

## A study on the felting propensity of Egyptian and New Zealand wool fibers

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### Abstract:

This work focuses on the effect

Felting is a unique property of many animal fibers. It is an ancient and historic way of transforming fleece into felt hats, caps, vests, skirts, boots, scarves and many other manufacturing felted products. In this research, felting propensity of Egyptian and New Zealand wool fibers has been examined. The Aachen felting test method was employed. The diameter of each ball and the density were calculated to recognize the felting degree. The effect of scouring, bleaching as well as four different variables of pre-treatment water baths - pH, temperature, liquor ratio and agitation- on the felting propensity of these pre-treatment fibers were investigated. Also, the effect of four felting medium – acidic, alkaline, salty and soapy mediums - on the degree of felting process was studied. The results show that the pre-treatment wool fibers in different water baths have higher felting propensity than untreated one (control sample) especially with scoured wool. There is a higher tendency of felting for bleached followed with scoured fibers than raw fibers. In the most cases of pre-treatment water baths; acidic medium has a remarkable influence on the propensity of fibers felting specially in case of using temperature and agitation. The acidic felting medium solution has a great influence effect on the values of felting fibers especially with raw wool fibers than scoured fibers in both Egyptian and New Zealand wool; and soapy felting medium has the lowest tendency on wool felting than acidic and alkaline mediums compering with buffer pH=7. The present study would help increasing the utility of the local wool in the industry to revive felt making industry and to increase the competitiveness of the Egyptian product and achieve greater Egyptian industry's ability to integrate into the global economy, creating new jobs and increase national income as a result of increasing the volume of industrial exports and reduce dependence on imports. Also this study can be applied on some agricultural wastes (non-wood plants) as potential resources and alternative fibers in textile and paper industries.

### Keywords:

*Felting*  
*Scouring*  
*Bleaching*  
*Egyptian wool*  
*New Zealand wool.*

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### 1. Introduction

Textile occupies important positions in the national economy for Egypt industries. . It is very necessary to invest available resources in Egypt investment ideal, especially since the possibilities available to it, particularly the manufacture of wool locally rather than export, and an increase in the value added through the wool manufacturing process to yarn and fabrics, interior and clothing and outdoor otherwise. This increases the size of the industry and its evolution, in addition to its role in development various economic activities and reduce dependence on imports and to support the export capacities of the country.

**Felt** is an ancient and historic way of transforming fleece into felt hats, caps, vests, skirts, boots, scarves and many other manufacturing felted products, by using wool, detergent water, pressure, friction and heat. Pressed felt is produced from wool or animal hairs by mechanical agitation and compression of the fibers in warm, moist conditions. No spinning, weaving or knitting is used in the production of such felts <sup>(1,2,3,4)</sup>. The end-uses for pressed felt are spread throughout many industries and felt materials are to be found

in many diverse applications, for it is the most valuable and versatile material <sup>(5)</sup>.

#### 1.1 Research Problem

- 1- During the last decade, the vast majority of the scientific researches focused on wool shrink-resist process; meanwhile, no studies were imbued with wool felting, especially the Egyptian wool materials.
- 2- Felting is an inevitable process which is highly desired in the manufacturing of felted products, specifically in woolen fibers, such as Egyptian and New Zealand wools.
- 3- Take advantages from the results of this study in felt making manufacturing in Egypt, support these traditional occupations, participate with the cultural heritage and the owners of traditional crafts and continuing occupations traditional culture, the fact that these professions are in the way of extinction; as well as, sharing in Egyptian industrial modernization program.

#### 1.2 Research Objectives

- The research aims to provide benchmark data for Egyptian and New Zealand wool fibers' pre-treatment as well as felting medium on their

felting propensity to benefit from this study to revive felt making industry and to increase the competitiveness of the Egyptian product and achieve greater Egyptian industry's ability to integrate into the global economy, creating new jobs and increase national income as a result of increasing the volume of industrial exports and reduce dependence on imports.

- The study can be applied in the production of environmentally friendly products through recycling wastes of manufacturing process, cutting wastes, used clothes as well as agriculture wastes; to minimize wastes, improves the usage of recycled materials and brings important economic benefits, in addition to reducing the environmental impact on its incineration and storage at landfills.

### 1.3 Research Hypothesis

Scouring, bleaching, pretreatment water baths as well as felting mediums effect on the felting propensity of Egyptian and New Zealand wool fibers. This maybe a source for felt making industry.

### 1.4 Research Methodology

Experimental and comparative study.

### 1.5 Research limitations

#### *The spatial limit:*

This work was carried out in Textile Research Division – National Research Center, Giza, Egypt.

#### *The objective limit:*

- a- Study the effect of felting process on raw (untreated) Egyptian and New Zealand wool fibers (control sample).
- b- Study the effect of scouring and bleaching treatment of Egyptian and New Zealand wool fibers on felting process.
- c- Study some water bathes treatment of raw and scoured Egyptian and New Zealand wool fibers on felting process.
- d- Study the effect of some felting medium on raw and scoured wool fibers.

### 1.6 Research Tools and Materials

- 1- New Zealand and Egyptian wool fibers.
- 2- Chemicals: Hydrogen peroxide 35%, sulphuric acid 98%, sodium hydroxide and sodium carbonate, were purchased from El Nasr Pharmaceutical Chemicals Company; and Epyptol PLM is a non- anionic detergent from starch and yeast comp. Alexandria; Phosphate buffer (pH=7)
- 3- Oven and water bath with shaker and other laboratory apparatus.
- 4- Three- Dimensional Shaking Machine: The method applied is a process known under the name of "Aachen Felting Test" and is used to determine the felting property of loose wool and combed top.

## 2. Theoretical Study

### 2.1 Wool

Wool is fine, soft, curly hair that grows on the body of the sheep and some other animals forming a protective covering known as a fleece <sup>(2)</sup>. Wool was used for manufacturing apparel and interior textiles such as rugs and carpets based on fiber diameter. Wool in Egypt and New Zealand was classified as coarse wool (fiber diameter >32 micron). Wool production in Egypt is harsh, bulk and short length fiber, so it is often processed in local mills producing poor quality carpet, rugs, clem, blankets,...etc. ;therefore, the manufacturers are reluctant to buy this wool and they offer reduced prices and prefer to buy the expensive imported wool such as New Zealand wool <sup>(6)</sup>. On the other hand, 90% of New Zealand's clip was coarse wool which traded either raw (greasy or clean), and also as finished consumer products such as carpets and rugs <sup>(7)</sup>. The wool industry had traditionally been a major contributor to the New Zealand economy.

#### 2.1.1 Morphology of wool

Wool fiber has a very complex hierarchical structure, as shown schematically in Figure 1<sup>(8)</sup>. It can be considered as a biological composite consisting of regions that are both chemically and physically different. The wool fiber consist of a roughly cylinder, with diameters of different wools covering a range that can be as 20 to 40  $\mu\text{m}$ . The cross-section is slightly elliptical. Fiber lengths range roughly from 5 to 50 cm. The fibers are helically crimped to varying degree <sup>(13,14,15)</sup>. The fiber of fine wool consists of two major morphological parts: the cuticle and the cortex, while the hair of coarse wool has a third layer called medulla <sup>(16)</sup>.

*The cuticle:* Wool fiber is surrounded by cuticle cells which are composed of the scales overlapping each other in one direction <sup>(9)</sup>. The complex physical structure of cuticle cells is shown in Figure 2 (a,b).These scales are somewhat horny and irregular in shape. The exposed edge of each cuticle cell points from the fiber root towards the tip. This gives rise to a larger surface frictional value when a fiber is drawn in the against-scale direction than in the with-scale direction. The frictional difference helps to expel dirt and other contaminants from the fleece, but it is also responsible for wool's property of felting when agitated in water. This characteristic, which is not shared by any other textile fiber, enables fabrics with very dense structures to be produced, such as blankets, felts and overcoat materials. <sup>(10,11,12,13, 14, 15)</sup>

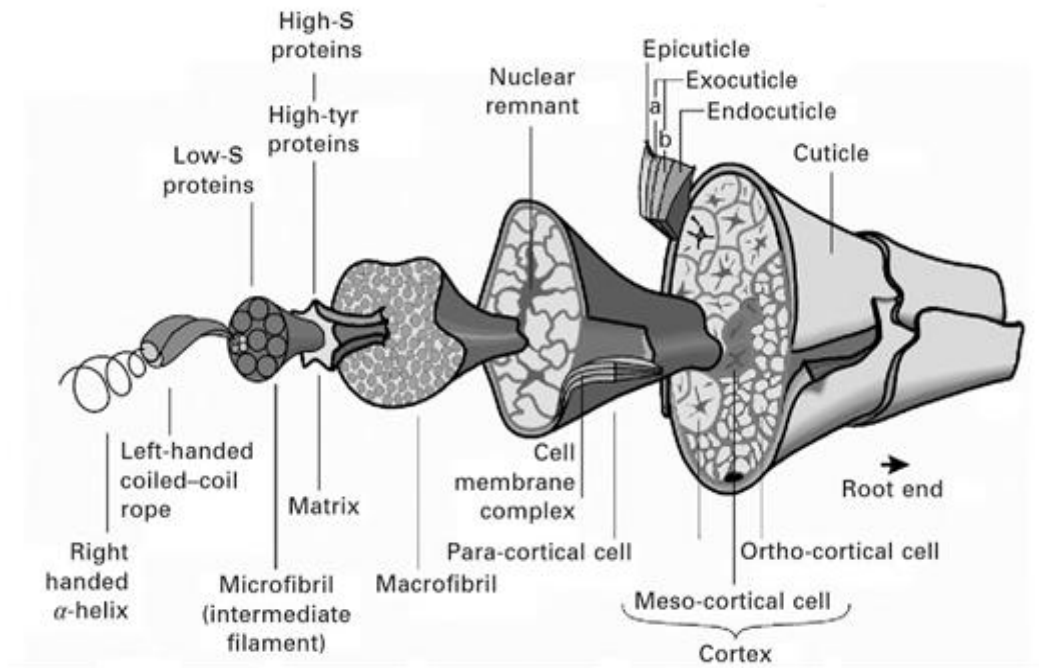


Figure 1: Schematic diagram of wool fiber <sup>(8)</sup>.

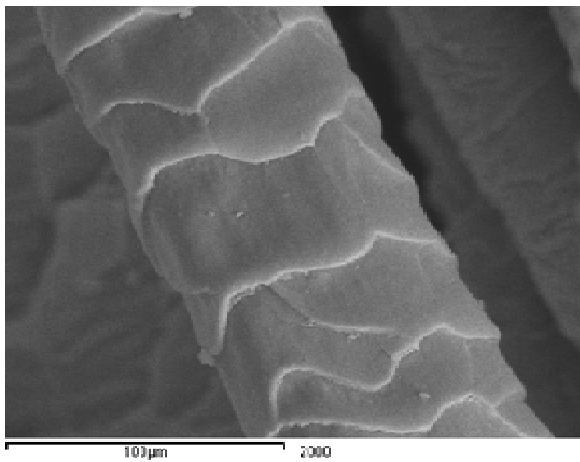


Figure 2.a; Scanning electron micrograph of raw Egyptian wool fiber showing the scaly structure of wool fiber (National Research Center, Giza, Egypt).

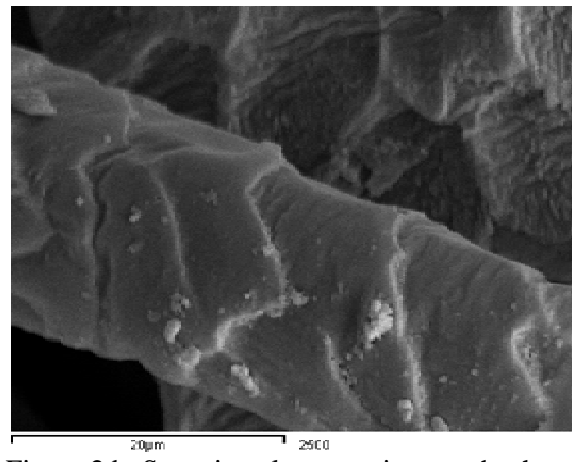


Figure 2.b; Scanning electron micrograph; shows the effect of the scouring/ bleaching on the morphological structure of Egyptian wool fiber.

### 2.1.2 Molecular structure of wool

Wool is a semi-crystalline, proteinaceous polymer, called  $\alpha$ -keratins. It consists of 18  $\alpha$ -amino-acids with typical percentages and with general structure  $(H_2N-CH(R)-COOH)$ ; where (R) represents the side group of the amino acid. The different amino-acids are joined together by means of peptide links  $(-CO-NH-)$  to form the long polypeptide chains with a general structure  $-(NHCHRCO)_n-$  <sup>(16,17, 18,19)</sup>. In wool, individual polypeptide chains are joined together to form proteins by a variety of covalent (chemical bonds), called crosslinks, and non-covalent physical interactions. The most important crosslinks are the sulphur containing disulphide bonds, which make keratin fibers

insoluble in water and more stable to chemical and physical attack than other types of proteins. The most important of the non-covalent interactions are the ionic, or 'salt linkages' between acidic (carboxyl) and basic (amino) side groups. The carboxyl and amino groups in wool are also important because they give wool its amphoteric or pH buffering properties. This is its ability to absorb and desorb both acids and alkalis <sup>(8,20)</sup>.

### 2.2 Felting

The committee D-13 on textiles of the American Society for Testing and Materials (ASTM) defines felt as "a textile structure composed entirely of fibers physically interlocked and consolidated by the utilization of mechanical work, chemical action and moisture without the use of weaving,

knitting, stitching, thermal bonding or adhesives. Wool felt is a textile material composed wholly of any one or a combination of new or recycled wool fibers. Part-wool felt is a felt composed of any one or combination of new or recycled wool fibers mixed with one or more man-made fibers, vegetable fibers, or animal fibers other than wool”<sup>(3,5)</sup>.

### 2.2.1 Theory of felting

The felting of wool is dependent on a range of factors which fall into two groups; the properties of the wool and the conditions of felting<sup>(21,22)</sup>.

#### *The properties of the wool:*

Felting is caused by the outside scales of wool fiber. It is a form of tangling produced by the directional frictional effect (D.F.E) of scales on the fiber surfaces; when the force is in the tip-to-root direction (against scale), the fibers are able to move and felting will take place<sup>(5, 23,24,25)</sup>. The factors involved in felting are the fiber structure, crimp, and the ease of deformation and the fiber's power of recovery from deformation<sup>(26)</sup>.

#### *The conditions of felting:*

- The moist is the most important factor; because wool absorbs water, which raises the scales of the fiber, so the flexibility increases and also the frictional coefficients increase<sup>(23,27,28,29)</sup>.
- Felting is carried out in alkaline or in acid, due to the ability of these media and especially in acids to accentuate the D.F.E. Alkali and soap felting are used, because they give a good and soft handle cloth, but acid felting gives a strong cloth, durability as well as wool dyes are applied from acid solution<sup>(23)</sup>.
- Mechanical agitation helps fiber to travel in the direction of the root-end which they are mechanically entangled under the action of the felting machine.
- Temperature: Alkali felting is carried out in warmth (not more than 45°C) because there is a big danger of hot alkali attacking the wool; in case of acid felting; it can be carried out at higher temperature because wool is much more chemically stable to acid<sup>(23,29,30)</sup>.

### 2.3 Woolen and Worsted

Woolen and Worsted are two major classifications for wool yarns and fabrics.

**The woolen system:** Woolen fabrics are characterized as being fuzzy, thick, bulky and weaker than worsted yarns and are spun with a low to medium twist. They are made from fibers that are one to three inches in length that have been carded only (worsted yarns are carded and combed). They are used to make heavier fabrics with a slightly fuzzy surface, such as coatings,

tweeds and flannels and are ideal for jackets, coats, skirts, blankets and rugs. Woolen fabrics are usually less expensive, more durable and felt more easily than worsted wool fabrics.

**The worsted system:** Worsted yarns are spun from longer (three inches and longer) fibers that have been carded, *combed* and *drawn*. Combing machines further straighten the wool sliver making the individual fibers lie parallel. The combing process also eliminates “noils” or shorter fibers which grow mostly on the belly of the sheep. (Noils are used in the production of less expensive woolen fabrics and for the manufacturing of felt, a non-woven wool fabric). Worsted yarns are twisted tighter and thinner in the spinning process and are manufactured into lightweight fabrics, such as: gabardine and crepe<sup>(31)</sup>.

### 2.4 Wool scouring

Treatment process of washing wool in water and detergent to remove all or some impurities like fats, waxes, oil, dust, dirt and other foreign matters except vegetable matter<sup>(10,32,33)</sup>.

### 2.5 Wool bleaching

A procedure used to remove or lighten the natural color (pigment) of animal fur; related to the character of the environment in which the animal lives. Bleaching can help to solve the problems of fibers processing industry caused by natural pigmentation<sup>(34)</sup>.

### 2.6 Density

Felt density by ASTM definition is "the weight per unit volume of the felt under test as distinguished from the volume of the fiber"<sup>(35)</sup>.

### 2.7 Pulp and Paper

The growth rate of paper consumption is fast; therefore, the demand for wood- plant will undoubtedly increase remarkably. The decreases in availability of raw materials for pulp and paper production have led paper making to search for new raw material resources. Several studies have been carried out to discover these resources<sup>(36)</sup>. Non- wood plants and recycled fibers offer a great opportunity to replace wood fiber. There are wide varieties of non- wood plant fibers, annual plants and agricultural wastes, such as: rice, wheat straws, sorghum stalks, and some annual plants, such as sugar cane bagasse, jute, olive tree pruning and oil palm leaves, which cause environmental problems; however, they are the most important raw materials resources for pulp and paper production and have the compositions and properties that are suitable to be used as composite, textile not to mention being vital in producing fuel, enzyme, chemicals and animal feeds. These wastes must be considered more valuable as that there will be an economic



motivation to prevent pollution<sup>(37,38)</sup>.

Therefore there is a renewed interest in the non-wood fiber sources due to the number of advantages these materials offer to the pulp and paper industry. First many of these materials have annual and biannual production compared to the long growth cycles for wood production. Also most of the non-wood sources have lower lignin contents making chemical and mechanical processes for non-wood pulping easier than pulping wood sources. Non-wood fibers from different plant materials can be used in every grade of paper, paperboards and other composite materials. Non-wood materials are more available due to the fact that they can regenerate easily and as a result they are less expensive<sup>(39)</sup>.

### 2.7.1 Pulp and Paper production

#### 2.7.1.1 Chemical components analysis

Analyzing the different constituents of the plants' materials is important to be able to know the cellulose content, hemicellulose content, lignin content, ash... etc.<sup>(39)</sup>.

*Cellulose content* is an important constituent. A high content of cellulose produces a high pulp yield and a good quality. *Hemicellulose* is similar to cellulose in composition and function. High hemicellulose content correlated with high strength of the paper produced especially in tensile and burst indices. *Lignin* contents are satisfactory level if the value is less than 30%. Low lignin content is considered advantageous as it utilizes less chemicals and energy during the pulping process. Low lignin will also generate whiter paper and therefore, requires less bleaching.

Finally, the *ash* content indicates the mineral component of lignocellulosic materials. High ash content will contribute to decrease in the strength properties of the product and reducing pulp yield<sup>(38)</sup>.

#### 2.7.1.2 Physical properties

Fiber length is an important parameter in measuring the quality of the pulp to be used in paper based industries. The shorter fibers length contributes to excellent formation and increases inter-fiber bonding as well as increasing the strength properties of produced paper. In addition, short fiber length will also give smoothness of the surface morphology of produced paper.

Fiber diameter is also important to determine the quality of fibers in pulp and paper-based industries. A small diameter of fiber indicates that less fiber flexibility<sup>(38)</sup>.

#### 2.7.1.3 Felting in paper making

Felting power is widely used to determine the suitability of raw materials for paper production. This power is important to the physical properties

of paper such as: breaking length, bust and tear index. The acceptable value for felting rate is more than 33%. It is desired to be between 70 and 90 for soft wood and 40 and 60 for hard woods.

The felting power (rate) of the fiber was determined according to the following equation, Felting power (rate) = Fiber length / Fiber width<sup>(36,38)</sup>

### 2.7.2 Stages of Papermaking

Pulp and paper are manufactured from raw materials containing cellulose fibers. Cellulosic pulp is manufactured from the raw materials, using chemical and mechanical means. Chemical pulping is used on most papers produced commercially in the world today. Traditionally, this has involved a full chemical treatment in which the objective is to remove non-cellulosic (lignin and impurities) components leaving the cellulose fibers without sacrificing fiber strength. Chemical pulps are made by cooking (digesting) the raw materials, using the Kraft (sulfate) and sulfite processes. The method evolved from soda pulping (which uses sodium hydroxide for digestion- carried out only with highly alkaline cooking liquor). Sulphite pulping usually uses acid digestion, neutral and basic variations exist<sup>(40,41,42)</sup>.

#### 2.7.2.1 Mechanical pulp

By cutting, chipping or grinding the wood or non-wood plants.

#### 2.7.2.2 Pulping condition

Several studies have been carried out several pulping conditions with different variables of cooking bathes, such as: pH value (acidic, alkaline, and salt), temperature, liquor ratio and time, to reach the optimum cooking conditions for each non-wood plant.

#### 2.7.2.3 Bleaching

Bleaching is a multi-stage process that refines and brightens raw pulp. Each bleaching stage is defined by its bleaching agent, pH (acidity), temperature and duration. After each bleaching stage, the pulp may be washed with caustic to remove spent bleaching<sup>(40)</sup>.

#### 2.7.2.4 Felting process

The pulp then moves into the press section, where the water is squeezed out through the felts, which are large piece of continuous fabric similar in texture to carpet. The felts are supported by a series of rollers, which move the felts around at a very fast speed. The run of paper leaves the press section to progress through the dryer section where it passes over approximately 50 steam-heated cylinders to further reduce the moisture content. The finished paper is then cut into manageable sizes on the winder and packaged for distribution<sup>(43)</sup>.

### 3. Experimental Work

#### 3.1 Chemical treatments

##### 3.1.1 Scouring process

Egyptian and New Zealand wool fibers were scoured to evaluate the effect of scouring process on raw Egyptian and New Zealand wool fibers on their felting propensity.

##### 3.1.2 Bleaching

This study evaluates the bleaching process for raw Egyptian and New Zealand wool fibers on their felting propensity. Two selective bleaching pH values were used to bleach wool tops.

**Bath 1:** Wool is oxidatively bleached in acid

media (pH 4-4.5) using sulphuric acid (to adjust the pH)

**Bath 2:** Wool is oxidatively bleached in alkaline media at (pH 8.9-9) in the presence of sodium carbonate.

##### 3.1.3 Pre-treatment water bath

Untreated as well as scoured wool tops were pre-treated in water bath under several conditions to study the effect of some water bath treatments conditions on the felting propensity of Egyptian / New Zealand wool fibers; the treatment bathes variables as shown in table 1:

Table 1: the treatment bathes variables on wool fibers

Type of sample	bath ratio g/ml	Temperature	Bath agitation	Bath medium
1- Untreated Egyptian wool	- 1:20 - 1:30	-At room temperature (25±2°C)	- Without shaking (soaking)	- <u>Acidic medium</u> 1% acidic solution (H <sub>2</sub> SO <sub>4</sub> )
2- Scoured Egyptian wool	- 1:40 - 1:50		- With shaking (60 shake/min)	- <u>Alkaline medium</u> (NaOH)
3- Untreated New Zealand wool		- At 45°C		
4- Scoured New Zealand wool				

### 3.2 Felting of wool fiber

#### 3.2.1 Control sample

The main field of application of the felting test is the determination of the feltability of raw wool before scouring or bleaching or any other treatment (control sample), to help in evaluation of other treatments fibers.

#### 3.2.2 Felting Test

Untreated, scoured, bleached as well as other pre-treatment water baths of wool fibers were milled in the Aachen three- dimensional shaking machine in solutions, to study the effect of wool different treatments on the felting propensity.

#### Felting Test Methods

The felting test steps are:

- 1- Weigh accurately 1 gm. Of the fiber.
- 2- Make a ball from this sample.
- 3- Reweigh the sample to ensure its weigh.
- 4- Put the sample in a stainless steel container together with 50 ml. of phosphate buffer (pH= 7) and 1% wetting agent.
- 5- Shake the container in the Three- Dimensional Shaking Machine and the machine was set to run for (1 hour) at 140 turns/min. (figure 3).
- 6- The felt ball was generated and air dried (figure 4).
- 7- The diameters of the ball were measured with an absolute digimatic caliper in nine directions (as illustrated in figure 5), and the average

diameter for each ball was used to calculate the ball density in g/cm<sup>3</sup>, by the following formula:

$$\text{Density} = (6 \times G) \div (\pi d^3)$$

Where; G = weight of wool fiber sample in gram (1 gm.)

$$\pi = 22/7 (3.14)$$

d = felt ball diameter in cm (the mean of 9 values)

**Note:** As the felting shrinkage of wool top increases, the felt ball diameter decreases and the felt ball density increases. In other words, there is a direct proportion between density and felt value of the ball (the higher the value of the ball density is, the greater the felt of the fibers is too).



Figure 3. “Aachen Felting Test“ and is used to felting property of loose wool and determine the combed top.



Figure 4. Felt balls

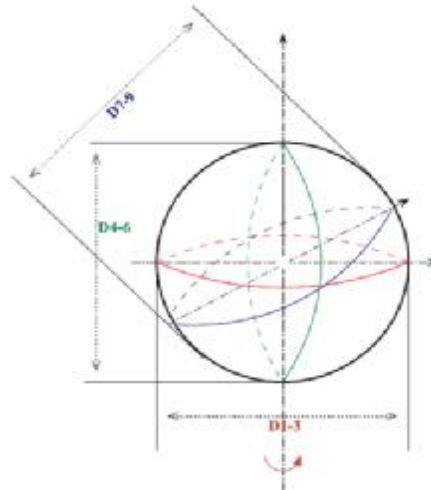


Figure 5. Schematic of the measurement of the felt ball diameter<sup>(27)</sup>.

**3.3 Felting Medium**

The Three- Dimensional Shaking Machine was employed in this study to measure the degree of felting of wool fibers in four different felting medium. 1g of fiber was selected from raw and scoured Egyptian and New Zealand wool fibers and added to 50 ml of felting solution (acidic, alkaline, salty and soapy solution) and 1% wetting agent in 150 ml standard stainless- steel container (the pot of the machine) at room temperature (25 ±2°C) for 60 min at 140 turn/min.

**The four felting medium solutions were:**

- Strong acidic medium (pH=1) was adjusted by Sulphuric acid.
- Alkaline medium (pH=9) was adjusted by Sodium hydroxide.
- Salty solution (pH=9) was adjusted by sodium carbonate.
- Soapy solution made by commercial soap (3g/L), and its pH was 9.

**4. Results and Discussion**

Fist: The result of the effect of felting process on raw (untreated) Egyptian and New Zealand wool fibers (control sample).

The average of nine reading of diameters of the felt balls as well as density was calculated. Results of this investigation are illustrated in Table 2.

Table 2: The results of the average of the felt ball diameters as well as density for raw Egyptian and New Zealand wool fibers

Wool sample	Felt ball diameter mm	Density g/cm <sup>3</sup>
Raw Egyptian wool	2.413	0.136
Raw New Zealand wool	2.403	0.138

Almost similar results of felting process have been recorded in both raw Egyptian and raw New Zealand wool fiber.

Second: The result of the effect of scouring and bleaching treatment of Egyptian and New Zealand wool fibers on felting process

The degree of felting of scoured and bleached of Egyptian and New Zealand wool fibers were calculated. Results of these investigations were illustrated in table 3.

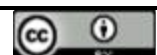
Table 3: The results of the average of the felt ball diameters as well as density for scoured and bleached Egyptian and New Zealand wool fibers

Wool sample	Felt ball diameter mm	Density g/cm <sup>3</sup>
scoured Egyptian wool	2.364	0.145
Bleached Egyptian wool (pH 4.5)	2.262	0.165
Bleached Egyptian wool (pH 9)	2.341	0.149
scoured NZ* wool	2.373	0.143
Bleached NZ* wool (pH 4.5)	2.354	0.146
Bleached NZ* wool (pH 9)	2.360	0.145

NZ\* = New Zealand

The results of scoured and bleached wool fibers for both Egyptian and New Zealand wool were

compared with raw wool fibers. In all cases, maximum tendency of wool fibers to felt is the



highest when using bleached bath 1 (pH 4.5), but rather lower in scoured and bleached bath 2 (pH 9); the lowest felting is obtained in case of raw wool fiber (control sample). This property may be attributed to:

- Hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>) causes fiber surface modification which affects the speed of fiber moisture absorption. The bleached fiber is quicker to absorb water. This phenomenon would affect moisture content of fibers during processing of felting. The moisture is the most important factor, because it causes the wool fiber to increase in elasticity<sup>(44)</sup>; and also, the acidic media accentuate the D.F.E which is playing an important role in felting efficiency.
- On the other hand, scouring of wool fibers

resulted in removal of the greasy matters found on wool surface. The greasy matters act as lubricant which makes the fibers slide past each other and minimize the DFE and so decreased the feltability of wool<sup>(23)</sup>. Upon removing this greasy layer from wool surface, its tendency to felting increased remarkably.

Third: The result of some water baths treatment of raw and scoured Egyptian and New Zealand wool fibers on felting process.

Four different variables of water baths treatment were studied; pH, liquor ratio, temperature as well as the effect of agitation; table 1. The treatment wool fibers were rinsed then dried by oven at 35-40°C. The obtained results, along with appropriate discussion were as follow; table 4(a, b) and 5(a, b).

Table 4a: The results of the average of the felt ball diameters for raw and scoured Egyptian and New Zealand wool fibers treated in acidic and alkaline medium at room temperature (25±2°C) and at (45°C) for an hour with and without agitation; at liquor ratio (1:50)

Wool type Bath treatment	Average of ball diameter- raw Egyptian wool (mm)		Average of ball diameter- scoured Egyptian wool(mm)		Average of ball diameter- raw NZ wool (mm)		Average of ball diameter- scoured NZ wool (mm)	
	Acidic medium	Alkaline medium	Acidic medium	Alkaline medium	Acidic medium	Alkaline medium	Acidic medium	Alkaline medium
R. temperature + soaking	2.373	2.499	2.122	2.183	2.156	2.372	2.017	2.181
45 °C + soaking	2.199	2.291	1.860	2.083	2.072	2.198	2.002	2.040
R. temperature + shaking	2.212	2.323	2.000	2.153	2.151	2.286	2.015	2.175
45 °C + shaking	2.125	2.244	1.847	2.079	2.016	2.142	1.977	2.020

Table 4b: The results of the felt ball density for raw and scoured Egyptian and New Zealand wool fibers treated in acidic and alkaline medium at room temperature (25±2°C) and at (45°C) for an hour with and without agitation; at liquor ratio (1:50)

Wool type Bath treatment	Average of ball diameter- raw Egyptian wool (g/cm <sup>3</sup> )		Average of ball diameter- scoured Egyptian wool (g/cm <sup>3</sup> )		Average of ball diameter- raw NZ wool (g/cm <sup>3</sup> )		Average of ball diameter- scoured NZ wool (g/cm <sup>3</sup> )	
	Acidic medium	Alkaline medium	Acidic medium	Alkaline medium	Acidic medium	Alkaline medium	Acidic medium	Alkaline medium
R. temperature + soaking	0.122	0.200	0.184	0.191	0.143	0.143	0.233	0.184
45 °C + soaking	0.159	0.297	0.211	0.215	0.180	0.180	0.238	0.225



R. temperature + shaking	0.152	0.239	0.191	0.192	0.160	0.160	0.234	0.186
45 °C + shaking	0.199	0.169	0.303	0.213	0.233	0.194	0.247	0.232

Table 5a: The results of the average of the felt ball diameters for raw and scoured Egyptian and New Zealand wool fibers treated in acidic and alkaline medium at 45°C for an hour with shaker water bath (60 shake/min) in different liquor ratio

Wool type \ Liquor ratio	Average of ball diameter- raw Egyptian wool (mm)		Average of ball diameter- scoured Egyptian wool (mm)		Average of ball diameter- raw NZ wool (mm)		Average of ball diameter- scoured NZ wool (mm)	
	Acidic medium	Alkaline medium	Acidic medium	Alkaline medium	Acidic medium	Alkaline medium	Acidic medium	Alkaline medium
1:20	2.327	2.259	2.076	2.204	2.078	2.179	2.038	2.126
1:30	2.144	2.258	1.989	2.153	2.074	2.160	1.994	2.064
1:40	2.135	2.277	1.847	2.104	2.031	2.151	1.982	2.025
1:50	2.125	2.244	1.845	2.079	2.016	2.142	1.977	2.020

Table 5b: The results of the felt ball density for raw and scoured Egyptian and New Zealand wool fibers treated in acidic and alkaline medium at 45°C for an hour with shaker water bath (60 shake/min) in different liquor ratio

Wool type \ Liquor ratio	Average of ball diameter- raw Egyptian wool (g/cm <sup>3</sup> )		Average of ball diameter- scoured Egyptian wool (g/cm <sup>3</sup> )		Average of ball diameter- raw NZ wool (g/cm <sup>3</sup> )		Average of ball diameter- scoured NZ wool (g/cm <sup>3</sup> )	
	Acidic medium	Alkaline medium	Acidic medium	Alkaline medium	Acidic medium	Alkaline medium	Acidic medium	Alkaline medium
1:20	0.152	0.166	0.214	0.178	0.213	0.185	0.226	0.199
1:30	0.194	0.166	0.243	0.191	0.214	0.190	0.241	0.217
1:40	0.196	0.162	0.304	0.205	0.228	0.192	0.245	0.230
1:50	0.199	0.169	0.303	0.213	0.233	0.194	0.247	0.232

- Results of this study clarify the following:
- The tendency of pre-treated wool fiber to felting is higher than raw/ untreated wool (control sample).
- Decreasing the pH of pre-treatment bath resulted in enhancement of the felt ability of wool fibers. This maybe owed to the higher resiliency and the higher swellability of wool fibers in strong acidic medium than in alkaline medium. The greater the swellability of wool fiber, the easier will be its feltability<sup>(23,45)</sup>.
- Since wool is a protein fiber, it suffers a loss of tensile strength when it is wet. Wool can also become more susceptible to chemical damage in an aqueous medium, since the protein chains can be ionized and attract small charged molecules, such as: acids and alkalis. Alkaline conditions (pH > 7) are far more damaging than acid conditions. The alkaline

- nature of suint means that this is a potential source of alkalinity; therefore, the suint content of the raw wool is critical in pre-treatment using alkaline medium conditions. Suint (sweat) is described as the potassium salt of various long chain fatty acids. It is soluble in warm (>30°C) and can act as soap at pH>9<sup>(44)</sup>.
- Maximum tendency of pre-treated wool fiber to felt is higher when using scoured wool but rather lower in raw wool, because scouring removes the greasy matters found on wool surface, so wool will have more fiber/fiber contacts, which would encourage entanglement in opposite with raw wool fibers, it contains dirt and grease which work as barrier in between<sup>(30)</sup>.
- In all cases, as the heat and agitation were used in different pre-treatment baths, the

degree of felting increased remarkably; because heat and moisture make the fibers swollen and flexible, the D.F.E increases and the effect being to opening up the scales to a greater extent, so that they present a much larger free margins and consequently interlock more readily and firmly. In addition, when heat and agitation are applied, the dirt and grease (the main substance of wool grease is wax with a melting point around 43°C) are dislodged into the bulk of the pre-treatment medium, making wool fibers cleaner, which would encourage felting process<sup>(2,22,31,46)</sup>.

- It is clear that the best result of felting process occurred when the wool fibers pre-treated at liquor ratio baths 1:50. The suitable quantities of liquid make the wool fibers move freely

which enhance the fibers treatment and retard fibers entanglement in water baths because larger amount of liquid acts as barrier between the wool fibers.

Fourth: The result of the effect of some felting medium on raw and scoured wool fibers

In this investigation, the degree of felting of raw and scoured Egyptian as well as New Zealand wool fiber were milled in acidic, alkaline, salty and soapy felting bath solutions and the results were compared with each other. The pH of the all felting baths were adjusted by sulphuric acid (pH 1), Sodium hydroxide (pH 9), sodium carbonate (pH 9) and commercial soap (pH 9) as well as phosphate buffer (pH 7). The results of this study were shown in table 6a and 6b.

Table 6a: The results of the effect of different felting medium solution on the average of the felt ball diameters for raw and scoured Egyptian and New Zealand wool fibers

Wool Type	Type of felting medium solution				
	Acidic solution (H <sub>2</sub> SO <sub>4</sub> )	Alkaline solution (NaOH)	Salty solution (Na <sub>2</sub> CO <sub>3</sub> )	Soapy solution 3g/L	Phosphate buffer (pH= 7)
	Average of ball diameter (mm)	Average of ball diameter (mm)	Average of ball diameter (mm)	Average of ball diameter (mm)	Average of ball diameter (mm)
Raw Egyptian	1.840	2.239	2.199	3.283	2.413
Raw NZ	1.910	2.184	2.092	3.682	2.403
Scoured Egyptian	1.914	2.270	2.310	3.243	2.364
Scoured NZ	1.963	2.260	2.259	3.622	2.373

Table 6b: The results of the effect of different felting medium solution on the density of the felt ball for raw and scoured Egyptian and New Zealand wool fibers

Wool Type	Type of felting medium solution				
	Acidic solution (H <sub>2</sub> SO <sub>4</sub> )	Alkaline solution (NaOH)	Salty solution (Na <sub>2</sub> CO <sub>3</sub> )	Soapy solution 3g/L	phosphate buffer (pH= 7)
	Average of ball diameter (g/cm <sup>3</sup> )	Average of ball diameter (g/cm <sup>3</sup> )	Average of ball diameter (g/cm <sup>3</sup> )	Average of ball diameter (g/cm <sup>3</sup> )	Average of ball diameter (g/cm <sup>3</sup> )
Raw Egyptian	0.308	0.170	0.180	0.054	0.136
Raw NZ	0.273	0.183	0.209	0.038	0.138
Scoured Egyptian	0.272	0.163	0.156	0.056	0.145
Scoured NZ	0.252	0.165	0.166	0.040	0.143

It is clear from table 6a and b that:

- The degree of felting of wool fibers in acidic and alkaline felting medium is better than the degree of felting of wool fibers (control samples) using buffer pH=7 as a felting medium.

- The maximum felt ball density occurred at pH 1 (adjusted by sulphuric acid). This maybe owed to the higher swellability of wool fibers in strong acidic medium. The greater the swellability of wool fiber, the easier will be its felt; due to the ability of acids to accentuate

the D.F.E<sup>(23,25)</sup>.

- At pH 9 (adjusted by Sodium hydroxide and sodium carbonate), low felting values were obtained compared with acid felting medium. On the other hand, acid felting has some general advantages; that there is a saving in chemicals and water, since it is not necessary to wash thoroughly the textile materials after felting with acid as with alkali or soap, which are difficult to remove from wool, a residue of acid, within certain limits, is not harmful to wool.
- The lowest values of felt ball density occurred with the conventional method of felting which utilize soap (3g/L). It has been established that soap reduced the friction between the fibers in the felting bath causing slipping of fibers past each other and so reducing feltability value of wool<sup>(23,28,45)</sup>.

## 5. Conclusion

By using the Aachen felting test method, Egyptian and New Zealand wool fibers have been found to felt to higher degree in different conditions. Pre-treatment wool fibers in different water baths have been found to have higher felting propensity than untreated one (control sample) especially with scoured wool. There is a higher tendency of felting for bleached followed with scoured fibers than raw fibers. In the most cases of pre-treatment water baths; acidic medium, heat and agitation have a remarkable influence on the propensity of fibers felting. The felting medium solution has a great influence effect on the values of felting fibers. Acidic medium has played an important role in felting with a higher degree especially with the raw wool fibers than scoured fibers in both Egyptian and New Zealand wool and there is a lower tendency of felting for soapy felting medium than acidic and alkaline mediums compering with buffer pH=7.

## 6. Recommendation

- Applying more studies on the woolen clothes and woolen textiles, especially in the field of recycling.
- The information generated from this study can be utilized in exploring the potential of those non-woods plants especially with rice and wheat straws, palm and banana leaves as well as sugar cane bagasse in Egypt- as alternative fibers resources for the applications as felted textile industries. Also, the pulp and papermaking researcher can use the information generated from this study in their field as well.

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