatments on Fabric Sett

Sett is defined as the number of threads per 1 cm length of fabric also referred to as thread count. There are two types of fabric sett: these are warp sett and weft sett. The warp runs longitudinally and the weft interlaced horizontally through the warp [2]. In weaving process the higher the fabric sett, the higher the crimp leading to improvement in fabric crystallinity and elasticity [24].

The results of this investigation are outlined in Fig. 3. The thread count for grey, scoured, bleached, mercerized and esterified samples are 24, 26, 26, 29, 27 for warp direction and 16, 18, 18, 25, 23 for weft direction respectively. These results revealed that the number of threads/cm increased as the grey fabric was subjected to the various treatments especially along the warp direction. The relaxation effect on the fabric sett caused by esterification may be the reason for the slight decrease in the thread count after mercerization.

However, according to Fashola and Alonge [24] the overall effect means that the esterified fabric is more flexible and elastic due to the exceptional flexibility and free rotation about the O-CO- ester bond [25] in the cellulose ester formed [3]. It also implies that *Balanites aegyptiaca* seed oil acted as a lubricant. It effect resulted to a finer and smoother fabric that is expected to have a better crease recovery. This is contrary to resination of cellulosic fabric using urea and melamine formaldehyde which resulted to a stiffer and coarse fabric [7].

3.8 Effect of Treatment on Fabric Shrinkage

The primary cause of shrinkage of cellulosic fabric is the fact that these fabrics can readily absorb moisture thereby facilitates the movement of internal polymer chain. Cellulose fibre can take up more than 10 % their weight in water. As the fibre swell, the fabric must crease and shrink to relieve the internal stress roused by swelling [26]. The result of the fabric shrinkage in percent is presented in Fig. 4. The values for grey, scoured, bleached, mercerized and esterified samples are 0, 10, 10, 31, 28 along warp direction and 0, 6, 6, 21, 19 along weft direction respectively.

The grey fabric had zero shrinkage because it did not undergo any chemical treatment. Generally, there was no difference in shrinkage between the scoured and bleached samples since the physical and mechanical properties remained unchanged except for the removal of colouring matters. Any difference is very minimal and may be because scouring and bleaching treatments are aimed at removal of impurities and colours in order to give a permanent white effect [27].

The observed highest percentage shrinkage in the mercerized fabric may be attributed to the formation of alkali cellulose which has a better fibre alignment and fabric consolidation [8,28, 29]. The esterification from these results has contributed in the reduction of percentage shrinkage due to the formation of ester bond with dimensional stability [30,31]. This is another

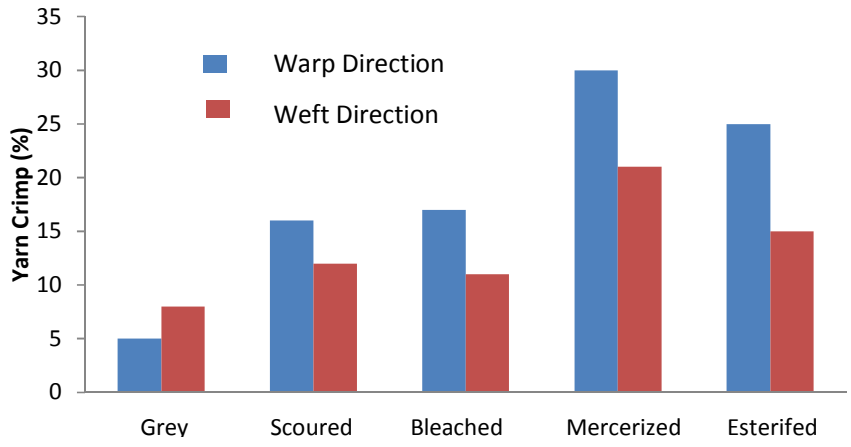


Fig. 1. Effect of Treatments on Yarn Crimp (Warp and Weft Directions)

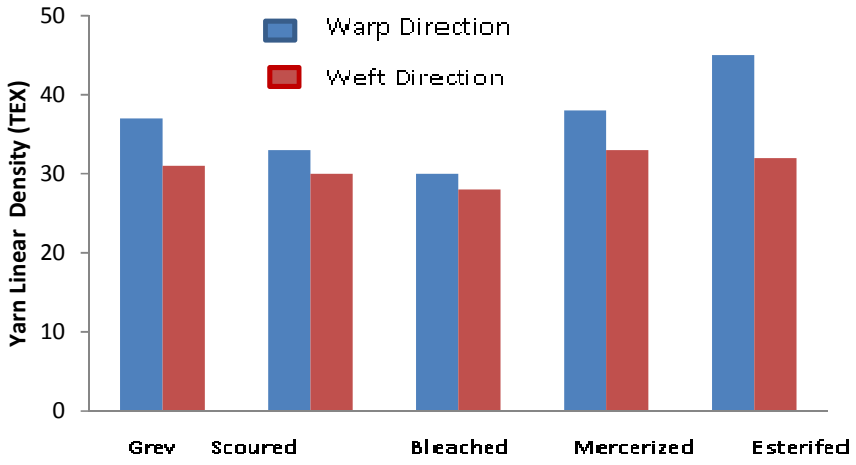


Fig. 2. Effect of Treatments on Yarn Linear Density (Warp and Weft Directions)

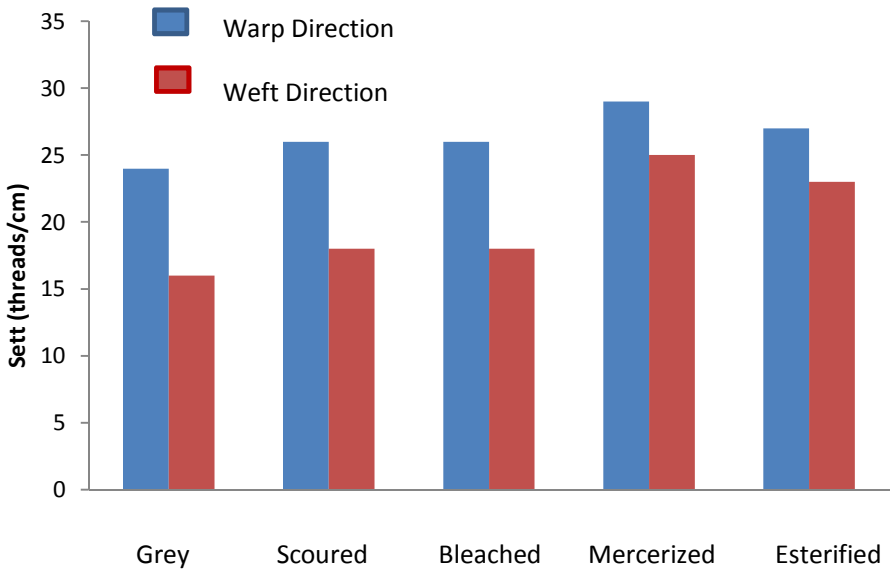


Fig. 3. Effect of Treatments on Fabric Sett (Warp and Weft Directions)

evidence to show that esterification helps to cushion the effect of treatment of cellulosic fabric with 20 % alkali by causing the threads to relax and stretch out a bit.

3.9 Effect of Treatments on Fabric Strength Parameters

The ability of a fibre to resist stress is referred to as the tensile strength. This is expressed in terms of breaking load and extension as shown in Table 3. It is calculated to be the maximum force that can rupture a material on application of tension [32].

The strength of cotton fibre is attributed to the good alignment of its long polymer chain and its countless regular hydrogen bond formations between adjacent polymers. The stronger the fibre, the stronger will be the fabric [23]. The mercerized samples gave the highest strength with a breaking load of 282.88 N and 176.10 N as well as breaking extension of 20.20 mm and 17.74 mm along warp and weft direction, respectively. This may be attributed to realignment and consolidation of fibres along the axes after treatment with concentrated alkali. However, the observed coarseness and much creasing of the fabric after mercerization are undesirable.

The strength of Balanites esterified fabric was 262.60 N and 166.24 N with extension of 13.92 mm and 12.23 mm along warp and weft direction respectively. While that of grey sample was the lowest 223.87 N and 109.39 N with extension of 3.64 mm and 3.56 mm along warp and weft direction respectively. Studies by Yuping et al. [33] and Omizegba et al. [5] showed that esterification reduces the crystallinity of cellulosic fabric. This may be the reason for the observed decrease in strength between the mercerized and esterified samples.

3.10 Effect of Treatments on Dry Crease Recovery

Several investigations have taken place regarding crease and crease recovery in

Table 3. Results of Breaking Load/Extension of Fabrics

	Warp		Weft	
Sample	**Load (N)**	**Extension (mm)**	**Load (N)**	**Extension (mm)**
Grey	223.87	3.64	109.39	3.56
Mercerized	282.88	20.20	176.10	17.74
Esterified	262.60	13.92	166.24	12.23

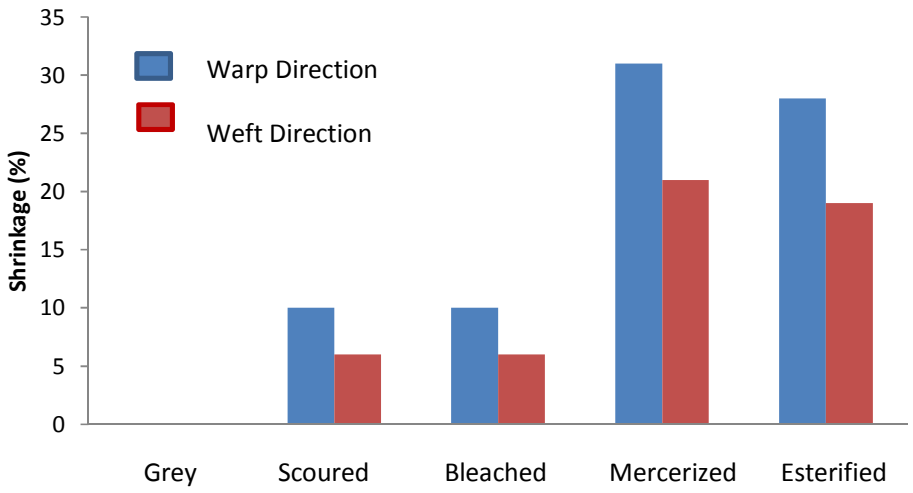


Fig. 4. Effect of Treatments on Fabric Shrinkage (Warp and Weft Directions)

cellulose, cotton/polyester blend and polyester fabrics [7,29,34,35]. These researchers have concluded that crease recovery whether dry or wet is improved after chemical treatment such as scouring, bleaching, mercerization and resination. According to Klemn et al. [6], hydrogen bonds in cellulose shift position after being immersed in water. This shift causes a rise in wet crease recovery but is less compared to dry crease recovery.

Crease recovery whether wet or dry is a measure of the strength of a fabric [36].The ability of a fabric to return to its original position after creasing load has been removed is known as crease recovery and is measured in terms of recovery angle. It gives information on the flexibility of the material and how easily the material can recover from deformation. If the angle is 0º then there is no recovery and if 180º then recovery is full [8,29]. The dry crease recovery angle for the grey, scoured, bleached, mercerized and esterified samples are 50º, 75º, 75º, 80º, 105º, for warp direction and 45º, 70º, 70º, 76º, 102º, for weft direction respectively are presented in Fig. 5. Clearly, it can be observed that the esterified sample recorded the highest and remarkable crease recovering in both warp and weft directions. This is very obvious and indicates that the esterified fabrics are more flexible and elastic than the rest of the samples. This again is attributed to the O – CO - ester bond formed in the new cellulose monoester [5]. The lowest dry crease recovery displayed by the grey sample may be due to the rigidity of the fabric caused by the presence of the 3 – OH bonds capable of keeping the cellulose chain in a fixed position.

3.11 Effect of Treatments on Wet Crease Recovery

A material that easily recovers from distortion or deformation while wet or dry is more desirable especially as clothing materials [37]. The ability of a material to snap back from deformation after wet treatment is referred to as wet crease recovery. The results of this investigation as revealed in Fig. 6. For grey, scoured, bleached, mercerized and esterified samples are 37º, 48º, 48º, 54º, 65º, along warp direction and 35º, 39º, 40º, 49º, 59º in the weft direction respectively. The observed low wet crease recovery compared to the dry crease recovery may be as a result of a shift in the position of the hydrogen bonds in water by the cellulose structure [6]. The esterified fabrics exhibited slight resistant to water which agrees with the investigation carried out by Yuping et al. [33]. This again may be attributed to the presence of a hydrophobic –O-CO- ester bond in the new cellulose chain.

3.12 Effect of Treatments on Water Imbibition

Water imbibition is the property of many biological substances which include cellulose, protein and starch [38]. Protein materials have the highest affinity for moisture absorption followed by starch, then cellulose least [39]. Water potential gradient between the absorbent and the liquid imbibed is essential for imbibition. It is important to note that affinity between the

absorbent and the liquid is also a prerequisite for any material to imbibe a liquid. The water imbibition of grey mercerized and esterified fabrics is shown in Fig. 7. It could be clearly seen that the mercerized fabric recorded the highest water imbibition (95 % at 20 min drying time) which could be attributed to the effect of treatment of the fabric with 20 % alkali leading to swelling of the fabric. This swelling is responsible for increase in absorbency. Next to mercerized fabric is the grey fabric due to the presence of the 3 – OH groups. The observed lowest values of water imbibition (65 % at 20 min drying time) for the esterified fabric may be due to the replacement of one out of the 3-OH groups in cellulose with O-CO- ester bond in the cellulose mono ester as revealed by x-ray diffraction [5]. Hence the esterified fabric is expected to have better resistance to formation of mildew during storage.

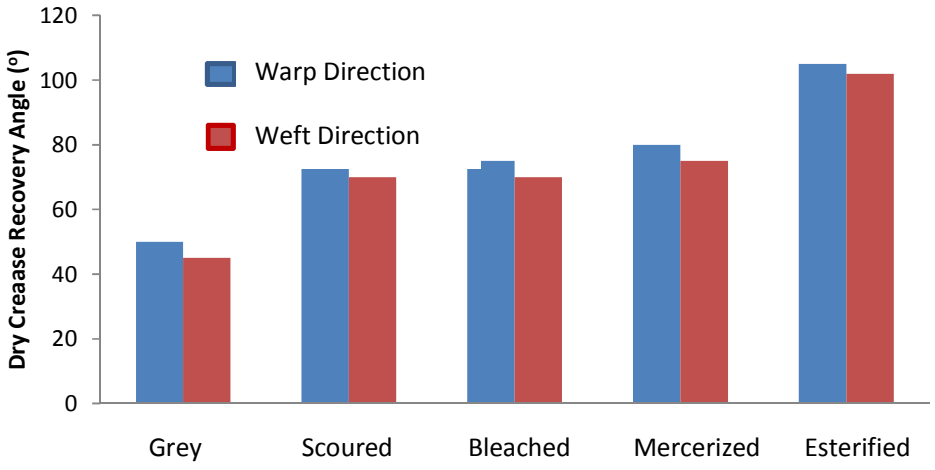


Fig. 5. Effect of Treatments on Dry Crease Recovery Angle (Warp and Weft Directions)

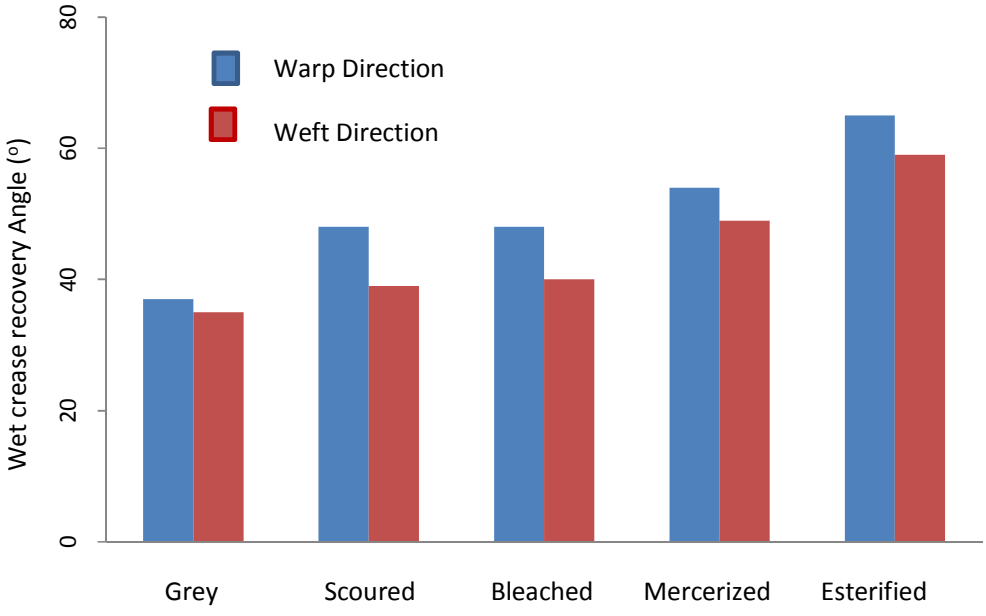


Fig. 6. Effect of Treatments on Wet Crease Recovery Angle (Warp and Weft Directions)

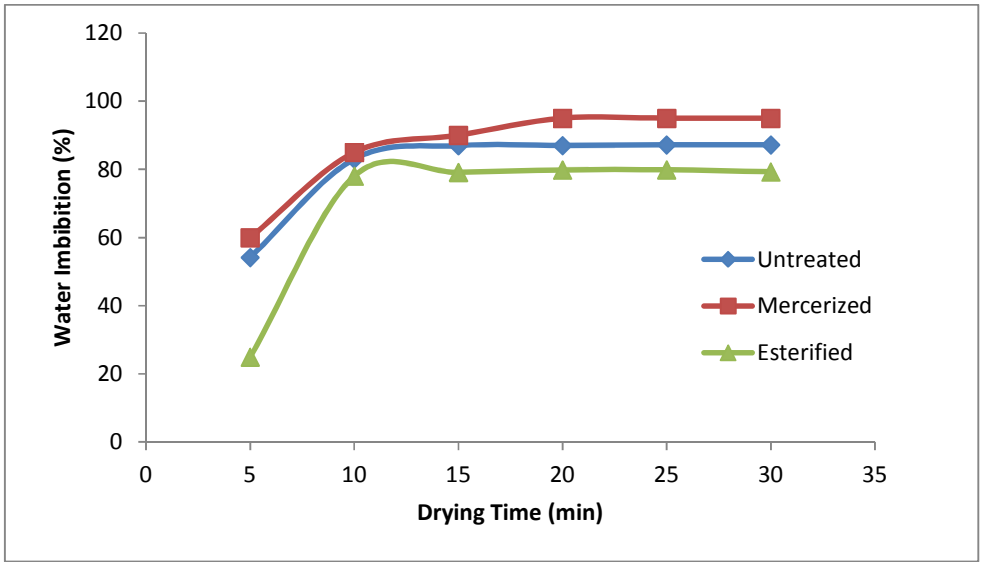


Fig. 7. Effect of Treatments on Water Imbibition

4. CONCLUSION

This study investigated the impact of seed oil from *Balanites aegyptiaca* on some physicochemical properties of cellulosic fabric via esterification. The results showed that generally there were significant improvements in all the properties after esterification except tensile property. However, it is still much improved compared to that of the grey fabric. The improvement in crease recovery was remarkable. Based on the findings, the oil from the seed of *Balanites aegyptiaca* is rich in oil that is non-toxic and biodegradable. It is cheap and locally available than amino resins. Hence, it could be fully harnessed for easy-care finish in the textile industry for the improvement of quality and reduction in the cost of the finished products.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Akpa FAO, Olugbemide AD, Ekebafe LO. Isolation and characterization of cellulose microfibre from sugar bagasse for use in the production and quality assessment of cellulose-based biodegradable polyurethane foams. Nigerian Journal of Science and Technology.2016;11:109–114.
ISSN: 1119-4111
2. Gordon C. The grove encyclopedia of decorative arts. Oxford University. 2006;1: 365.
3. Omizegba FI, Bello KA, Abayeh OJ, Adamu HM, Boryo DEA, Osemeahon SA. Structural Modification of Cellulosic Fabric via Esterification using *Jatropha curcas* Seed Oil. International Research Journal of Pure and Applied Chemistry. 2017;14(2):1 -13.
4. Anonymous. Cellulose acetate propionate and butyrate product data sheet. Eastman Chemical Company; 2006.
Available:www.eastman.com
(Assessed February 15, 2016)
5. Omizegba FI, Bello KA, Abayeh OJ, Adamu HM, Boryo DEA, Chindo IY. Structural Modification of Cellulosic Fabric via Esterification using *Balanites aegyptiaca* Seed Oil. Chemical Science International Journal. 2017;19(2):1 -11.
6. Klemn D, Briggitle H, Hans-Peter F, Andreas B. Cellulose: fascinating Biopolymer and Sustainable raw Material. Chemical Information. A Journalof the Gesellchaft Deutscher Chemiker. John Wiley & Sons, Ltd. 2005;36:36.
7. Omizegba FI, Boryo DEA, Oni O, Ezeribe AI. Effect of Dye-Resin-Fibre Network on some Mechanical Properties of Cellulosic Fabric. *Nigerian* Journal of Polymer Science and Technology. 2016;11:56–62.
8. Omizegba FI, Bello KA, Adamu HM, Boryo DEA, Abayeh JO, Oguike RS, Kolo, AM.

Effect of Esterification by Varying the Volume of Balanites aegyptiaca Seed Oil on Some Physicochemical Properties of Cellulosic Fabric. International Journal of Development Research. 2018;08(11): 23921 – 23927.
ISSN:2230-9926

9. Timar-Balazsy A, Eastop D.Chemical Principles of Textile Conservation. Routlege 2 Park Square, Milton Park, Abingdon, Oxon. New York. USA. 2011; 106.
10. Eugenio L. Labs on Chip: Principles, Design and Technology. Taylor and Francis group. 300 Boca Raton, Florida. 2014;44.
ISBN: 13:978-1-4665-6073-4
11. March J. Advanced Organic Chemistry. (4th Ed.). John Wiley and Sons. New York.1992;227–268.
ISBN 0-471-60180-2
12. Khalid H, Elkamali A, Atta E. Trade of Sudanese Natural Medicine and their Rolein Human Wildlife Health Care; 2010. Available: www.cropwatch.org.
(Retrieved September 08, 2016)
13. Chothani DL, Vaghasiya HU. A Review of Balanites aegytiaca Del (Desert Date). Phytochemical Constituents, traditional uses, and Pharmacological activity. A publication of PhcogNet. Pharmacognosy Revew. 2011;5(9):55–62.
14. Gutti B, Bamidele SS, Bugaje IM. Characterization and composition of *Balanites aegyptiaca* seed oil. 2011;1–25. Available:www.worldwidescience.org
(Retrieved May 12, 2013)
15. Pearson D. Fats and Oils Composition and Analysis of Foods**.** Concord Publishers. London. 1991;70–84.
16. British Standard Handbook 11. Methods of Test for Textiles. British Standard Institution; 1974.
ISBN: 13:9780580076480
17. American Society for Testing Materials ASTM. StandardTest Method for Tear andResistance of Woven Fabrics by Falling Pendulum (Elendrof) Apparatus (9.01)**.** American Society for Testing and Materials, Philadelphia, PA USA. 1994;38–74.
18. American Society for Testing Materials ASTM D6774. American Society for Testing and Materials, Philadelphia, PA USA. 2010;38–74.
19. Gubitz GM, Mittelbach M, Trabi M. Exploitation of the Tropical oil seed plant *Jatropha curcas* L. Bioresour Technol. 1999;67:73–82
20. Sadov F, Korchagin M, Matelsky A. Chemical technology of fibrous material**.** MIR Publishers. 1973;14:512-642.
21. Francis T. The effect of fibre crimp on fabric quality; 2008.
Available: www.tandfonline.com
(Retrieved July 4, 2013)
22. Arthur R. Properties of cotton fabric. 2009; Available:www.textileclass.com.
(Retrieved October 13, 2012)
23. Bradow JM. Quality measurements. The Journal of Cotton Science. 2000;2:48–60.
24. Fashola KO, Alonge CM. Influence of Fibre Content on the Properties of some selected woven Fabrics. Man-made Textiles in India. 2002;45(8):345–348.
25. Bello MA. Polymersthe chemistry and technology of modern materials**.** Concept publications Ltd. Lagos. 2001;33(46):225–226.
ISBN: 978–2309-79–6
26. Morton WE, Hearl JWS. Physical Properties of Textile Fibres. Textile Institute: Henmann. (2nd Ed.) London. 1975; 376–438.
27. Cai Y. A New Method for Improving the Dyeability of cotton withreactive Dyes. Textile Research Journal. 2000;6:440–446.
28. Ajayi JO, Omizegba FI, Barminas JT, Osemeahon SA. Reactive dye-resin complexation of cellulose substrate. European Journal of Scientific Research. 2005;4(2):61–70.
29. Omizegba FI, Boryo DEA, Chindo IY, Oni O. Effect of degree of substitution and viscosity of urea formaldehyde resin on creasing property of cellulose fabric. Journal of Chemical Society of Nigeria. 2015;40(2):106–109.
30. DeguchiS Tsuji K, Horikoshi K. Cooking cellulose in hotand compressed water. Chemical Communications.2006;31:3293.
31. Pantze A. Studies of Ester Formation on a Cellulose Matrix**.** Licentiate Thesis, Lulea University of Technology. LTU Skelleftea, Sweden; 2006.
32. Ashraf R. Determination of tensile strength of cotton grey fabric by strip method;2015.
Available:www.textileinsight.blogsp.com
(Retrieved February 2, 2017)
33. Yuping W, Cheng F, Guili H. Synthesis and Properties of Fatty Acid Esters of

Cellulose. Journalof Scientific and Industrial Research.2007;66:1019–1024.
34. Boryo DEA. Evaluation of Chemical Damage of Kenaf *(Hibiscus Canabinus) Fibres during Processing*, M.Sc. Thesis Abubakar Tafawa Balewa University, Bauchi; 1999.
35. Shabiya T. Durable Press Treatments to Cotton, Viscos, Bamboo and TencelFabrics. International Journal of Research in Engineering and Technology. 2014;3(8):32–35.
Available: www.ijret.org
(Retrieved December 27, 2016)
36. Steele R. The relation of Wet and Dry Crease Recovery to Wash Wear Behaviour. Textile Research Journal.2016; 30(1):37–46.
37. Hammett KE. Permanent Press: Facts behind the fabrics; 2008.
Available: www.organicclothing.blogs.com
(Retrieved September 16, 2012)
38. Oxford University. Imbibition. A Dictionary of Ecology. Oxford University Press. 2004;
Available:Encyclopedia.com: https://www.encyclopedia.com/science/dictionaries-thesauruses-pictures-and-press-releases/imbibition
(Retrieved July 07, 2019)
39. Kumar S. Imbibition; 2016
Available:www.biologydiscussion.com
(Retrieved December 12, 2016)

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/52137