# Optimal Processing of Flax and Hemp Fibre Nonwovens

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Processing was studied for air-laid nonwovens from natural hemp and flax fibres using SPIKE® air-laying technology (Formfiber Denmark ApS Company). The process of web-formation and the properties of the fibre-webs before needle-punching and reinforced fibre-mats were evaluated. The settings of the air-laying machine were found to influence the web-formation process and nonwoven properties. In order to monitor web-formation processes and evaluate the fibre-web or fibre-mat quality, several machine settings were defined that enhanced the productivity of the machine or favoured fabrication of nonwovens with high density or great tensile properties.

*Keywords: Air-laying; Air-carding; Flax; Hemp; Natural-fibre; Nonwoven*

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## INTRODUCTION

In recent years, environmental legislation and consumer concern have increased pressure on manufacturers of materials and end-products to consider the environmental impact of their products during all stages of their life-cycle (Garkhail *et al.* 1999). Eco-design is a philosophy that is increasingly applied to materials and products, and thus natural fibres based on lignocellulose including flax, hemp, jute, sisal, abaca, cotton, coir, or kapok have received considerable attention as environmentally friendly alternatives to various man-made fibres (Garkhail *et al.* 1999; Maity *et al.* 2014; Yan *et al.* 2014). The use of natural fibres in nonwovens has increased remarkably, but the overall market share of these fibres is lower than that of man-made fibres. Natural fibres can be utilized in many sectors, including the automotive, construction, marine, acoustic, and electronic industries. Natural fibres may not only be cheaper than synthetic fibres, but they also demonstrate recyclability, eco-friendliness, biodegradability, renewability, and lower overall energy consumption during production. All of these facts are seen as helpful in finding novel applications (Sgriccia *et al.* 2008; Das *et al.* 2012; Maity *et al.* 2014). However, problems with natural fibres are often related to their non-uniform physical properties, quality variation based on region of origin, deterioration of physical properties from exposure to moist conditions, and lower resistance to microbial attack (Anandjiwala and Blouw 2007; Das *et al.* 2012).

In this study, flax and hemp fibres were assessed as raw materials for air-laying nonwoven fabrication. It is hypothesized that through proper production processes, the competiveness of flax and hemp fibre based nonwovens can be significantly improved. It is anticipated that the material properties can be improved by adjusting effective machine settings, for which a small-sized air-laying nonwoven machine and the fibre fleece quality was assessed by adjusting the production velocity and spike-related parameters.

## EXPERIMENTAL

### Materials

Raw flax and hemp fibres supplied by the Waldland Company (Waldland Naturstoffe GmbH, Friedersbach, Austria) were used for the preparation of air-laid and needle-punched nonwoven fabric. Whilst supplied hemp fibres included many shives, flax fibres were pre-cleaned by the supplier. For the purpose of this research, it is important to keep the properties of the fibres constant; this was achieved by using both hemp and flax fibres from only one bale.

### Methods

*Opening and cleaning of fibres*

The raw material included many foreign particles. Foreign particles such as stems were manually shaken out from tufts of fibres, and then these tufts of fibres were placed in an opening-roller (F.W.G. Schiermeyer, Bremen, Germany) to reduce their size, open them and remove the remaining foreign particles (Batra and Pourdeyhimi 2009; Das *et al*. 2012). The more times the raw fibres were treated in the opening-roller, the more foreign particles were removed, but the processing also degraded the fibres. As particles from stems were mainly in the hemp bales, the separation was repeated three times. Flax fibres were treated in the opening-roller only once.

*Air-laying*

Spike air-laying technology was used to form a web of fibrous material. A schematic of a forming box is shown in Fig. 1.

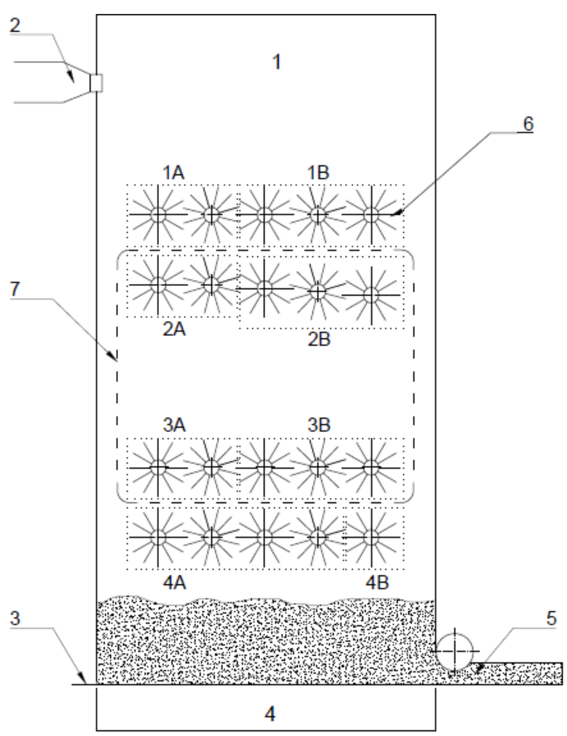


**Fig. 1.** Side view of the forming box. 1) Forming box, 2) inlet, 3) forming wire, 4) vacuum box, 5) fibre-web, 6) row of spike rollers, 7) belt screen

The forming box consists of a transparent housing into which fibres were supplied from an inlet. Fibre clumps were manually put into a suction pipe. A vacuum box was positioned beneath a forming wire, where fibres were air-laid to form fibreboard in a dry forming process. A number of the spike rollers in four rows inside the forming box were fibre-separating rollers, which separate clumps of fibres. The rollers have radially outward projecting fingers or spikes that contact fibre clumps. Each row contained five spike rollers that were numbered in ascending order (Fig. 1). In Fig. 1, the spike rollers that were surrounded by a dotted line indicate a grouping of spike rollers that were manipulated by one motor.

On the machine control panel and in Fig. 1, the grouping of spike rollers on the left side was marked with the symbol A, and on the right side it was marked with the symbol B. An endless belt screen is also provided inside the forming box. This endless belt screen, also called a fibre catcher, includes an upper run, a vertical section where the belt screen moved in a downward direction, a lower run where the belt traveled parallel with the underlying forming wire, and an upwardly oriented run. Each motor of spike rollers was driven in two directions, and revolutions were set with intervals of 0 to 90 $s^{-1}$ (Andersen 2009).

Large clusters of fibres are blown into the upper part of the forming box *via* the inlet. After crossing through the first two rows of spike rollers, in the space between the second and third row of spike rollers, the clusters of fibres are smaller than in the upper part. Optimally, fibres should be fully opened after crossing through the third and fourth rows of spike rollers. The fibre catcher includes closed portions and openings provided in a predetermined pattern. If some fibre clusters are not fully disintegrated after crossing the third row of spikes rollers, these oversized fibres and fibre clumps are retained on the belt screen and are returned to the upper section of the forming box for further disintegration and shredding. Another important element used to ensure the smooth functioning of entire system is the vacuum box. The forming wire is made up of a sieve. This perforated belt enables suction stream to be created, through which the fibres are sucked downwards and the fibre web is gradually layered. The vacuum fan decreases leakage of fibres from the housing and increases friction force between the fibres and forming wire so that the fibre web can be carried away from the forming box (Andersen 2009).

Opened, separated, and cleaned fibres were manually fed into the suction pipe of the air-laying machine. Feeding was done as continuously as possible. The speed and direction of rotation of the rotating spiked wheels were adjusted to various combinations. Nine combinations of spike rotation were chosen; these combinations are schematically shown in Fig. 2.

Spike rollers that are installed in one horizontal line are supposed to work together (Andersen 2009), and therefore, the direction of rotation is constant in each row (except for the lowest). The lowest row of spike rollers is supposed to have a great influence on the fibre deposition, and it was therefore decided to test all combinations of direction of rotations.

The plus or minus signs symbolize the direction of the rotation of the group of spike rollers (connected with a belt) according to Fig. 1. The plus sign symbolizes a positive mathematical direction of rotation (counter clock-wise), and the minus sign symbolizes a negative direction. Fibre webs of a nominal length of 200 cm, nominal width of 50 cm, nominal height of 12 cm and nominal basis weight of 750 $g \cdot m^{-2}$ were produced.

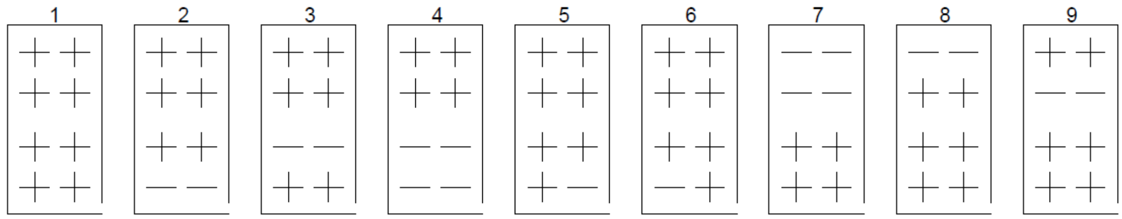


**Fig. 2.** Directions of spike rotations

Based on results from the first phase, some spike rotation settings were chosen to further adjust the process. The criteria used were the tenacity of nonwovens and quality of the webs. Spike rotation settings numbers 1 and 5 were chosen. Based on the influence between the velocity parameters of the machine elements and the nonwoven properties, the two levels of velocity for the spike rollers (frequency of rotation) were 40 $s^{-1}$ and 80 $s^{-1}$.

*Needle-punching*

A needle-punching process was applied in order to intensify mechanical bonding between fibres (Russel 2007). Needle-punching is a suitable method for producing thick nonwovens (Maity *et al.* 2014). The feeding speed for needle-punching was set to 0.45 $m \cdot min^{-1}$, and the punching rate was 118 $strokes \cdot min^{-1}$. The needle-head, 125 mm × 490 mm in size, held 442 needles (punch density was 23.65 punches/$cm^2$) and the punching depth was set to 20 mm. After needle-punching, the fibres in the nonwoven felts were fully entangled and interacted. Figure 3 shows a reinforced mat; punctures caused by barbed needles are visible on the section.

**Fig. 3.** Section of a reinforced mat

*Nonwoven quality evaluation*

In order to evaluate the quality of the air-laid nonwovens, various parameters of nonwoven properties were measured after air-laying and needle-punching. Before needle-punching, the following properties of the webs were evaluated: surface waviness along and across the production direction, areas of low density on the surface, and the size and frequency of fissures. These properties could not be measured exactly because of the fibrous structure of the webs. Due to this phenomenon, the boundaries of the fissures and surfaces were not unequivocally determined, but the boundaries were often more than 2 centimetres broad. The webs were categorized into the quality scale (Table 1) on the basis of a verbal evaluation. Fibre trajectories and fibre process times were observed to evaluate fibre deposition dynamics. Measurements of fibre process times were carried out with ball-shaped clusters of hemp fibres weighing 10 g. The fibres were coloured to ensure high visibility. The fibre process time was defined as the time between the entering of a cluster into the forming box and deposition of all fibres from the cluster on the forming wire.

**Table 1.** Web Quality Scale

| Quality level | Allowed errors of webs |
|---|---|
| 1 | Low-dense areas in the surface layer (in the case of flax fibres, surface waviness was allowed) |
| 2 | Surface waviness along and across the production direction, low-dense areas in the surface layer, fissures in the surface layer |
| 3 | Low-dense areas in the surface layer, fissures with a depth max. of one half of web high, low consistent web |
| 4 | Frequent fissures with a depth higher than one half of web high, inconsistent web |

After needle-punching, the basis weight, tenacity, and stretching of mats along and across the production direction were measured. Stretch was measured as elongation at a maximum load. Breaking force is defined as the maximum force applied to a material when it is carried to rupture (EN ISO 9073-18 2007). Tenacity was calculated from breaking force (Sengupta *at al.* 2008), as follows,

$$Tenacity\ \left(\frac{cN}{tex}\right) = \frac{Breaking\ force\ (cN)}{Specimen\ width\ (mm) \cdot Fabric\ basis\ weight\ (\frac{g}{m^2})} \qquad (1)$$

According to EN ISO 9073-18 (2007), five specimens in the machine direction (MD) and cross direction (CD) were prepared from each nonwoven sample. A die was used for specimen preparation to ensure the same dimensions of all specimens (length of 340 mm and width of 50 mm). Specimens were conditioned in a standard atmosphere at a temperature of 20 ± 2°C and 65% relative air humidity. A tensile testing machine Zwick Roell Z020 (Zwick GmbH & Co. KG, Ulm, Germany) was used. The gauge length was set at 200 mm, and the constant extension rate was 100 $mm \cdot min^{-1}$. A pretension of 2 N was applied to the specimens (EN 29073-3 1992; EN ISO 9073-18 2007).

*Statistical methods*

The measured data allowed for estimations of whether the settings of spike rollers influenced the stretch and tenacity of webs. For this purpose, statistical hypotheses that put equalities between the means of tenacity and stretch of nonwovens produced by various machine settings were formulated. A one-way analysis of variance was used to determine whether any of the pairwise differences from the number of means were significant. The Tukey (HSD) test was employed in order to determine the significant differences between group means. This post hoc test is more conservative than the Fisher LSD test, but less conservative than Scheffe's test. It is suitable to use the Tukey test in the case of a small amount of specimens in each group (Winer *et al.* 1991). Computations were carried out using Statistica12 software (StatSoft CR s.r.o., Prague, Czech Republic). A significance level of $\alpha = 0.05$ was selected, where rejection of the null hypothesis leads to accepting the alternative hypothesis that expresses inequality of means.

## RESULTS AND DISCUSSION

### Observed Phenomenon during Air-Laying

*Surface layer*

The laid web was generated in the forming box by a forming wire and a pressure roller that was positioned on the output from the forming box. The function of this roller was to form and even out the surface of the webs. The drift of fibres before the pressure roller was higher than the one behind it. This roller compressed the fibre webs and made it so that two layers could be observed on the vertical profile of a web. In the surface layer, the position of fibres was affected by pressure from the roller, and the fibres were oriented in the horizontal position. This layer occupied approximately one-third of the total height of the web. The lower layer was not affected by pressure from the roller, and the position of fibres was determined by the laying effect of spike rollers. Most of these fibres were vertically oriented and tangled. These thickness profiles were produced when settings number 1, 3, 5, 7, 8, and 9 were used. An example profile and surface layer are shown in Fig. 4a. An inverse thickness profile was created for settings 2, 4, and 6. Only a small amount of fibres were near the 4A spikes in the back part of the forming wire, and these were horizontally oriented. Most fibres were positioned using the 4B spike in front of the pressure roller; these were vertically oriented and created a high drift. With these vertically oriented fibres, a low consistent or inconsistent web with fissures was produced. The thickness profile was the opposite of the previous case. The inverse profile is shown in Fig. 4b.


**Fig. 4. (a)** Thickness profile (flax fibres), **(b)** Inverse thickness profile (hemp fibres)

*Creation of fissures*

Depending on the direction of the rotation of spike rollers in the two bottom rows, fibres were blown into the front or into the back part of the forming wire. If the fibres were blown into the front part, there was a very high drift of fibres before the pressure roller, and the fibres were extensively compressed.

**Fig. 5.** Creation of fissures and flax fibres

The more the fibres were compressed, the more they expanded behind the roller. The expansion effect was so great that the consistency of the fibre web sometimes broke. In the second case, fibres were blown into the back part of the forming wire. There was a low drift of fibres before the pressure roller, and no fissures were created on the surface of a web behind the pressure roller. The creation of fissures is shown in Fig. 5.

## Fibre Deposition Dynamics and Fibre-Web Quality

As noted by Andersen (2009), the upper two rows of spike rollers reduced fibre clusters, and the bottom two rows determined the fibre trajectory in the lower part of the forming box and the fibre alignment on the forming belt. The observation of the function of the fibre-catcher (belt screen) was the same as Andersen assumed. However, in this study, the fibre-catcher was not as essential as Andersen predicted. The air-laying machine was able to produce a web with acceptable quality without the fibre-catcher.

Settings 1, 7, 8, and 9 were characterized by the rotation of all spike rollers in the two bottom rows in the production direction. Good-quality webs from both flax and hemp fibres were produced *via* these adjustments. The surfaces were wavy, and only small fissures occurred in the surface layer. The upper two rows of spikes in setting 7 rotated opposite to the production direction. This adjustment caused the fibres from the inlet to be directly sucked into the space under the first two rows of spikes, and only a small amount of fibres were circulated in the upper part of the forming box. This setting was used when high productivity was required. However, the fibres need to be well-opened. If they are not well-opened, there is a danger of seizure of fibre tufts within spikes, or between the belt screen and the decking of the belt screen.

Setting 5 was determined by running the 4B spike in the opposite direction to the production direction. The last bottom spike blew fibres into the back part of the forming wire, which caused the fibres to settle in the forming web, and the web was denser. Secondly, due to the 4B spike rotating in the opposite direction, there was a low drift of fibres before the pressure roller and any fissures arising in the web. By using this adjustment, webs were produced with the best quality from both flax and hemp fibres. This adjustment should also be used to manufacture high-density webs.

In setting 2, the bottom row of spikes rotated in the direction opposite to the production direction. Fibres were blown into the front part of the forming wire, and there were very few fibres in the back part of the forming wire. This resulted in fissures in the web and a less consistent web. The same fibre trajectories were achieved *via* setting 6. Settings 2 and 6 were obviously unsuitable for web laying. Setting 4 was determined by running the two bottom rows of spikes in the direction opposite to the production direction. Usage of this setting resulted in an overturned thickness profile of webs, inconsistent webs, and poor web quality from both flax and hemp fibres.

The two lower rows of spike rollers formed the fibre web, and it was observed that the faster they rotated, the more the drift of fibres was compressed on the forming wire. When the fibres are compressed when they are lying, they do not have to be compressed as extensively by the pressure roller on the output from the machine. Because of this effect, a good quality web with higher density was made. This compression of fibres was observed by the settings when the lower two rows of spikes were rotating at a frequency level of 80 $s^{-1}$. In the cases of laying a web from flax fibres and using setting 5, an undesirable fibre flow was observed when the opposite-rotating 4B spike was rotating at the high frequency level. In such cases the opposite-rotating 4B spike had such a high suction effect that the fibres from the forming screen were sucked into the upper parts of the machine and/or blown from the output to the back part of the forming wire. No webs were created by using these settings. This phenomenon occurred only when flax fibres were used. The lying of hemp fibres was problem-free, and the quality of hemp webs was good. Flax fibres have a fluffier structure than hemp fibres, and thus it is easier for them to be sucked-in than hemp fibres. However, it is assumed that at an even higher frequency level than 80 $s^{-1}$, the hemp fibres would also be sucked back to the machine.

The observation of the fibre process time in the machine shows that the frequency of rotation of spike rollers had no influence on the fibre process time. Fast-rotating spike rollers in the two upper rows threw fibre clusters into the upper part of the forming box with great energy, and the fibres rotated in this part. The slower rotating spike rollers do not throw fibre clusters with such high energy, and the fibres were able to continue faster to the next part of the machine.

## Fibre-Mat Quality

Figure 6 depicts the results from the analysis of variance of the tenacity of nonwovens. Vertical columns represent 95% confidence intervals, and dots symbolize sample means. The graphical results are shown only for adjusting the direction of spike rotation. In terms of adjusting the frequency of spike rotation, there was no influence between machine settings and tenacity. With regard to stretch, the results are not shown because the measured data of fabric stretch was unsuitable for making comparisons.

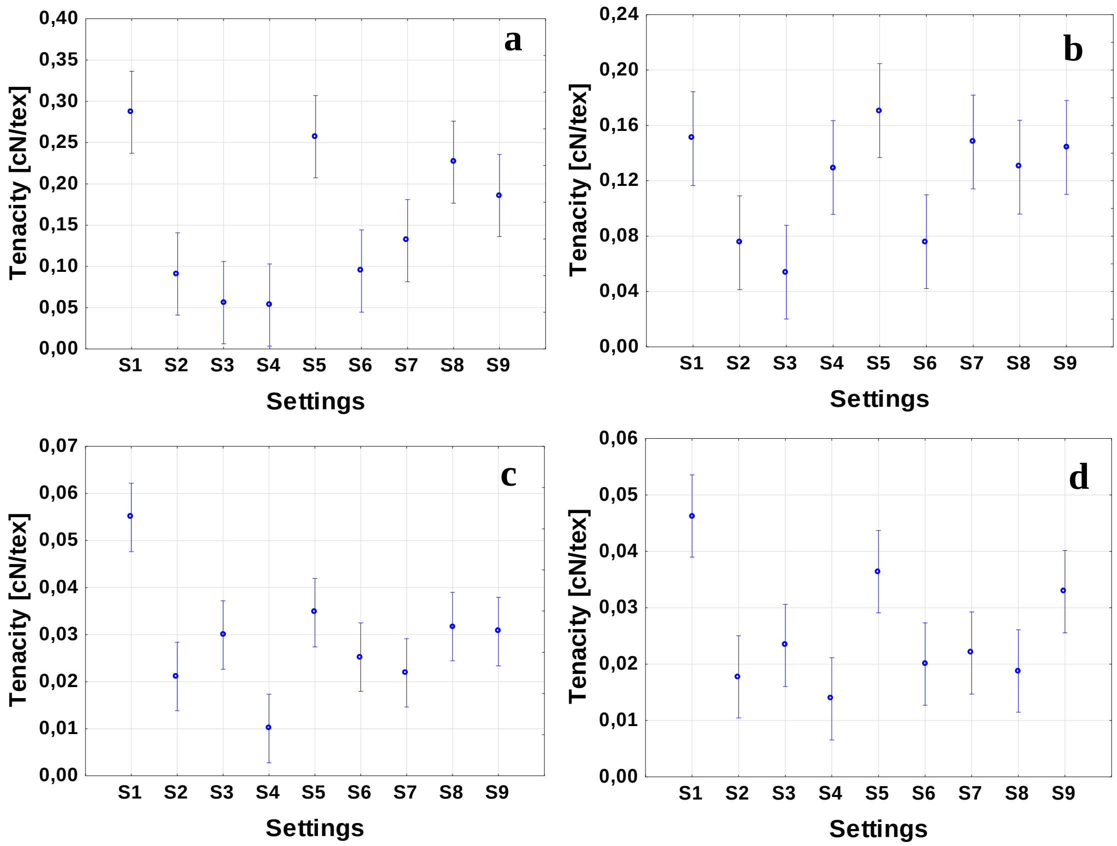


**Fig. 6.** ANOVA – tenacity of nonwovens – adjusting direction of rotation**:** **(a)** flax nonwovens in MD, **(b)** flax nonwovens in CD, **(c)** hemp nonwovens in MD, **(d)** hemp nonwovens in CD

Figure 6 shows that nonwovens made using settings 1 and 5 reached higher tenacity than nonwovens made by the other settings. These differences were mostly statistically significant. Tenacity is widely used to characterize the tensile properties of fabrics in the textile industry (Midha and Mukhopadyay 2005; Sengupta *at al.* 2008; Roy and Ray 2009). This characteristic expresses a breaking load applied to a specimen related to its basis weight. Basis weight does not influence the tenacity of nonwoven fabrics directly; regrettably, the indirect influence has not been quantified. The tenacity first increases with the increase of the basis weight up to an optimum level (different for various fabrics), and then decreases. The increase is caused by higher interlocking of fibres, and thereafter the tenacity is reduced with increased web weight due to non-interlocking of fibres (Midha and Mukhopadyay 2005; Sengupta *at al.* 2008; Roy and Ray 2009). Despite this indirect influence, tenacity was used to compare fabrics with different basis weight. Therefore, a low variance of basis weight of the fabrics was required. Due to the manual feeding of fibres into the suction pipe and manual manipulation with webs, a coefficient of variation of basis weight equal to 12% was achieved. This variation led to an even higher level of the coefficient of variation of the tenacity.

Elongation at a maximum load, called stretch, was the second observed tensile property. This property is an important characteristic of nonwovens used as reinforcement in composites, especially in formed composites. The basis weight of nonwoven fabric also influences its stretch. An increase in fabric weight reduced the fabric stretch due to restrictions of fibre movement in a highly interlocked structure. As the contact between horizontal and vertical structure increased, the structure became more rigid and less extensible. As the fabric weight increased further, needling action became more severe, causing breakage of the fibre and resulting in a reduction in inter-fibre friction. As a result, fibres separated more easily due to a relative lack of resistance to straining, and the stretch decreased continuously (Midha and Mukhopadyay 2005; Roy and Ray 2009). This direct effect of weight on stretch cannot be eliminated as in the case of tenacity, and this can be the reason why any influence between the fabric stretch and the machine adjustments was not observed. In terms of stretch, the high variation of basis weight makes the results incomparable and unsuitable for further statistical analysis.

The harvesting time of plants, or fibre ripeness, fundamentally affects the mechanical properties of fibres. Both flax and hemp plants can be grown for fibres or for seeds (Struik *et al.* 2000; Pickering 2008). Unfortunately, the harvesting time of fibre harvest differs from the harvesting time of seed harvest. Generally, in the time of fibre harvesting, seeds are not fully ripe, and conversely, in the time of seed harvesting, fibres are overripe and do not have the best mechanical properties (Mediavilla *et al.* 1998; Baltina *et al.* 2011). Thus, hemp and flax plants can be grown either for fibres, or for seeds. Whilst the flax fibres used in this research come from a fibre flax plant, the hemp fibres originated from seed hemp plants that were harvesting remainders. This origin of hemp fibres is one of the reasons why the tensile properties of fabricated hemp nonwovens were lower than the tensile properties of flax nonwovens. Furthermore, hemp fibres have, on average, a lower tensile strength than flax fibres (Cheung *et al.* 2009; Shahzad 2012; Yan *et al.* 2014). However, the tensile strength of single fibres was not measured in this research. Another reason for the lower tenacity of hemp fabric is that hemp fibres were treated in the opening roller three times, while flax fibres were treated only once. This triple treatment shortened the fibres. Fibre length plays a very important role in the tensile properties of needle-punched fabric. A longer and finer fibre in the web leads to greater fabric tensile properties. A small increase in length causes a marked increase in stiffness and strength due to the reduced slippage of fibres (Midha and Mukhopadyay 2005). Despite the triple treatment of hemp fibres in the opening roller, they still contained more shive fraction than flax fibres. This shive fraction also decreased the tensile properties of nonwovens.

In comparing fibre-web quality and fibre-mat quality, there were small inconsistencies and fissures in the fibre web (low-dense areas in the surface layer, fissures in the surface layer, or rare fissures with a maximum depth of one half of web height) that did not significantly deteriorate the tensile properties of needle-punched fabric. The fibre web was compressed during the needle-punching process from *circa* 12 cm to *circa* 1 cm (depending on basis weight) *via* the action of barbed needles. These needles mechanically entangled the fibre mat so extensively that the missing entanglement of fibres in the fibre web (due to small fissures) was fully compensated. Needle-punching improved the compactness or packing of fibre assembly and caused structural changes in the fibre web (Sengupta *at al.* 2008).

It is often said that air-laying technology produces webs with a more balanced structure and random orientation of fibres (Fang *et al.* 2000; Midha and Mukhopadyay 2005; Russell 2007). The results here show that spike air-laying technology does not produce randomly laid webs. Firstly, it was obvious during the visual observation of fibre webs that there was predominant orientation of fibres in the web, and secondly, the tenacity ratio MD:CD was not 1:1. On average, the tenacity ratio was lower than 2, and hemp nonwovens had a slightly lower ratio than those made of flax. The lower tenacity ratio of hemp fabric could have been caused by shorter hemp fibres.

Unlike synthetic fibres, natural fibres have greater variability in their mechanical properties due to the conditions experienced in the field and potential damage arising from production (Dicker *et al.* 2014; Yan *et al.* 2014). There are several different stages in the production of flax/hemp fibres, and in each stage, several factors influence the quality of fibres (Yan *et al.* 2014). In this research, hemp and flax fibres from one bale were used to minimize factors affecting fibre variability, but there are other possible origins of variability. Manual feeding of fibres into a suction pipe was as uniform as possible; however, the air-laying technology is very sensitive to any unevenness in fibre supply. A small unevenness in fibre supply creates uneven fibre alignment or variability in the basis weight of a fibre web, which consequently varies the properties of the end product (Fang *et al.* 2000). Air-laying technology is even more demanding on fibre supply than carding technology (Russell 2007). The high variance of fabric basis weight caused even higher variance of the tensile properties, and thus the differences in quality were not as clear.

## CONCLUSIONS

The following finding can be stated for the production of air-laid nonwovens from hemp and flax fibres using SPIKE® air-laying technology:

1. The settings of the air-laying machine affect the web-formation process and nonwoven properties. The upper two rows of spike rollers reduce fibre clusters, and the bottom two rows predominantly determine the fibre trajectory in the lower part of the forming box and the fibre alignment on the forming belt.
2. The more the fibres are compressed by the pressure roller, the more they expand behind the roller. In order to prevent fissures in the fibre-web, it is appropriate to use settings that throw fibres onto the back part of the forming wire. These are settings where the lowest row of spike rollers rotates in the production direction.
3. The setting where the upper two rows of spikes rotate opposite to the production direction, and the bottom two rows in the production direction, can be used when high productivity of the machine is required. This adjustment causes the fibres from the inlet to be sucked directly into the space under the first two rows of spikes, and only a small amount of the fibres circulate in the upper part of forming box.
4. The setting where only the last spike roller before output from the machine rotates opposite to the production direction, and other spike rollers rotate in the production direction, should be used to fabricate high-density webs. The last bottom opposite rotating spike (4B) blows fibres onto the back part of the forming wire, which causes the fibres in the forming web to be compressed and form a denser web. Webs with high density can also be produced using settings where the lower two rows of spikes rotate at a high frequency level (80 $s^{-1}$).
5. The frequency of rotation of spike rollers has no influence on the fibre process time. Thus, lower frequencies are suitable because rotation the slats of the belt screen are less stressed, and the fibres are also less shredded by the spikes.
6. Nonwovens with great tensile properties can be fabricated by using Settings 1 (all of the spike rollers rotate in the production direction) and 5 (the last lower 4B spike rotates in the opposite direction).

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