PROCESSABILITY OF NORTHERN NIGERIAN SILK FIBRES FOR TEXTILE MANUFACTURE

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Abstract

The degumming of the cocoons from the wild silk and followed by the characterization of the degummed silk such as microscopic, breaking load, elongation, fineness, density, tenacity, solubility in alkaline and acidic concentrated solutions were carry out respectively. The results show that the silk have high elongation (41.5%), tenacity (2.07N/tex), breaking load (0.063N) and fineness (0.033tex) but low density using water (0.52g/cm³) and using nitrobenzene (0.85g/cm³) respectively. From the characteristics analyzed, it is obvious that the silk can be used for textile manufacture where light weight silk is of paramount importance due to the low density and high tenacity of the silk.

Keywords: Processability, silk, cocoon, tenacity, fineness, density

Introduction

Raw silk is made up of two parts-fabroin and sericin, they can be analyzed separately. Fibroin represents from 75 to 90% of the fibre, sericin (silk gum) from 10 to 25% (Cliffs, 1980). There are small traces of wax, fat, and salts. Fibroin and sericin are similar components and are classified as protein. The chemical formula of fibroin is $C_{15}H_{23}N_5O_6$ and that of sericin is $C_{15}H_{25}N_5O_8$ (Cliffs, 1980). The silkworm is actually the caterpillar of the silk moth *(Bombyx mori)* and its cocoon is the shell it constructs to protect itself during its growth from caterpillar to chrysalis to moth. Sericulture can be described as the production of natural silk fibre through the keeping of silk worm, *Bombyx mori* using mulberry leaves as feeding medium. There are two types of silk worm, the cultivated and the wild ones. It is the former type which is under strict control that produces the highest quality of silk. Wild silkworms usually give a stronger, more alkali resistant silk, but it has the disadvantage of lacking uniformity (Cliffs, 1980; Komatsu, 1980). The cultivated silkworm known as *Bombyx mori* feed on mulberry leaves. The wild silk or tussah is produced by the caterpillar of the Anteraea type of moth and except for its irregular cross-section, its properties are somewhat similar to those of cultivated silk (Hall, 1980). The tussah silk worm grows wild and feeds on leaves of the oak tree, castor oil plant, cherry tree, and uncultivated mulberry tree. The filament if spins is not round like that of the *Bombyx mori.* It is flat and ribbon –like, generally considered harder than the cultivated type and is about three times as thick in structure (Nkeonye, 1993; Kawahara, et al., 1995). Some spiders can produce silk to swath its prey, and the female spiders requires a silk cocoon to protect the eggs (Robert, 1976). The characteristics of silk could be based on its strength, softness, pleasing lustre and excellent elasticity. In addition, silk is a bad conductor of heat and thus, handless warmly. All these desirable properties united in the fibre makes silk the most valuable of all the fibres used in textile manufacture. The rayon industry has arisen with the initial idea of producing artificial fibres at least equal to silk (Taylor, 1983; Kawahara, et al., 1995). Raw silk has a specific gravity of l.33g/cm^3 but degummed silk gives pure fibroin having lower specific gravity of 1.25g/cm^3. With this change brought about by degumming, the silk fibre become nearly white or transparent and gain in softness (Taylor, 1983). Tussah silk, the most important wild silk obtained from India, is indeed quite resistant to alkalis. Freeze-dried silk sericin from commercial mulberry silk can be prepared by degumming raw mulberry silk with hot pressurized water at 130°C (Yutaka, 2003). Silk when woven and degummed has a soft and bulky touch, elegant lustre, excellent resilience, and good drape, while those made from degummed yarns are stiff and thin (Matsudaira and Kawabata, 1988). The handle of silk fabrics and synthetic fabrics have been classified into basic and total hand values as related to the mechanical properties of fabrics (Nagata, 1989). Degummed silk is hydrophilic and under ordinary conditions retains about 11% of moisture (Taylor, 1983). Raw silk (Cultivated) is off-white to yellow in colour. Unlike cultivated silk, wild silks are uneven, brown and slightly less lustrous than those from cultivated silks (Sonthisombat and Speakman, 2004). The dry silk fibre has a tenacity varying from 2.4 to 5.1 grammes per denier. The wet strength of the fibre is about 80 to 85% of the dry strength. The elongation at break of silk fibre is around 20 to

25% under normal conditions. The extension at break is 33% at 100% relative humidity (Sonthisombat and Speakman, 2004; Yutaka, 2003). Specific gravity of raw cultivated silk and raw tussah silk are 1.33 and 1 .32g/cm^3 respectively. On the other hand, weighted silk has specific gravity of l.60g/cm^3 (Sonthisombart and Speakman, 2004). When silk is subjected to tin- weighting it becomes thicker and heavier in feel and it also acquires a higher draping quality without losing its other excellent characteristics (Mihira, 1925; Ikuzo, 1969). Silk can be found in Japan, China, Europe, Nigeria, etc. In this paper, Northern Nigerian silk would be purified and characterized in order to ascertain its textile manufacture.

Materials and Equipment

Materials include wild silk cocoon (obtained from Jama'a Local Government Area of Kaduna State, Nigeria), nitrobenzene, olive oil soap, distilled water sodiumtioxocarbonate (IV), ammonium chloride, concentrated tetraoxosulphate (VI) acid, hydrochloric acid and trioxonitrate (V) acid. The equipment used are top loading balance, Mettler balance, Instron tensile tester, pH meter, meter rule, heating mantle, measuring cylinder and WIRA fineness tester.

Methods

The Wild silk cocoon was obtained from uncultivated mulberry tree. The major impurity present in the cocoon was the gum (sericin), which was purified before the characterization. Due to the chemical similarity between fibroin (pure silk) and sericin (silk gum), the soap method of degumming (Sonthisombat and Speakman, 2004) was employed as follows: A soap solution of 15g/ cm^3 containing 0.5g/cm^3 Na_2CO_3 (to soften the water) was prepared and the pH was noted so as to ensure that the required pH was attained (normally 10.2 -10.5), the temperature control was adjusted to the working temperature range (92-98^{o}C). The cocoon was immersed in hot water to soften the cocoon and to destroy any life, before heating.

The soap solution was heated to 90^{o}C using the heating mantle before actual degumming commenced. The degumming was carried by immersing the cocoon in the soap solution at the working temperatures, the degumming was carried out for 2.5 hours followed by washing with 1.5g/cm^3 of Na_2CO_3 and dried. The silk fibres were teased out (using a needle –like object) from the cocoon.

Testing of Silk

Standard atmospheric conditions of testing were adopted which is defined as the atmospheric at the prevailing barometric pressure with a relative humidity of 65±2% and a temperature of 25±2^{o}C.

Solubility Test of Silk Fibre

The solubility test of the silk in concentrated hydrochloric acid, tetraoxosulphate (VI) acid, trioxonitrate (V) acid and strong hot sodium hydroxide (35^{0}C) was carried out.

Determination of Silk Fibre Fineness and Breaking Load

The fibre fineness which is a measure of the linear density (Cliffs, 1980) of the fibre in tex was carried out based on a known mass and span length of twisted fibres. The breaking load (Yutaka, 2003) was determined by computation from the instron plot.

Determination of Silk Fibre Tenacity

Tenacity usually referred to as specific strength and is defined as specific stress at break (Yutaka, 2003). It is used to compare the strength of different fibres. The tenacity was obtained by dividing the values of the breaking load by the linear density of the fibre in tex system.

Determination of Silk Fibre Density

The density of the fibre was measured based on the principles of floatation which states that a substance displaces its weight in the liquid in which it floats. The values were tabulated using the relationship □= Mass/Volume.

Where; □is the density of the silk fibre

The liquids used in this case are water and nitrobenzene respectively. The results obtained were compared.

Determination of Silk Fibre Elongation

The elongation of silk fibre was computed based on the change in length per unit length (5cm) and expressed in terms of percent.

Results

Table 1: Solubility Test of Silk Fibre

Acid / Base	Solubility
Conc. H_2S0_4	Soluble with dark brown coloration
Conc. HCl	Readily soluble with brownish black coloration
Cone. HNO_3	Soluble with yellowish coloration
Strong hot NaOH (35°C)	Soluble with brownish coloration.

Table 2: Fineness and breaking load of silk fibre

Sample No.	1	2	3	4	5	6	7	8	9	10
Fineness (tex)	0.020	0.035	0.030	0.040	0.045	0.042	0.039	0.025	0.029	0.023
Breaking load(N)	0.025	0.075	0.075	0.040	0.075	0.075	0.050	0.075	0.088	0.050

Average fineness and breaking load of silk fibres=0.033Tex and 0.063N

Table 3: Tenacity of silk fibre

Sample No.	Fineness (tex)	Breaking Load (N)	Tenacity (N/tex)
1	0.020	0.025	1.250
2	0.035	0.075	2.140
3	0.030	0.075	2.500
4	0.040	0.075	1.875
5	0.040	0.075	1.667
6	0.045	0.075	1.786
7	0.042	0.050	1.282
8	0.039	0.075	3.000
9	0.025	0.088	3.017
10	0.029	0.050	2.174

Average Tenacity of silk fibre =2.07N/tex.

Table 4: Density of silk fibre using water

Sample No.	Mass (gm)	Volume (cm^3)	Density (g/cm^3)

1	0.40	1.50	0.27
2	0.40	1.00	0.40
3	0.40	1.50	0.27
4	0.40	0.50	0.80
5	0.40	1.00	0.40
6	0.40	1.50	0.27
7	0.40	0.50	0.80
8	0.40	0.50	0.80
9	0.40	1.00	0.40
10	0.40	0.50	0.80

Average density of silk fibre = 0.52g/cm^3

Table 5: Density of silk fibre using nitrobenze

Sample No.	Mass (gm)	Volume (cm^3)	Density (g/cm^3)
1	0.50	0.50	1.00
2	0.50	0.50	1.00
3	0.50	0.50	1.00
4	0.50	0.50	1.00
5	0.50	0.50	1.00
6	0.50	1.00	0.50
7	0.50	0.50	1.00
8	0.50	1.00	0.50
9	0.50	0.50	1.00
10	0.50	1.00	0.50

Average density of silk fibre = 0.85g/cm^3

Table 6: Elongation of silk fibres

Sample No.	Sample Length (cm)	Extended Length (cm)	Extension (cm)	Elongation %
1	5.00	6.50	1.50	30
2	5.00	6.25	1.50	30
3	5.00	6.50	1.25	25
4	5.00	6.50	1.50	30
5	5.00	7.00	2.00	40
6	5.00	7.50	2.50	50
7	5.00	7.00	2.00	40
8	5.00	6.50	1.50	30
9	5.00	8.00	3.00	60
10	5.00	9.00	4.00	80

Average percentage elongation of silk fibre =41.5%

Discussion of Results

Fineness of Silk Fibre

Fibre fineness represents the relationship between weight and length (Hall, 1980) of fibre or yarns otherwise known as linear density (weight in grammes per 1000m of a given sample of the fibre). After weighing 10 different samples of twisted filaments and their corresponding lengths, the calculated fibre linear density (tex) was found to be 0.033 tex . Since the change in the various tex values obtained was not wide throughout the tests, it is of little effect on the physical properties of the fibre, it is affected by the fibre density. Compared to the literature value of fibre fineness (0.17tex), this fibre of higher fineness though irregular.

Breaking Load of Single Silk Fibre

The breaking load which is the mass that breaks a given sample length was calculated to be 0.063 N. The variation in the breaking load is as a result of the fibre irregularity (for wild silk). For this reason, it is obvious that the fibre has high breaking load which gives it greater strength.

Elongation of Silk Fibre

The elongation was found to be 41.5% which is much higher than that stated in literature (Sonthisombat & Speakman, 2004). This can be attributed to the type of silk (tussah) used which is said to be of higher strength than cultivated silk. This is an indication that the fibres can be used to produce fabrics that can withstand rigorous condition most especially when cross-bred with the right breed. The elongation signifies how elastic the fibre is. It is important to note that silk is the only natural fibre in continuous filament form.

Tenacity of Silk Fibre

This is said to be the specific strength or stress at break (Yutaka, 2003). From the experimental results, the value was found to be 2.07N/tex. The tenacity obtained is about six times that of the literature value. This is also an advantage over the cultivated silk fibre. The high tenacity obtained depends on breaking load and linear density.

Density of Silk Fibre

From the densities obtained using water and nitrobenzene (0.52g/cm^3 and 0.85g/cm^3 respectively), the difference in the density is as a result of the fact that the fibre is hydrophilic (water –loving). The value obtained for nitrobenzene is almost that of the literature value (1.25g/cm^3) which implies that it is of a lower density (volume displaced by a given mass of the fibre). It is also important to note that this will give fabrics of light weight.

Solublity of Silk Fibre

The results indicates that the fibre is susceptible to both concentrated solutions of tetraoxosulphate (VI) acid, trioxonitrate (V) acid and hydrochloric acid. It is also attacked by warm caustic soda (35^{0}C).

N.B: The length of the silk fibre could not be determined due to the emergence of the moth from the cocoon which tampered with the continuous nature of the filament.

Conclusion

The purification and characterization of Northern Nigerian silk (Amere-Southern part of Kaduna State, Nigeria) has been of help in evaluating its possible textile manufacture. From the results obtained, it can be concluded that the wild silk is of high strength, as a result of the high breaking load at break and higher elasticity compared to literature values (mostly cultivated silk). The research work has shown that wild silk is of higher strength than cultivated silk. This has also helped in determining the density of the fibre which is an indication of its weight in terms of comfort. Finally, it can be inferred that it is possible to use the fibre for textile manufacture based on the characteristics evaluated.

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