Effects of Alternative Mercerizing Agents on Some Mechanical Properties of Cotton / Polyester Blend Fabric

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Doi:10.5901/ajis.2014.v3n5p91

Abstract

This study was concerned with sourcing for suitable and reliable, safe and cheap alternative mercerizing agents that may improve the mechanical properties of cotton/ polyester blend fabric. The pH of the used liquor was evaluated. Cost analyses for the agents were investigated. Six alternative 19-23% mercerizing agents were used (namely liquid NH_3, NH_4OH, $(NH_4)_2C_2O_4$, CH_3CH_2OH, CH_3COOH, $(COOH)_2$ and NaOH as the control) after bleaching the fabric respectively. The optimum experimental results for the mercerizing agents showed that 19% NH_4OH optimally improved the breaking load (16.19kgf) more than the control. The optimum value for breaking extension (24.98%) of the mercerized fabric was by 19% $(NH_4)_2C_2O_4$ ranking the highest. 19% CH_3CH_2OH mercerized fabric recorded the highest linear density (4.6904 tex). 21% NH_4OH mercerized fabric ranked the highest for dry crease recovery (132°). The alkalinity and acidity (pH) of the alternative agents after the mercerizing process were environmentally friendly in comparison with the highly alkaline NaOH (pH range of 12.20-12.30), hence unfriendly. The cost analysis revealed some of the alternative agents far cheaper than the NaOH. These imply that the alternative agents are suitable and reliable as mercerizing agents than NaOH. Therefore the alternative agents could be employed in the Textile Industry and commercially as mercerizing agents so that the world could be a better and safe place for fabric users.

Keywords: *alternative mercerizing agents, mechanical properties, suitable, reliable, safe, cheap*

1. Introduction

Mercerization is one of the most important processes before finishing processes on fabric. This consist of treatments of fabric with concentrated solutions of 20-22% of NaOH at a very low temperature (5-18^oC) as described by Sadov *et al.*(1973), Trotman (1975) and Taylor (1990). The demand for NaOH is high because of its numerous applications like in scouring and mercerization processes, thereby making it scarce and costly. This highly alkaline NaOH attacks the textile material if not properly handled leading to reduction in mechanical and poor finishing properties of the fabric. The effluents of these processes are corrosive and harmful to the environment too.

When the waste water from such a mercerizing process is released, it has effect on the soil and water bodies. SCHER (2006) reported that pH should be one of the basic traditional parameters to be regularly monitored in waste waters. For example, Cutler and Peter (2008) concluded that an important factor affecting soil fertility is soil pH. Soil pH affects the health of microorganism in the soil and controls the availability of nutrients in the soil solution. Strongly acidic soils (pH less than 5.5) hinder the growth of bacteria that decompose organic matter in the soil. This result in a buildup of undecomposed organic matter which leaves important nutrients such as nitrogen in forms that is unusable by plant (Cutler and Peter, 2008).

During mercerization, selective bonding of sodium to cellulose takes place according to the following schemes (Moji, 2000).

$$C_6H_7O_2(OH)_3 + 3NaOH \rightarrow C_6H_7O_2(ONa)_3 + 3H_2O$$

Scheme 1: Formation of trisodium cellulose (alcoholate)

The equation was explained by Sadov *et al.* (1973) that the formation of trisodium cellulose, took place on subjecting cellulose to action of solution of metallic sodium. Other researchers, believed formation of alcoholate by the action of aqueous solution of caustic soda on cellulose is impossible. This is because alcoholate are hydrolysed by small amount of water (March, 1978),

Another possible reaction is that caustic soda combines with cellulose to form a molecular compound:

$$C_6H_7O_2\,(OH)_3 + NaOH \rightarrow C_6H_7O_2(OH)_3NaOH$$

Scheme 2: Formation of alkali cellulose

The effects of this result to increase in luster, tensile strength, hygroscopicity, dye absorbability and specula reflection (gloss) (Sadov *et al.*, 1973; Neal, 2004; Safra *et al.*, 2004 and Smith, 2010).

Recent work by Lee *et al.* (2005) revealed the use of liquid ammonia (NH_3) treatment to be more effective at improving the fabric hand of cotton and regenerated cellulose fibres than the usual NaOH. Literature search has not revealed the use of such alkali and others or any other agents on synthetic and cotton blends than the traditional NaOH. Thus, are there no other mild alkalis or agents to be use for cotton and synthetic blends than the traditional NaOH? Such highly alkaline NaOH mercerizing effluent is also for sure very hazardous to the environment more than in the case with NaOH scouring effluent. This is because the NaOH mercerizing effluent is at higher concentration.

However, the use of ammonium oxalate by Ajayi *et al*. (1997), Boryo *et al*. (1999) and Boryo (1999) has proved to produce better mechanical properties on bast fibre than the traditional NaOH. Further findings by Boryo *et al.* (2013a) and Boryo et al. (2013b) proved the use of the alternative agents for scouring with improved dyeing and mechanical properties than the commercial NaOH. These findings contributed a part to the birth of this present work.

This paper seeks to search for alternative mercerizing agents that will improve on the mechanical properties, cheaper and environmentally friendly, so that this will in turn improve on the economy of the nation and to also satisfy the fashion desire of the consumers of textile materials.

The specific objectives are to determine the optimum alternative mercerizing agents with:

- Little or no damaging effects on the cotton/polyester blend fabric by evaluating some mechanical properties like breaking load, breaking extension, linear density and dry crease recovery.
- Friendly effects on the environment by monitoring the pH of the liquor before and after the mercerizing processes.
- To evaluate the cost implications of the alternative mercerizing agents with respect to the usual NaOH by cost analysis.
- Thus, this research aim at improving on the quality of fabrics and safety of the environment which is in line with the vision of repositioning of Nigeria, that is “vision 20:20:20”

Hence, this study envision that the same alternative scouring agents may give promising results as alternative mercerizing agents on cotton/ polyester blend fabric with respect to mechanical and dyeing properties

2. Methods

2.1 Sample Collection

35% cotton/ 65% polyester blend fabric was bought from Funtua Textile Company Ltd in Katsina State, Nigeria. The fabric were cut into 10cm by 10cm dimension

2.2 Souring Process

The fabrics were completely immersed in a beaker containing 2 % NaOH which had boiled for 5 minutes. It was allowed to boil for 1 hour, rinsed, neutralized, washed in detergent solution and then rinsed and dried in the labouratory. This was done according to the standard method of Sadov *et al* (19 73) and Trotman (1975).

2.3 Bleaching Process

The scoured samples were bleached with 4g/l $NaClO_2$ solution in accordance to procedure described by Sadov *et al* (1973).

2.4 Mercerization Process

The standard method of Sadov *et al* (1973) and Trotman (1975) was employed in this process. The bleached samples were mercerized in separate beakers of 19%, 20%, 21%, 22%, and 23% NaOH as control. Mercerization was carried out for 45 minutes at below 5^oC. Samples were rinsed, neutralized (appropriately), washed in detergent solution, rinsed and dried in the laboratory. The pH of the process was monitored and recorded. The procedure was repeated for 19-23% NH_4OH, liquid NH_3, $(NH_3)_2C_2O_4$, $(COOH)_2$, CH_3COOH and CH_3CH_2OH as alternative agents

3. Evaluation of the Effects of Alternative Mercerizing Agent

3.1 Determination of Breaking Load and Breaking Extension:

- These were evaluated in accordance with British Standard Method and American Standard for Testing Materials using Tensometric Tester model 220D (Anon, 1974 and Anon 1995).

3.2 Determination of Linear Density

The linear density of fabrics describes the fineness or coarseness of textile and can be expressed as tex. The expression proposed by Anonymous (1974); Morton and Hearle (1975) Anonymous (1995) and used by Boryo, (1999) was employed. It is defined as mass (g) per unit length (m). For the evaluation of linear density, the stretched samples were cut at both ends removing the masking ends. The remaining 5cm portions were weighed and recorded as mass of fabric then employed in the calculation of the linear density.

$$\text{Linear Density} = \frac{\text{Mass (g)} \times 1000}{\text{Breaking Elongation (mm)}} \text{ (tex)}$$

3.3 Determination of Dry Crease Recovery:

- The method described by Anon (1974) and Anon (1995) was also adapted for this evaluation.
- “Shirley” loading device (DL 28) and “Shirley” crease recovery tester (SDL 3A) was calibrated and used for this evaluation.

3.4 Determination of pH of Alternative Mercerizing Liquor

The pH values of the alternative mercerizing liquor were monitored before and after the mercerizing process using pH.

3.5 Determination of cost Implication of the Control and Alternative Mercerizing Agents

Market survey of the cost of the alternative mercerizing agents was carried out in comparison with that of the control. Three different chemical shops in Jos, Kano and Bauchi were involved. The average costs were calculated and the costs per 1 ml or 1g were evaluated for comparison.

4. Result and Discussion

4.1 Effects of Scouring, Bleaching and Alternative Mercerizing Agents on the Physical Properties of Cotton/Polyester Blend Fabric

Some physical changes were recorded during and after the pretreatment processes of the cotton/polyester blend fabric.

4.1.1 Scoured Samples

The scouring solution changed from colourless to slightly yellowish solution. This implies that purification has taken place. The scoured fabric samples were cleaner, improved texture and there were little decrease in dimensions of the treated fabrics. It is expected to improve the mechanical and dyeing properties of the samples in accordance to Sadov *et al.* (1973), Darinka *et al.* (2000) and Safra *et al.* (2004).

4.1.2 Bleached Samples:

It was observed that the bleaching solution of $NaClO_2$ changed from cloudy solution to slightly faint yellowish colour. This indicates that pigments and any remaining impurities in the fabrics were removed. The bleached fabrics were whiter and brighter than the unbleached samples.

4.1.3 Mercerized Samples with Alternative Agents:

All the samples swell and gradually untwist during mercerization especially for NaOH (control) than the alternative agents. After drying, the samples became smooth, lustrous and glossy. There was also reduction in dimension of the fabrics, which was more for the control than the fabrics mercerized with the alternative agents.

These changes are as a result of the chemical reaction between the fabrics and agents, which led to the formation of alkali cellulose. This in turns led to the hygral swelling making the fabric to be lustrous, smooth and glossy due to specula reflection. This agrees with the theory of NaOH mercerization described by Sadov *et al.* (1973); Neal (2004); Safra *et al.* (2004) and Smith (2010). Since similar changes were observed for the alternative mercerization agents, it is assumed that during mercerization, the fabric reacted with the respective agents to form molecular compounds with the cellulose:

$$C_6H_7O_2(OH)_3 + (NH_4)2C_2O_{4(aq)} \rightarrow C_6H_7O_2(OH)_3(NH_4)_2C_2O_{4(aq)} \text{ or}$$
$$C_6H_7O_2(OH)_3 + 3(NH_4)2C_2O_{4(aq)} \rightarrow C_6H_7O_2(ONH4)_3 + 3H_2C_2O_4$$
$$C_6H_7O_2(OH)_3 + NH_{3(aq)} \rightarrow C_6H_7O_2(OH)_3NH_3 \text{ or}$$
$$C_6H_7O_2(OH)_3 + 3NH_{3(aq)} \rightarrow C_6H_7O_2(ONH_4)_3 + H_2O$$
$$C_6H_7O_2(OH)_3 + NH_4OH_{(aq)} \rightarrow C_6H_7O_2(OH)_3NH_4OH \text{ or}$$
$$C_6H_7O_2(OH)_3 + 3NH_4OH_{(aq)} \rightarrow C_6H_7O_2(ONH_4)_3 + H_2O$$
$$C_6H_7O_2(OH)_3 + (COOH)_2 \rightarrow C_6H_7O_2(OH)_3(COOH)_2 \text{ or}$$
$$C_6H_7O_2(OH)_3 + 3(COOH)_2 \rightarrow C_6H_7O_2(O\text{-}COH)_3 + 3H_2O$$
$$C_6H_7O_2(OH)_3 + 3CH_3COOH \rightarrow C_6H_7O_2(OH)_3CH_3COOH \text{ or}$$
$$C_6H_7O_2(OH)_3 + CH_3COOH \rightarrow C_6H_7O_2(OCOCH_3)_3 + 3H_2O$$
$$C_6H_7O_2(OH)_3 + 3CH_3CH_2OH \rightarrow C_6H_7O_2(OH)_3CH_3CH_2OH \text{ or}$$
$$C_6H_7O_2(OH)_3 + 3CH_3CH_2OH \rightarrow C_6H_7O_2(OCH_2CH_3)_3 + 3H_2O$$

Scheme 1: Proposed Reactions of the alternative agents with cellulose

This is believed to structurally modify the fabric and effect improvements on hygroscopicity, mechanical and dyeing properties.

4.2 Effects of NaOH (control) and Alternative Mercerizing Agents on Mechanical Properties of Cotton/Polyester Blend Fabric

The alternative mercerizing agents displayed some effects on breaking load, breaking extension, linear density and dry crease recovery properties of cotton/polyester blend fabric.

4.2.1 Effect of Mercerizing Agents on Breaking Load of Cotton/Polyester Blend Fabric:

Breaking load describe the force that can break the fabrics or fibre (Morton and Hearle, 1975 and Taylor 1990). Figure 1 shows independent responses to breaking load of each mercerizing agents in each case. This is confirmed by the significant improvement in breaking load as compared with that of the untreated sample (9.75kgf). With respect to the control treatment, there is a kind of very close competition with the alternative agents. This implies that these agents are effective as mercerizing agents. Table 1 shows 19% NH_4OH with optimum breaking load of 16.19kgf, slightly higher than the control (23% NaOH 15.8 kgf). The other alternative agents recorded optimum breaking load of 20% $(NH_4)_2CO$ 15.40kgf, 21% $(COOH)_2$ 15.26 kgf, 19% liquid NH_3 14.93kgf, 23% CH_3CH_2OH 14.81kgf and 23% CH_3COOH 14.79kgf. These are compared favourably with the control.

This signifies that these agents actually modified the structure physico-chemically (Sadov *et al.,* 1973). This is to say that, when the fabric swells during mercerization, it leads to change in the arrangements of units in the cellulose macromolecule. The fibres in the fabric became tightened and the threads oriented to give smoothened alignments, improving and increasing crystallinity. The fabric becomes strong. This is confirmed by these competitive breaking loads. These improvements by alternative agents for mercerization process are even more effective than when used as scouring agents. This is because the breaking loads of the fabric treated with the mercerizing agents are higher than those with the scouring agents.

4.2.2 Effect of the Mercerizing Agents on Breaking Extension of Cotton/Polyester Blend Fabric

Figure 2 shows the effect of mercerizing agents on breaking extension of cotton/polyester blend fabric. It is observed that all the mercerizing agents improved the breaking extension of the fabric samples. This is seen in the higher values of the breaking extension at various concentrations of the agents as compared to that of the untreated sample (10.81%). This implies that these agents have positively modified the internal structure of the fabric. This led to reorientation and alignment of the molecular units, thus improved crystalllinity of the fabric, hence improved breaking extension (Safra *et al.,* 2004 and Smith, 2010**).**

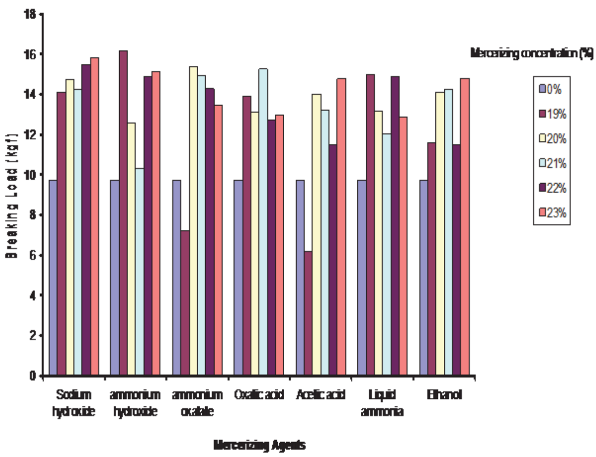

Figure 1: Effect of the NaOH (control) and alternative mercerizing agents on Breaking Load of cotton/polyester blend fabric

Table 1: Optimum breaking Load for the effect of Mercerizing Agents on Cotton/Polyester Blend Fabric

Mecerizing Agent	Concentration of mercerizing Agent (%)	Breaking load (kgf)
NH_4OH	19	16.19
NaOH	23	15.83
$(NH_4)_2C_2O_4$	20	15.40
$(COOH)_2$	21	15.26
Liquid NH_3	19	14.98
CH_3CH_2OH	23	14.81
CH_3COOH	23	14.79
Untreated	0	9.75

Breaking extension shows the extent of fabric damage. Then this implies that the mercerizing agents did not damage the fabric since there is improvement in the breaking extension of the treated samples compared to the untreated sample.

However, only 19% $(NH_4)_2C_2O_4$ mercerized fabric that recorded higher values (24.98%) than 21% NaOH (control) mercerized fabric (23.84%) while 19% CH_3COOH mercerized fabric (22.92%) competed favourably with the control. The other agents gave a range between 17.35 - 13.82% higher than untreated fabric (10.81%), (Table 2).

4.2.3 Effect of the Mercerizing Agents on Linear Density of Cotton/Polyester Blend Fabric

Fine (smooth) fabrics have high linear density and are less damaged (Trotman, 1975 and Morton and Hearle, 1975). With reference to Figure 3, it is observed that the untreated fabrics recorded highest linear density (5.153 Tex) than the fabrics mercerized with the different agents. This implies that the agents must have affected the surface of the fabrics making the fabrics less fine (coarse and not smooth).

However, the interesting observation in the Figure 3 and Table 3 is that all the alternative mercerizing agents recorded at one concentration or the other a higher value than the control. The fabrics mercerized with the alternative agents recorded optimum linear density ranging from 3.8138 - 4.6904 tex, with 19% CH_3CH_2OH mercerized fabric recording the highest and the control (NaOH) has a value of 3.4749 tex. This means that the alternative agents have achieved mercerizing better than NaOH treatments. It is believed that during mercerization fibre lumen swell and become round and untwist out, when dry, the lumen collapse with fewer twist, creating a round, smooth surface that reflect light creating a lustrous sheen (Beaudet, 1999). This implies that these alternative agents are suitable and reliable substitute for the industrial and commercial agents NaOH.

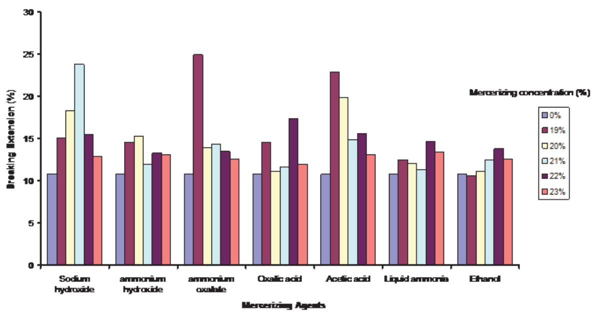

Figure 2: Effect of the NaOH (control) and alternative mercerizing agents on Breaking extension of cotton/polyester blend fabric

Table 2: Optimum Breaking Extension for the effect on Mercerizing Agents of Mercerized Cotton/Polyester Blend Fabric

Mercerizing Agent	Concentration of mercerizing Agent (%)	Breaking extension (%)
$(NH_4)_2C_2O_4$	19	24.98
NaOH	21	23.84
CH_3COOH	19	22.92
$(COOH)_2$	22	17.35
NH_4OH	20	15.27
Liquid NH_3	22	14.64
CH_3CH_2OH	22	13.82
Untreated	0	10.81

Secondly, these alternative agents truly affected mercerization better than the control. This is in the sense that the hygral swelling or expansion or contraction of the fibre length is due to increase in the mass per unit length (tex) of the fibres. Hence better or more improvement in linear density in the fabrics mercerized with the alternative agents than the control.

4.2.4 Effect of Mercerizing Agents on Dry Crease Recovery of Cotton/Polyester Blend Fabric

Crease recovery describes the ability of creased or wrinkled fabrics to recover its original shape over time. For any textile to be used in clothing, it must be flexible and capable of being crease and folded to confirm the figure and be comfortable to wear (Taylor, 1990). If textiles are to retain a good appearance, the textiles must have good crease shedding properties, which is recovery from unwanted crease that occurred in use and during laundry (Taylor, 1990)

With reference to Figure 4, it is observed that the alternative mercerizing agents influenced and modified the fabric samples better than the control and the untreated samples. This can be seen in the higher values of their dry crease recovery angles. Table 4 shows the optimum dry crease recovery for the various agents. The order is 21% NH_4OH (132.0 ^{o}), 19% liquid NH_3 (130.5 ^{o}), 20% CH_3CH_2OH (126.5 ^{o}), 19% CH_3COOH (126.5^o), 19% $(COOH)_2$ (124.5^o) 19% CH_3COOH (126.5^o), 19% $(COOH)_2$ (124.5 ^{o}), 21% NaOH (123.5^o) (control), 19% $(NH_4)_2C_2O_4$ (116.5 ^{o}) and 0% untreated fabric (50^o). Thus, alternative agents proved to be far better mercerizing agents for cotton/ polyester fabric compared to the NaOH control and the untreated fabric.

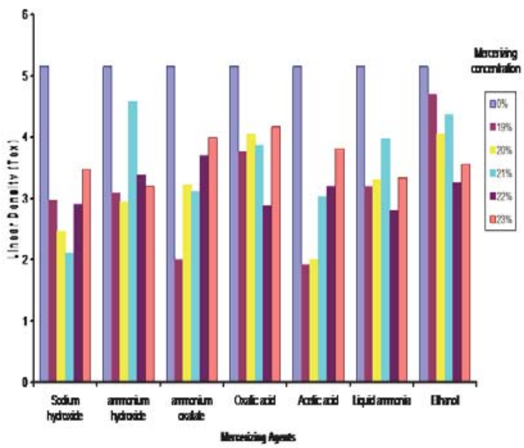

Figure 3: Effect of the NaOH (control) and alternative mercerizing agents on linear density of cotton/polyester blend fabric

Table 3: Optimum Linear Density for the effect of Mercerizing Agents on Cotton/Polyester Blend Fabric

Mercerizing Agent	Concentration of mercerizing Agent (%)	Linear density (Tex)
CH_3CH_2OH	19	4.6904
NH_4OH	21	4.5833
$(COOH)_2$	23	4.1666
$(NH_4)_2C_2O_4$	23	3.984
Liquid NH_3	21	3.9717
CH_3COOH	23	3.8138
NaOH	23	3.4749
Untreated	0	5.153

This is also explained theoretically on a structure molecular level. When fabric structure is bent into crease, Morton and Hearle (1975) and Taylor (1990) suggested that two things can happen; the cross-link may break and reform at new position. On removal of the load there will be no recovery. Alternatively, the cross-links may be strained without breaking. Under this condition, there would be a recovery on moving the load and no crease will result. In view of this, fabrics with lower crease recovery angle in this study might have been weakened more than those with higher dry crease recovery angle, resulting in the breakage of the cross-links and little recovery. However mercerization has drastically improved the crease recovery property compared to the original sample and even the control treatments. It is also observed that these alternative agents were far more effective as mercerizing agents than as scouring agents in the previous work by Boryo et al. (2013b). This is because the dry crease recovery angles for mercerization are far higher than the dry crease recovery angles for scouring. This is possible because of the improved alignment and crystallinity of the treated fabrics by the mercerizing agents than the impurity removing property of the scouring agents.

4.2.5 Effect of Alternative Mercerizing Agents and Control (NaOH) on pH of Mercerized Liquor of Cotton/Polyester Blend Fabric

It is observed that in most cases, there is decrease in pH at the end of the process and in a few cases there is slight increase. This suggests that reactions occurred between the fabric and each of the mercerizing agents.

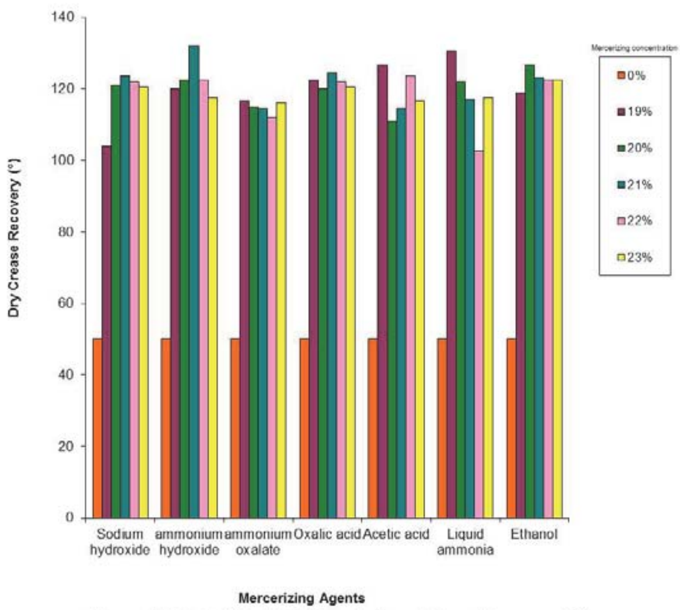

Figure 4: Effect of the NaOH (control) and alternative mercerizing agents on Dry Crease Recovery of cotton/polyester blend fabric

Table 4: Optimum Dry Crease Recovery for the effect of Mercerizing Agents on Cotton/Polyester Blend Fabric

Mercerizing Agent	Concentration of mercerizing Agent (%)	Dry crease recovery (°)
NH_4OH	21	132.0
Liquid NH_3	19	130.5
CH_3CH_2OH	20	126.5
CH_3COOH	19	126.5
$(COOH)_2$	19	124.5
NaOH	21	123.5
$(NH_4)_2C_2O_4$	19	116.5
Untreated	0	50.0

Table 5 shows the pH for the mercerization process. For NaOH mercerization process at the beginning, the pH ranged from 11.40 - 11.80 and increased from 12.20 - 12.30 after the process. This is highly alkaline and very unfriendly to the soil and aquatic lives when such a solution is released to the environment. This high alkalinity is as a result of high degree of dissociation of NaOH and thus high concentration of OH^-. That is why there is need for mild alternative agents.

Liquid NH_3 initially recorded a pH range of 11.17 - 11.24 and after the mercerizing process increased to a range of 11.40 - 11.52 (Table 5).

This is also high but is less harmful when compared to NaOH. This is because only a small percent of the molecules dissociated to form OH^- (Caret *et al.*, 1997).

$$NH_{3(g)} + H_2O_{(l)} \rightarrow NH_3.H_2O_{(aq)}$$
$$NH_3.H_2O_{(aq)} \rightarrow NH_4^+{}_{(aq)} + OH^-{}_{(aq)}$$

Scheme 2: Ionization of ammonia

Liquid NH_3 will ionize to a limited extend in solution to liberate NH_4^+ and OH^-. Hence liquid NH_3 is a weak alkali (Ababio, 2003). Therefore as a weak base, the concentration of OH^- is very low. Thus, this will have minimal effect on the environment.

At the start of NH_4OH mercerization process, the pH ranges from 11.63 - 11.80 (Table 5) for the various mercerizing concentrations (19 - 23%). As the reaction progressed the pH decreased from 11.37 - 11.46. Despite the high pH, NH_4OH ionizes to a limited degree in solution to liberate NH_4^+ and OH^-, because is a weak base. Thus, it is less harmful as compared to the control (NaOH).

Table 5 revealed that at the start of the CH_3CH_2OH mercerization process the pH ranged from 7.30 - 7.65. After the mercerization reaction the pH decreased to a range of 5.47 - 7.54. This pH values, although slightly acidic and faintly alkaline are within the optimum range of a suitable soil pH (7 - 8) for plant growth and streams/lakes pH (6 - 9) for aquatic lives (SCHER, 2006). Secondly being an organic component will be biodegradable. It also dissociates partially, so weak alkali. Therefore, is friendlier than NaOH.

Table 5 showed initial pH range of 7.27 - 8.20 for $(NH_4)_2C_2O_4$ mercerization process and decreased to a range of 6.62 - 6.96. This also will not have adverse effect on disposal on the soil or aquatic body. This is a better alternative to NaOH (control), since on dissociation it produces a kind of neutral solution.

$$(NH_4)_2C_2O_{4(aq)} \rightarrow NH_4OH_{(aq)} + (COOH)_{2(aq)}$$

Scheme 3: Ionization of ammonia oxalate

At the start of CH_3COOH mercerization the pH range was 2.25 -2.37. It changed with a pH range of 2.32 - 2.40 at the end of the mercerization process (Table 5). Despite this pH range is very acidic but being a weak acid an organic acid, it may not affect the environment much (soil and aquatic body). Thus, it dissociates partially and thereby a better alternative than NaOH (control).

Oxalic acid is another weak acid. At the beginning of the mercerization (Table 5), the pH ranged from 1.25 - 1.65 and changed from 1.29 - 1.47. This implies that it is an acidic solution but may not show pronounced acidic properties because it is a weak organic acid, thus dissociated partially. It may not have any harmful effects on the environment on disposal, so another alternative for the control (NaOH).

Table 5: pH Range for the effect of Mercerizing Agents before and after Mercerizing Process on Cotton/Polyester Blend Fabric

Mercerizing Agents mercerizing	pH range before mercerizing Process	pH range after process
NaOH	11.40 - 11.80	12.20 - 12.30
Liquid NH_3	11.17 - 11.24	11.40 - 11.52
NH_4OH	11.65 - 11.80	11.37 - 11.46
CH_3CH_2OH	7.30 – 7.65	5.47 - 7.54
$(NH_4)2C_2O_4$	7.27 – 8.20	6.62 - 6.96
CH_3COOH	2.25 – 2.37	2.32 - 2.40
$(COOH)_2$	1.25 – 1.65	1.29 - 1.47

5. Cost Implication of the Mercerizing Alternative and Control Agents

Market survey of the cost of the alternative agents was carried out in comparison to that of the control. This was done using chemical shops in Jos, Kano and Bauchi all in the Northern Nigeria.

NaOH, $(NH_4)_2C_2O_4$, $(COOH)_2$ are in solid form while CH_3CH_2OH, CH_3COOH, NH_4OH and Liquid NH_3 are in liquid state. Therefore it is assumed that 1 g is equivalent to 1 ml or vice versa.

From Table 6, the average rate per ml or g for the alternative mercerizing agents ranged from ₦ 9.30 – ₦1.50 with the control agent costing ₦5.50. This shows that only $(COOH)_2$ and $(NH_4)_2C_2O_4$ that cost (₦9.30 and ₦7.95 respectively) higher than the control. That notwithstanding since in some quality parameters evaluated, the $(COOH)_2$ and $(NH_4)_2C_2O_4$ recorded far better improvements than the control. Furthermore considering the hazardous effect of the control on the environment, still makes $(COOH)_2$ and $(NH_4)_2C_2O_4$ a better substitute for NaOH.

All other alternative agents cost far less than the control and have improved the quality performance of the treated cotton/polyester blend fabric. These agents are also environmentally friendlier than the control. Therefore, there is need for the embracement of these alternative agents industrially and commercially. This will go a long way to improve the economy and satisfy the fashion desire of the populace.

Table 6: Average Cost of Alternative Mercerizing Agents and Control Agent NaOH

Agents	Quantity	Average Rate (₦)	Average Rate per ml or g (₦)
$(COOH)_2$	500g	4,650	9.30
$(NH_4)_2C_2O_4$	500g	3,975	7.95
NaOH (control)	500g	2,750	5.50
NH_4OH	2,500ml	5,225	2.90
CH_3COOH	2,500ml	3,750	1.90
NH_3	2,500ml	4,000	1.60
CH_3CH_2OH	2,500ml	3,750	1.50

Assuming 1g is equivalent to 1ml

6. Conclusion

The alternative mercerizing agents (NH_4OH, Liquid NH_3, $(NH_4)_2C_2O_4$, CH_3CH_2OH, CH_3COOH and $(COOH)_2$) proved to be suitable and reliable because the physical changes observed on the treated fabric samples were in agreement with the theories of mercerization. The suitability and reliability of these alternative mercerizing agents were confirmed by the improved mechanical properties displayed by the mercerized fabric samples treated with alternative agents as compared to the control fabrics mercerized with NaOH agent. It was observed that the fabric sample treated with some of the alternative agents recorded higher values for breaking load, breaking extension, linear density, and dry crease recovery, than the control samples. In some cases fabric sample treated with the alternative mercerizing agents competed favourable with the control sample.

The pH values (degree of alkalinity and acidity) of the alternative mercerizing agents were friendlier to the environment and some are even biodegradable as compared to the highly strong alkaline NaOH, which may be very hazardous to the soil and aquatic lives, corrosive to skin and equipments.

The cost implication of using the alternative mercerizing agents is relatively cheaper when compared with that of the control. Thus, the study has provided alternative agents that are cheaper with improved quality fabric for the fashion conscious teaming population under safe environment.

7. Recommendation

It is recommended that the alternative mercerizing agents be adapted in the textile industry and commercially.

8. Acknowledgement

This work would not have been possible without the sponsorship received from Ocean Energy Nigeria Limited, Knorr 296, Ozumba Mbadiwe Street Victoria Island Lagos NIgeria. I am deeply indebted to the company for taking interest in research and development.

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