



Post-decortication Processing of Hemp Fibre using a Carding Machine

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**Written for presentation at the
CSBE/SCGAB 2011 Annual Conference
Inn at the Forks, Winnipeg, Manitoba
10-13 July 2011**

ABSTRACT An experimental study was carried out using a drum carder to separate fibre from decorticated hemp material. The effectiveness of carding machine on fibre separation was investigated for three different numbers of turns of the licker-in cylinder and five different feeding masses. After carding, different fractions (fibre, core, fibre attached with core, waste) of the hemp material were manually separated and measured before and after carding. Based on those measurements, the effectiveness indicators were determined. The indicators included fibre purity, detaching effectiveness, and waste production. Highest fibre purity was found for maximum number of turn and for top amount of mass. Peak detaching effectiveness was noticed for highest number of turn and for maximum amount of mass. In case of waste fractions, minimum value was noticed for least number of turns. Only turn played significant role as a carding parameter for detaching effectiveness and waste production.

Keywords: Hemp fibre and core, separation, carding machine, number of turns, mass.

INTRODUCTION Hemp plant is an excellent source of natural fibre. Natural fibre from hemp stalk is extremely durable and widely using in the production of textiles, paper, food and fuel, composites, construction materials and automobile parts. There is an increasing demand for high- grade hemp fibre. For getting high-grade fibre, processing of fibre is essential. Hemp processing includes two main steps: decortication and cleaning. Decortication is the technique of removing outer fibre from woody core of hemp plant and in this process hemp is broken into

pieces, resulting in different sizes of fibre bundles and core (Baker 2009). Thus the output of decortications is mixture of fibre bundle, core, fibre attached with core and chaff. Therefore, further cleaning is required to obtain clean fibres as a post-decortication process. The cleaner the fibre is, the higher is the value.

For material cleaning, sieving or screening is one of the oldest types of technique. Dass (2004) mentioned that the ultimate screener which is a new screen technology is an extensively used cleaning method by separating particles. Usually dry fine materials are cleaned in this method. Liu (2009) found that sieving, combined with winnowing or air flows can categories particles more effectively than sieving alone in separating dried distillers grains with soluble. Double deck banana screens are used for high capacity separation of iron ore and coal (Cleary et al. 2009a). Sweco separator separates solids from liquids, segregates smaller particles from larger particles and removes foreign material (Sweco 2003). Vorster et al. (2002) showed that for the same screen efficiency, the throughput increases by more than 810% by fitting a kroosher unit with Sweco. It is mainly used for separation of dry material.

Though there are different methods for material cleaning only few methods have been tried on fibre cleaning. Few cleaning machines have been specifically designed for separating fibre from decorticated hemp mixture. In most cases, people adopted cleaning equipment from other applications, such as screen type machines for separating solids from liquids or segregating dry materials into various sizes. Straw walkers from combine were used for fibre cleaning (Gratton and Chen 2004) and it was found those machines may be ineffective when they are used for fibre cleaning. Furl and Hempel (2000) reported 48-61% cores in decorticated hemp mixture from a hemp processing line. A similar level of core content was reported by Gratton and Chen (2004) for a field-going hemp decorticator. In some other industrial applications, decorticated hemp was feed into a multiple ultra cleaner to eliminate cores. The multiple ultra cleaner shake the material intensively, and short fibres and cores are being separated from the long fibres (Münder et al. 2004). Pecenka and Furl (2008) simulated the fibre cleaning process for comb shaker. The comb helps to separate the fibre and hurds by losing the fibre and fibre hard mixture from the decorticated sample. It can reduce 7% core of total mass. Another popular method to remove cores is scutching. This method is established for retted hemp. However, retting is not suitable in Canada due to the high risk of rotting, fungal or mold attack (Münder et al. 2004).

From this above description, it can say that fibre cleaning is a difficult process due to lack of knowledge and appropriate cleaning equipment. In addition, fibres tendency to tangle with other fibres and cores is a great challenge. Cores are being held in tangled with fibre bundles during a cleaning process, resulting in a poor core removal. Therefore, it is a big issue to find out proper cleaning equipment.

Carding is a mechanical process by which fibre clumps (A number of fibres in contact with each other) are opened, disentangled, and cleaned for different uses. It mainly cards the fibre to open the fibre bundle. Short fibres, dust and dirt from fibre bundle can be removed through this process. Important task of the card is to open individual fibers, which enables to eliminate impurities and provide better performance for further operations. Elimination of impurities occurs

mainly in the licker-in section. Significant fiber/metal and/or fiber/fiber friction is occurred in carding operation which eliminates dust bounded to the fibers. Disentangling of neps (aggregations of small fibres created during fibre processing) is also noticed in carding process. In industries, carding is the most commonly used method for cotton processing. It is easy to use and less time consuming. The degree of cleaning is very high in carding.

To obtain clean fibre from decorticated hemp mixture, a study was conducted by using carding machine as a post-decortication process. The objectives of the study were to investigate the effect of carding parameters on hemp fibre purity (clean fibre) and detaching effectiveness.

METHODOLOGY

MATERIAL Unretted hemp, which was collected from a hemp processing industry in Manitoba, Canada, was used as a material for the carding experiment. Prior to the experiment, the hemp sample was decorticated from a non hammer mill decorticator.

CARDING MACHINE In the carding experiment, a lab scale drum carding machine was used to separate fibre from its mixture. Figure 1 shows different components of drum carding machine used for this experiment. Table 1 shows the geometric dimensions of carding machine.

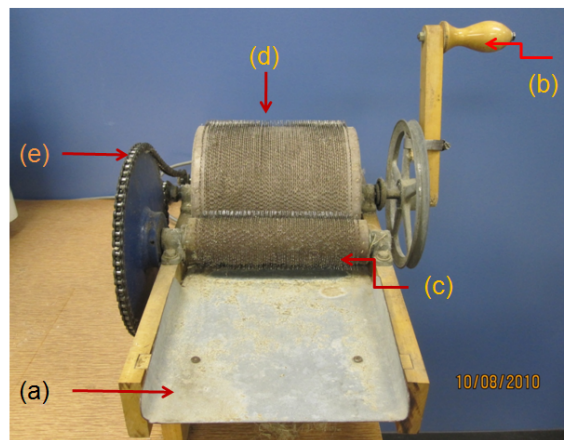


Figure1. Drum carder: (a) feeding tray, (b) rotating handle (c) licker-in cylinder (d) main cylinder and (e) chain drive.

Table 1. Geometry of carding machine.

Component	specification
Feeding tray	Length: 250 mm Width: 210 mm
Licker-in cylinder	Diameter: 54 mm Spacing of hook: 54 per square inch Height of each hook: 5 mm
Main cylinder	Diameter: 185 mm Spacing of hook: 60 per square inch Height of each hook: 5 mm
Gear ratio (main cylinder : licker-in)	7:1

EXPERIMENTAL DESIGN A completely randomized design was considered for the experiment. From hemp material, five different masses were taken, and they were 10, 20, 30, 40, and 50g. The lock-in cylinder of the carding machine was operated with a constant speed (50 rpm) for three different numbers of turns (100, 200, and 300 turns) for all masses. Masses and number of turns were selected based on preliminary trials. Five different masses and three different numbers of turns gave 15 treatments for the experiment. For each treatment, three replications were done. Therefore a total of 45 tests were conducted in the experiment.

SAMPLING PROCEDURE Hemp decorticated material was sieved through a Retsch sieve shaker (model AS 400, PA, USA) to remove chaff and dust. Materials were passed through different sizes of sieves in the shaker which were 20 mm, 10 mm, 5.0 mm and 2.80 mm respectively. For samples used for the carding experiment, nine groups were made with the decorticated hemp material. Five samples were taken from each group to obtain representative samples, giving a total of 45 samples for carding tests.

TEST PROCEDURE Hemp material sample was spread in the feeding tray as a “flat sheet” (Fig. 2a). Carding handle was used to manually rotate the main cylinder’s shaft which was connected to the licker-in cylinder shaft through the chain drive. Hemp materials were opened in very small tufts in licker-in section. Wastes (mixture of very tiny fibre, and core) were eliminated as materials traveled along the circumference of the licker-in cylinder and nep formation was reduced as well. After traveling in this licker-in cylinder, hemp material was transferred to the main cylinder surface (Fig. 2b). Fibre distribution was both transversely and longitudinally on the main cylinder. Between the licker-in and main cylinders, stripping action occurred. In both sections, inclined wire grip were noticed with same direction of material movement. This is known as point to back arrangement which facilitated shredding of fibre from the licker-in cylinder to the main cylinder. Figure 2c shows the end product (fibre, core, fibre attached with core and waste) from carding.

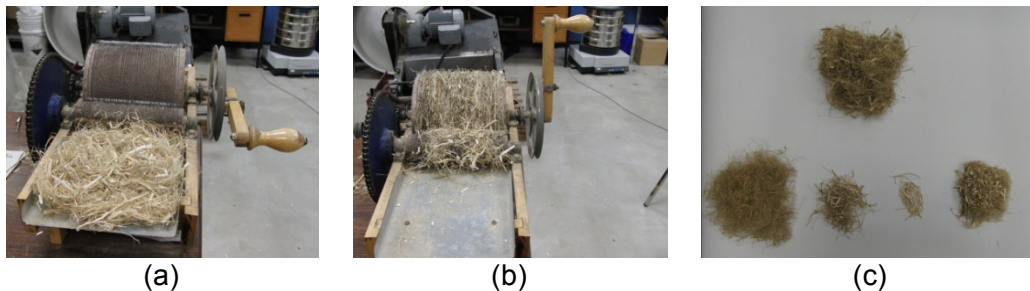


Figure 2. Fibre cleaning using the carding machine: (a) initial stage; (b) middle stage; (c) end product.

MEASUREMENTS Before carding tests, each sample was analyzed by separating manually into core, fibre and fibre attach with core. Weight was measured for each fraction by using a balance (Model MS- 2500, Mars, Canada) to determine the average percentage of these fractions. After a carding test, carded sample was separated into core, fibre, and fibre attached with core by manual separation. These fractions were weighted and the weight of each fraction was used to determine the performance indicators of carding, as described in the following sections.

Initial fibre purity To know how effective the carding was, initial fibre purity was determined before the hemp material was carded. The initial fibre purity was defined as the mass of fibre divided by the total mass of feed. It was determined by using the following equation:

$$f_b = \frac{(m_f)_b}{M} * 100 \quad (1)$$

Where,

f_b = fibre fraction before carding (%);

$(m_f)_b$ = Mass of fibre before carding (g).

M = Total feed mass (g).

In similar way, by following equation (1), core and fibre attach with core fractions were calculated.

Final fibre purity It was expected that carding would improve the fibre purity. After fibre was carded, its purity, i.e. final fibre purity, was measured again, so that comparisons could be made between fibre purities before and after carding. Final fibre purity was defined as the mass of fibre after carding divided by the deduction of waste from total feed mass. It was determined by using the following equation:

$$f_a = \frac{(m_f)_a}{M - W_a} * 100 \quad (2)$$

Where,

f_a = fibre fraction after carding (%);

$(m_f)_a$ = Mass of fibre after carding (g).

M = Total feed mass (g).

W_a = Waste after carding (g).

Similarly, equation (2) was followed for calculating core and fibre attach with core fractions after carding.

Waste Carding process also generate chaff and fine particles, i.e. waste. Percentage of the waste generated from the carding process was calculated by using the following equation:

$$W_a = \frac{m_w}{M} * 100 \quad (3)$$

Where,

W_a = Waste after carding (%);

m_w = mass of waste fraction after carding (g) and

M = Total mass of feed (g).

Detaching effectiveness Another function of carding is to further detach fibre which was still attached with core. For determining the detaching effectiveness of fibre from core, the mass of fibre attached with core after carding was deducted from mass of fibre attached with core before carding and then it was divided by mass of fibre attached with core before carding. It was expressed by the following equation:

$$E_d = \frac{(m_{f/c})_b - (m_{f/c})_a}{(m_{f/c})_b} * 100 \quad (4)$$

Where,

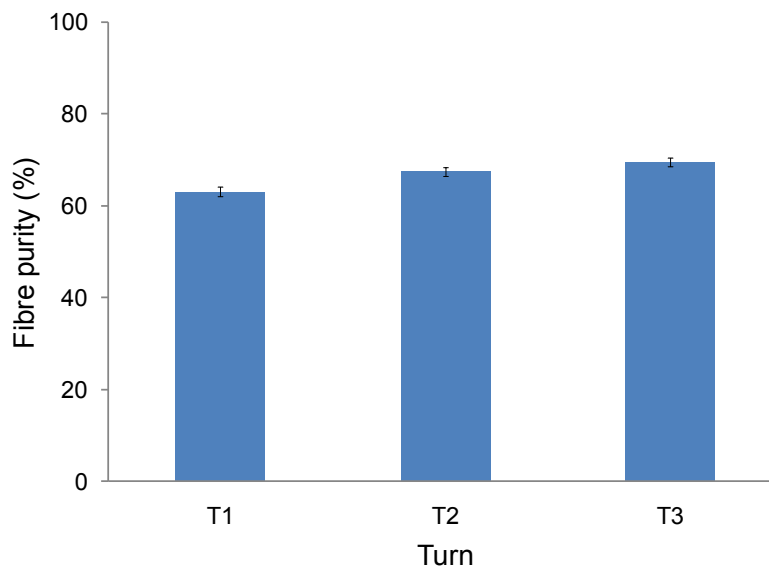
E_d = Detaching effectiveness (%);

$(m_{f/c})_a$ = mass of fibre attached with core after carding (g) and

$(m_{f/c})_b$ = mass of fibre attached with core before carding (g).

STATISTICAL ANALYSIS Statistical software SAS (version 9.1.3) was used to analysis the data for carding method. Two factor factorial analyses were done. Analysis of variance (ANOVA) was carried out to see the level of significance of each factor and their interaction. Further t- test was conducted to see which factor varies significantly from others.

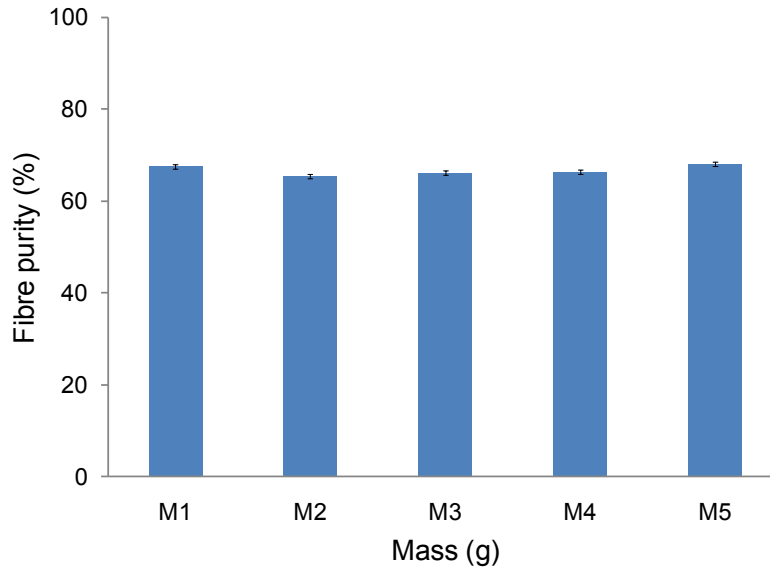
RESULTS AND DISCUSSIONS Fibre purity for different number of turns after carding is presented in fig. 3. It is observed that turn T3 (300 number of turns) resulted highest fibre purity and the value was 69.6%. Fibre purity showed rising trend with increasing number of turns. No significant effect was observed for any turn ($p > 0.05$) on fibre purity.



T1=100 turns; T2= 200 turns; T3= 300 turns;

Figure 3. Fibre purity for different number of turns after carding.

Fibre purity for various masses is presented in fig. 4. For M5 (50 g), maximum fibre purity was observed which was 68.04%. Significant effect was not observed for any mass ($p > 0.05$) on fibre purity.



M1= 10g; M2= 20g; M3= 30g; M4= 40g; M5= 50g;

Figure 4. Fibre purity for various masses after carding.

Figure 5 illustrates the detaching effectiveness of fibre from core in different number of turns. Highest detaching effectiveness was noticed in turn T3 and it was 74.85%. More turns allowed detaching more fibre from core. From ANOVA table, it was noticed that turn had significant effect on detaching effectiveness ($p < 0.05$). Furthermore from t-test it was determined that turn T1 varied significantly from T3 but T2 did not show any significant different with T1 and T3.

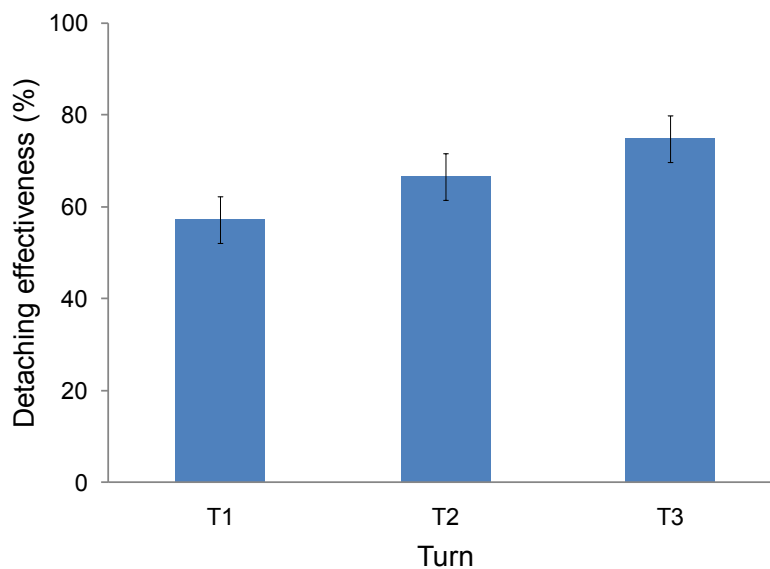


Figure 5. Detaching effectiveness of fibre from core for different number of turns after carding.

Detaching effectiveness for various masses is demonstrated in fig.6. Highest detaching effectiveness was observed for M5 and the value was 68.83%. No significant effect was found for any mass on detaching effectiveness ($p > 0.05$).

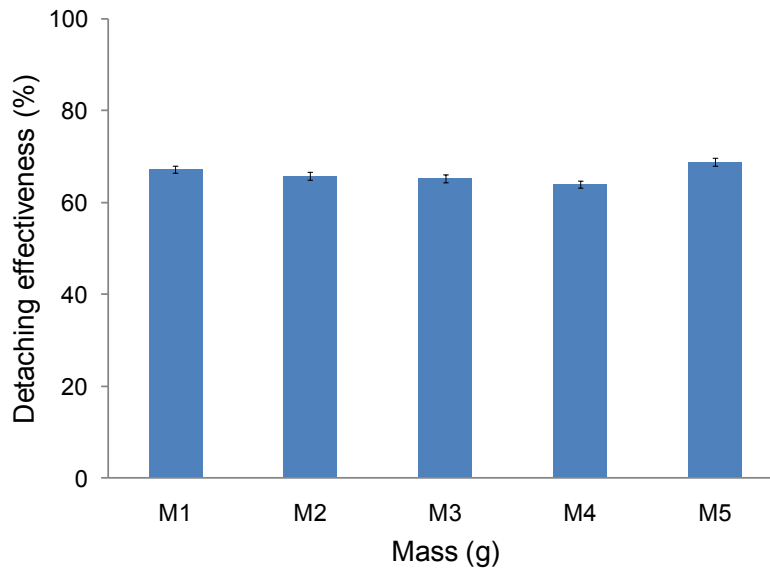


Figure 6. Detaching effectiveness of fibre from core for various masses after carding.

Figure 7 presents the waste percentage with different number of turns after carding. Minimum waste was noticed for T1 whereas T3 measured maximum waste. Waste production increased with increasing number of turns. The minimum value was 32.43% and the maximum one was 40.52%. From ANOVA table, it is observed that turn had significant effect on waste production ($p < 0.05$). From the t-test, it was further noticed that T1 differed significantly from T3. But T2 was not significantly different from T1 and T3.

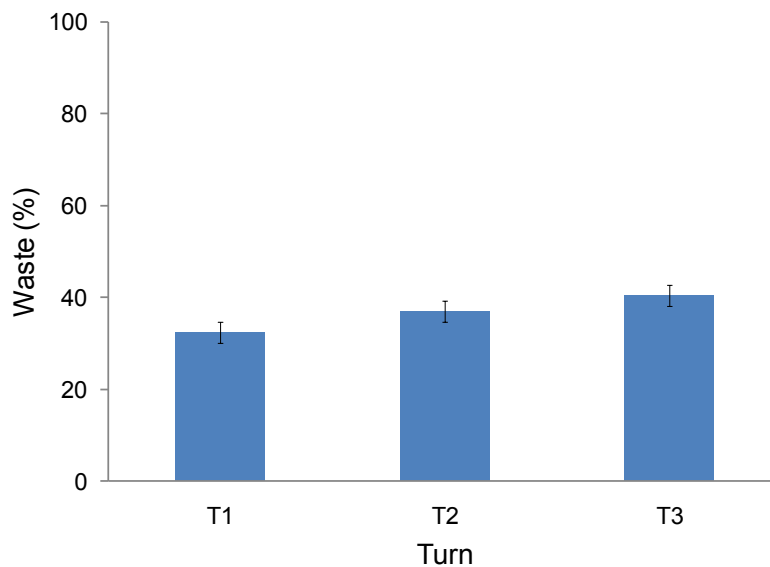


Figure 7. Waste fractions for various numbers of turns after carding.

Waste fractions for various masses after carding are shown in fig.8. Highest amount of waste was found for M1 and the value was 39.78%. Waste production showed a decreasing trend with increasing masses. But any mass did not show significant effect ($p > 0.05$) on waste production.

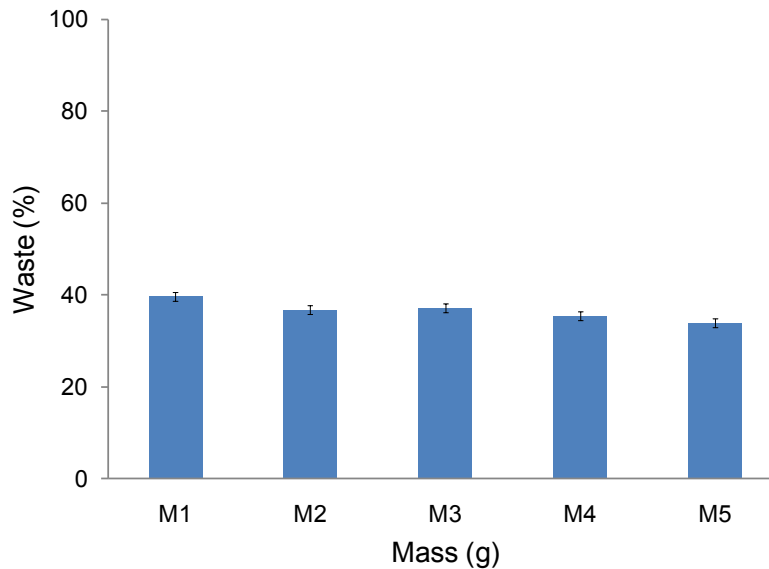


Figure 8. Waste fractions for different masses after carding.

CONCLUSIONS Carding method was applied in hemp fibre cleaning. In carding method utmost fibre purity which is considered as clean fibre was found for highest number of turn and for top amount of mass. Different number of turns and mass did not show any significant effect on fibre purity. Likewise fibre purity, peak detaching effectiveness was noticed for highest number of turn and for maximum amount of mass. Turn had significant effect on detaching effectiveness whereas mass did not show any effect. In case of waste fractions, minimum waste was noticed for least number of turns. On the other hand, least amount of mass produced highest fractions. Only turn played significant role in waste production as a carding parameter whereas mass did not show any significant.

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