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Effect of Water and Chemical Retting on Properties of Hemp Fibre and Hybrid Hemp/Cotton Spun Yarn

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Abstract: Hemp is original used by Hmong people, the mountainous tribe in Northern Thailand. Hemp cloth by Hmong is coarse fabric with traditional process. To introduce hemp into the industry, hemp need to be process as ordinary spinning yarn. This research aims to study the effects of water retting and chemical retting on properties of hemp fibre. Hemp was obtained from Northern Thailand and then retted using water and chemicals. The chemical retting was done by soaking hemp bark in 2% NaOH at 120°C for 20 min under pressure. Bark was soaked in a tank of water for 9 weeks in the water retting process. Fibres from the 2 processes were investigated for chemical properties and the spinnability of a hybrid hemp/cotton mixture using ring spinning technique. The results show that hemp fibres from different retting processes were affected on percentages of extractive, protein, hemicellulose and lignin of fibre. Hemp at 9 week of water retting showed the percentage of cellulose, hemicellulose and lignin at 72.7, 4.3 and 16.6%, respectively. The composition of chemical retted hemp fibres resulted in 83.4% cellulose, 0.1% hemicellulose and 12.7% lignin. The Degree of Polymerization (DP) of chemical retted hemp was lower than the DP of hemp fibres from the water retted process. Spinnablity test by spun hemp/cotton at a ratio of 1:1 by weight showed that the fineness, twist and strength of spun yarn from hybrid water retted hemp/cotton ($hemp_w$/cotton) were higher than those from hybrid chemical retted hemp/cotton ($hemp_c$/cotton). Futuremore, the intensive effect of water retting on bast fibre quality should be investigated.

Key words: Hemp, water retting, chemical retting, spun yarns, textiles

INTRODUCTION

Plant cellulose fibres are a natural resource that used in the eco-textile industry, especially for making environmentally friendly products. Plant cellulose fibres from seed, stems and leaves are mainly used . The main compositions of plant fibre are cellulose, hemicellulose, lignin, proteins, pectic substance, extractives, starch and inorganic chemical composition (Rowell *et al*., 2000). Lignin and hemicellulose in cell wall component function as amorphous while cellulose functions as crystalline (Krassing, 1992). Cellulose of bast fibre of hemp, flax, ramie and jute are formed in fibre bundles which attach to one other by pectic substance (Caffall and Mohnen, 2009).

Hemp, bast fibre from *Cannabis sativa* L. is used in Hungary as a fibre plant. A historical review shows that hemp has been planted in Prussia and the Plateau of Tibet for a 1000 years (Lu and Clarke, 1995). In Thailand, hemp is grown in the north by Hmong people, the hill tribe who live in mountainous areas. Hmong people wear cloth made from hemp in some ceremonies. The process of hemp yarn making is a traditional process as coarse textile (Sengloung *et al*., 2008). To introduce hemp fibre into current textile industry in Thailand, the process of spun yarn needs to use the existing equipment such as ring spinning and open-end spinning machine. There is difference from wet spinning, the ordinary process for linen in Europe. Hemp comprise of 20-40% bast fibre and 60-80% wood by weight. Bast fibre is high crystalline

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Table 1: Tap water quality used in water retting process

Content	Allowable
Color	5-15 units
Turbidity (silica units)	2-20 units
Odor	Unobjectionable
pH	6.5-8.5
Total solids	500-1,500 mg L^{-1}
Toxic substance	Standard of drinking water*
Total bacteria	500 colony/mg
MPN (100 cm^{-3})	< 2.2
E. coli	Negative

*Standard of drinking water (WHO)

Fig. 1: a) Water retting: b) Chemical retting process

cellulose at 57-77%, hemicellulose 9-14% and lignin 5-9% (Hearle and Peters, 1963; Franck, 2005; Thygesen *et al*., 2006a; Gumuskaya *et al*., 2007). Due to the parallel fibre orientation of hemp, also found in flax, hemp was bred to improve varieties for high fibre production (Thygesen *et al*., 2006b; Hearle and Peters, 1963). Hemp fibres are high hygroscopic absorption, high strength compared to cotton and flax. Short cultivation period, no chemical needed for pesticide and insecticide in comparison to cotton crop (Mohanty *et al*., 2005). The physical properties of Thai hemp are showed in Table 1. Sengloung *et al.* (2008) found that diameter of hemp analysis by Optical Fibre Diameter (OFDA) was close to hemp obtained from China and flax for spinning in the textile industry (Sengloung *et al*., 2008).

Hemp is a bast fibre that needs to be separated from the bark. The process of fibre separation is removed pectin and extractive before starting fibre applications. Hemp has to be prepare into fibre bundle as raw materials for yarn spinning. The processes involved, retting and scutching, are applied for separating fibrous from non-fibrous materials and separate the fibre into bundle form. The retting processes used for bast fibre are water, dew, enzymatic and chemical. Each retting processes has an impact on fibre quality for chemical properties, color, fineness and strength (Tahir *et al*., 2011; Akin *et al*., 2002). Hemp can be straight, less crimped or rigid (Fig. 1). Thus, yarn spinnability can be low but with high stiffness. Hybrid hemp/cotton spun yarn is an alternative option. The ratio of hemp to cotton affects from hemp fibre fineness and fibre crimp. This research aims to investigate the effect of the retting process on Thai hemp on the chemical properties and spinnability by using the ring spinning technique.

MATERIALS AND METHODS

Fibre materials and preparation: Hemp bark was supplied by the Queen Sirikit Botanical Garden, Chiang Mai. Cotton fibre supplies from Far East Knitting Co., Ltd. Thailand. The retting processes used for fibre separation were water and chemical. For water retting, hemp bark was soaked in a tank of tap water for 9 week (Fig. 2a). Figure 2b shown hemp fibre after water retting and the quality of tap water is shown in Table 2. After the hemp was soaked, fibres were removed from the tank at 1, 2, 4 and 9 weeks. Hemp fibre was cleaned by tap water until mucilage material was removed, then dried in an oven at 70°C for 24 h. With chemical retting, hemp bark was soaked in 2% NaOH at 120°C for 20 min, then rinsed with tap water and dried in an oven (Fig. 1b, Fig. 4a-f).

Hemp fibres were cut in 10 cm lengths and processed with hand carding for 2 times, then cut into small pieces and blended before a chemical properties analysis. According to Technical Association of the Pulp and Paper Industry (TAPPI, 1998) standard, the chemical properties of hemp fibre was investigated as follows: extractive in alcohol-benzene with TAPPI T204-cm 97, extractive in water with TAPPI T207-cm 99, holocellulose with Browing method (Browing, 1963), cellulose with TAPPI T203-om 93, lignin with TAPPI T222-om 98, protein with AOAC test method 2005 (AOAC, 1990), moisture content and degree of polymerization according to ASTM D 1795-94.

Spinning processes: Hemp fibre after hand carding were cut into 4.5 cm lengths then mixed with cotton at 1:1 ratio by weight. Then, card mixed hemp/cotton fibre for 1 time, then mixed fibre was processed by ring spinning machine (MESDANLAB) which was comprised of carding machine for preparing fibre web (Fig. 3), sliver machine for preparing fibre sliver (Fig. 3) and roving machine for spinning process (Fig. 3). The hybrid yarn number was estimated by electronic warp reel, twist (simple twist tester) and yarn strength using Instron Universal Testing Machine (BS EN ISO 2062) standard). Statistical analysis used the Statistical Package for Social Science (SPSS) 11.5 for Windows.

Table 2: Chemical and physical properties of hemp fibre (Franck, 2005)

The chemical constituents (%)	Values	The physical properties	Values
Cellulose	75.0	Diameter	15-50 µm
Pectin/lignin	9.5	Length	1500-5000 mm
Water soluble substances	2.1	Tenacity	40-70 N/Tex
Vegetable wax and fat	0.6	Elongation at breaks	23%
Mineral matter	0.8	Moisture Regain	12%
Hygroscopic water	10.0		
Other	2.0		

Fig. 2: Ring spinning process: a) Carding and waving; b) Sliver; c) Ring spinning

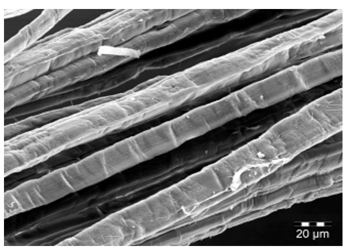

Fig. 3: Scanning electron micrograph of hemp fibre (reprinted with permission) (Sengloung *et al*., 2008)

RESULTS AND DISCUSSION

Chemical properties of hemp: Hemp bark is composed of cellulose, hemicellulose, lignin and extractive (Franck, 2005; Akin *et al*., 2002). Cellulose is used in application while other compositions are removed. The retting process removes non-cellulosic material. Water retting is known to produce a superior quality of hemp fibre compared to other retting methods. It allows bacterial activity to dissolve mainly pectic substances and other minor composition fibre (Akin *et al*., 2002). After 1 week of water retting, the hemp fibres remain form the raw material (Fig. 4b). Chemical retted hemp fibre treated by alkaline hydrolysis to dissolve hemicellulose and lignin, as the remained extractive in fibre decline along the retting time and cellulose was aggregated into fibre bundle form (Fig. 4). Fibres from water retting were paler than those from chemical retting process (Tahir *et al*., 2011).

Table 3 shown Thai hemp bark consist of 55.96% cellulose, 4.25% hemicellulose, 24.88% lignin, 7.01% protein and 16% extractive content (Ethanol-benzene,

Fig. 4: Hemp fibre after water retting and chemical retting: a) Raw hemp bark; b) Water retting 1 week; c) Water retting 2 weeks; d) Water retting 4 weeks; e) Water retting 9 weeks; f) Chemical retting

Ethanol and water soluble substance). The holocellulose content was increased after 1 week of water retting due to removal of extractive materials. Therefore more retting time allowed the increase in cellulose content while hemicellulose and lignin continuously declined due to the degree of removal. Cellulose, hemicellulose and lignin are combined into complex structure then there require time of degradation (Krassing, 1992; Caffall and Mohnen, 2009). After 9 weeks of water retting, hemp fibre remained 4.51% of extractive content and 3.73% of protein, so the cellulose content of 9 week water-retted fibre was 72.7%, less than chemical-retted fibre which was 83.5%. Hemicellulose is branches polysaccharides that dissolves in hot alkaline solution while lignin dissolved in alkaline (Brandt *et al*., 2013). Therefore, chemical retting process removes more extractive, hemicellulose and lignin than water retting process.

Water retting involves the behavior of microorganism that needs energy supply from food. They secrete enzymes to digest organic compounds on bast fibre into molecular substance to feed itself. Enzyme functions like catalyze specific with substrate which mean to fibre raw material in this experiment. The indirect cellulose molecular weight determine from intrinsic viscosity Degree of Polymerization (DP) of cellulose. DP of cellulose of 9 weeks water-retted fibre was higher than fibre obtained from chemical retting (Table 4). DP of cellulose terms in the cellulose molecular weight in cellulose molecule. High DP refers to high bonding which affects fibre strength. The chemical retting process may cause a

Table 3: Chemical properties of hemp fibre

Retting time dry weight (%)	Raw hemp	Water retting (weeks)				Chemical retting
		1	2	4	9	
Ethanol-Benzene soluble substance	8.73	10.20	7.73	6.30	4.51	1.01
Ethanol soluble substance	2.32	0.930	1.00	1.85	1.46	2.22
Water soluble substance	7.22	0.640	0.51	0.32	0.61	1.21
Holocellulose	60.20	70.20	70.33	72.65	76.96	83.50
α-cellulose	55.96	60.68	61.89	69.32	72.67	83.36
Hemicellulose	4.25	9.520	8.44	3.33	4.30	0.14
Lignin	24.88	24.33	23.95	20.94	16.58	12.71
Proteins	7.01	N/A	3.91	3.44	3.73	0.90

Table 4: Physical properties of hemp/cotton yarn

Properties	$Hemp_w^1$/cotton yarn	$Hemp_c^2$/cotton yarn	ρ
Yarn number			
Tex	90±20	115±6	0.030
NeC	7	5	N/A
Twist (tpm)	740±29.28	690±22.36	0.016
Load (cN)	673.87	633.13	N/A
Tenacity (cN/Tex)	7.49±1.96	5.49±0.72	0.002
Elongation (%)	6.92±1.30	8.25±1.32	0.010

[1]Hemp fibre from water retting 9 weeks; [2] Hemp fibre from chemical retting

Table 5: Intrinsic viscosity of cellulose (ASTM D, 1795)

Materials	η	DP
Water retting hemp (9wk)	5.46	1,037.40
Chemical retting hemp	3.92	744.31

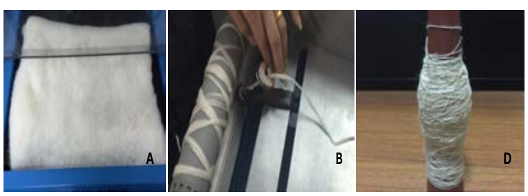

Fig. 5: Appearance of hemp/cellulose in spinning processes: a) Hybrid hemp/cotton web; b) Hybrid hemp/cotton sliver; c) Hybrid hemp/cotton yarn

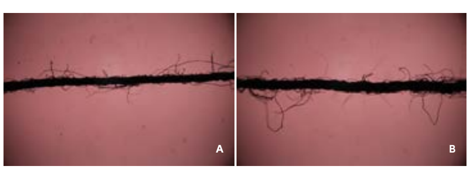

Fig. 6: Hybrid hemp/cotton yarn micrograph: a) $Hemp_w$/cotton yarn; b) $Hemp_c$/cotton yarn

decrease in the DP of cellulose due to alkaline hydrolysis reaction which causes to decrease the DP in fibre. Thus, retting process removed non-cellulosic materials with hydrolysis reaction and the effect is an increasing percentage of cellulose content in fibre.

Yarn properties: Hemp fibre is shown in a long sectional micrograph as erect, rigid and less crimped (Fig. 3). Thus, allowing less spinnability in an ordinary spinning machine. After hybrid hemp/cotton yarn was spun using ring spinning technique with 1:1 ratio (Fig. 5), $hemp_w$/cotton yarn was 90 tex with 740 twist per meter (tpm). Hybrid $hemp_c$/cotton yarn was 115 tex with 690 tpm. The cotton count of $hemp_w$/cotton yarn was 7 NeC and $hemp_c$/cotton yarn was 5 NeC (Fig. 6).

Thus, $hemp_w$/cotton yarn is both finer (yarn number) and with a higher twist than $hemp_c$/cotton yarn significant at the 95% confidence level (ρ = 0.03 and 0.016, respectively). The strength of $hemp_w$/cotton yarn is higher than $hemp_c$/cotton yarn as shown in load and tenacity of yarn (Table 5). Therefore, the spinnability of hybrid hemp/cotton yarn can perform with 50% hemp fibre in yarn which is high ratio. In the other hand, the natural fibre may difference from lot by lot and this may affect the yarn properties.

CONCLUSION

The retting process effects fibre quality. The water retting process produces a higher quality fibre in terms of yarn strength and spinnability than fibre obtained from chemical retting. Both retting processes can separate non-fibrous from fibrous materials. Thai hemp fibre can be introduced and applied to spin with ring spinning technique which is one of the ordinary techniques in the textile industry. Thus, Thai hemp fibre has the potential to apply into natural textile. The hybrid hemp/cotton fibre at 1:1 ratio was the 5-7 NeC, tenacity 5.5-7.5 cN/Tex and elongation 6.9-8.2%. Futuremore, the effect of water retting toward fibre quality and water quality will be investigated.

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