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Studies on physical properties of banana and banana/polypropylene blended non-woven fabrics

Vijay S Shivankar[a1*]
[a]Department of Textile Technology, MPSTME, NMIMS, Shirpur campus
[1]vijayshivankar@gmail.com, (0000-0002-3592-6650)

***Corresponding author**

Abstract

Global trend towards sustainable developments have brought natural, renewable biodegradable raw material into the focus, but due to lack of technical knowhow, only a small fraction of these non-conventional fibres harvested and utilized. In this study we have developed parallel laid 100% banana nonwoven fabric and cross laid banana/polypropylene (60:40) nonwoven fabric. Three varieties of banana fibres namely Mahalaxmi, Shrimanti and Graint Naine used for needle punched non-woven fabric preparations. Analysis of physical properties carried out in machine direction and cross direction. This paper concludes that irrespective of variety of banana fibre, cross-laid nonwoven fabric shows superior tensile properties as compared to parallel laid nonwoven fabric. Shrimanti fibre nonwoven fabric is stronger than Graint Naine and Mahalaxmi fibre nonwoven fabric for both the parallel laid and cross laid structure. Parallel laid Mahalaxmi banana nonwoven fabric and cross laid Graint Naine banana nonwoven fabric gives higher elongation % for machine and cross direction. Increased air permeability was observed in cross laid (60:40) banana/polypropylene blend non-woven fabric than parallel laid 100% banana non-woven fabric. Parallel laid Graint Naine non-woven fabric showed higher air permeability than Shrimanti and Mahalaxmi parallel laid non-woven fabric. Bursting strength of parallel laid nonwoven fabric is higher, both in the machine as well as in cross direction than cross laid nonwoven fabric for three varieties of banana fibres. Shrimanti banana non-woven fabric showed higher bursting strength for parallel laid and cross laid structure than Graint Naine and Mahalaxmi parallel laid and cross laid structure. Bending length of the cross laid banana nonwoven fabric is higher than the parallel laid nonwoven fabric. Parallel as well as cross laid Shrimanti fibre nonwoven fabric samples have more bending length than Graint Naine and Mahalaxmi nonwoven fabric.

Keywords: Shrimanti, Mahalaxmi, Graint Naine, Needle punch

1 Introduction

The rising concern for ecological preservation promotes the resources, which are safe, biodegradable and recyclable. Natural cellulosic fibres have successfully proved their qualities in consideration to ecological and economic view of fibre materials. Natural fibres possess important advantages like low density, biodegradability, high specific strength and modulus, appropriate stiffness, lightweight, corrosive resistance, renewable character, surface reactivity, low cost, large availability and possibility to generate energy, absence of associate health hazard. There are a number of fibres giving plants available in India, which used for common applications, but many of these fibres dumped as wastes, for lack of their technical knowledge. Among such non-conventional fibres like Banana, Sisal, Jute and Flax, Banana fibre is gaining importance and interest of researchers, due to its low cost and abundant availability.

Banana fibre produced from the waste part of banana plant i.e. pseudo-stem and leaves. Banana is a tropical crop and developed well in temperature range of 150-350 $^{\circ}$C with relative humidity of 75-85%.

Maitey, and Singha (2012) studied the influence of fibre arrangement on the tensile strength of non-woven fabric. Nonwovens made from natural fibres and specifically jute fibres more commonly used in almost all sectors of technical textile such as home textiles, geo-textile, agricultural textile, filter media, clothing, automobiles, industrial textiles, etc (Maity, Singha, Prasad, Paul et al., 2012).

It was observed that the application of batching oil affects the bulk density of non-woven fabric (Sengupta, 2009). For jute nonwoven fabric, if jute batching emulsion is applied on the web before needling, the higher tensile strength for fabric observed (Roy, and Ray, 2005a). The improved tensile properties observed in wet condition of the same non-woven fabric that may be due to increased cohesion between the fibres and more compact structure in swelling and shrinkage (Sengupta et al., 2008). Initially, tenacity, initial modulus and work of rupture increases with increase in fabric weight, but further increase in fabric weight shows a reduction in initial modulus and work of rupture and no change in tenacity (Roy, and Ray, 2005a, b). Elongation at break reduces with increase in fabric weight, punch density and depth of penetration.

Bursting strength of nonwoven fabric increases with increase in fabric weight, needle punch density and depth of needle penetration and for a further increase in the optimum value of needle density and depth of needle penetration, reduction in bursting strength observed (Roy, and Ray, 2006). With the increase in fabric weight, bending modulus of nonwoven fabric increases, on the other hand bending modulus achieves maximum value with the increase in punch density and depth of needle penetration, but further increase in such density and depth of needle penetration reduces bending modulus (Roy, and Ray, 2005b). For fabric weight, the study also shows the same trend for jute / viscose blend needle punched nonwoven fabric, but as the proportion of viscose, the fibre proportion increases with blend proportion the decrease in bending modulus observed (Madhusoothanan et al., 1998).

Paul, and Mukhopadhyay (1977) studied the thermal behaviour of woolenised jute and other blended fibre non-woven fabric. Blending woolenised jute improved thermal insulation property when it used with pineapple leaf and ramie fibre in blends (Sengupta, Samajpati, and Ganguly 1999). The effect of fabric weight and needle density on thermal resistance of jute / polypropylene blend needle punched fabric was analysed, an increase in thermal resistance observed to increase in fabric weight (Debnath, and Madhusoothanan, 2011).

Sengupta (2009) analysed the effect of process parameter on the water absorption of non-woven fabric. Debnath et al. (2012) studied the effect of needle density, depth of needle penetration and fabric area density on compression property of jute nonwoven needle punched fabric. Sengupta et al. (2005) concluded that with the increase in fabric weight, punch density and depth of penetration, the initial reduction in compressibility in terms of thickness loss observed, but after attaining minimum value, the reduction in compressibility is more for further increase in these variables.

Subramanium et al. (1988) investigated the behaviour of machine parameter and fibre length on air permeability of non-woven fabric. Air permeability of jute and jute blended non-woven fabrics were investigated by various researchers (Debnath et al. 2007, Roy et al., 2005a). Parikh et al. (2011) analysed the effect of process parameter on the sound insulation of non-woven fabric, and Thilagavathi et al. (2010) expressed the behaviour with needle penetration and sound loss of non-woven fabric.

The present work deals with studies of three varieties of banana fibre (Shrimanti, Graint naine, Mahalaxmi) nonwoven fabric made of stem banana fibres. The physical parameters like thickness, gram per square meter, tensile properties, air permeability, bursting strength and bending length discussed. A comparison of physical properties of three varieties of banana non-woven fabric of parallel laid and cross-laid discussed.

2 Materials and methods

Three varieties of banana fibres, namely Mahalaxmi, Shrimanti and Graint Naine were selected as raw materials for this study, these three varieties were extracted from Krishi Vidnayan Kendra, Pal, Maharashtra, India.

Needle punched banana nonwoven fabrics were manufactured using DILO needle punching machine. Table 1 displays the banana fibre properties and Table 2 displays the process parameters kept on needle punching machine for manufacturing of banana fibre needle punched nonwoven fabric.

Table 1 – Tensile property of banana fibres

Shrimanti Stem fibre			Graint Naine Stem fibre			Mahalaxmi Stem fibre		
Linear Density (Tex)	**Tenacity (gm/Tex)**	**Extension (%)**	**Linear Density (Tex)**	**Tenacity (gm/Tex)**	**Extension (%)**	**Linear Density (Tex)**	**Tenacity (gm/Tex)**	**Extension (%)**
7.5	88.20	3.1	6.5	76.60	3.1	5.84	69.40	1.85
[18.45]	[25.39]	[24.88]	[26.6]	[24.05]	[21.03]	[24.34]	[21.08]	[24.37]

Values in bracket indicate C.V. %

Table 2 – Process parameter for non-woven needle punching

Sr. No.	Variable	Value
1.	Stroke/min	200
2.	Needle loom feed	0.90 m/min
3.	Needle loom delivery	1.01 m/min
4.	Needles/cm of width	40
5.	Stitch density/cm	90
6.	Advance/stroke	4.5 mm
7.	Feed lattice speed	0.40 m/min
8.	Doffer speed	19.90 m/min

9.	Cross lapper speed	20.20 m/min
10.	Feed in card	600 g/m²
11.	Punch density	80

Before manufacturing of nonwoven fabric 3-4 layers of fibres were prepared and conditioning of banana fibres was carried out for 24 hours with emulsification (Table 3).

Table 3 – Emulsification concentrations

Sr. No.	Ingredients	Quantity
1.	Water	73%
2.	Mineral oil (Jute Batching Oil)	25.4%
3.	Emulsifier	1.6%

These layers of fibres processed through softener machine for softening of banana fibres and then carding of banana fibres carried out on breaker jute carding machine. After carding the 100% banana fibres web fed to needle punching machine and 100% parallel laid (P.L.) banana non-woven fabric was prepared. The cross laid (C.L.) non-woven fabric was prepared by mixing 60:40 % of banana fibres with polypropylene fibres and this carded web was fed to needle punching machine for preparation of 60:40 % cross laid banana: polypropylene non-woven fabric.

Testing Methods:

The thickness of non-woven fabric tested with ASTM D 5729-97 standard. Tensile properties of non-woven fabric measured according to ASTM standard D 5034. The gram per square meter of fabric measured by preparing the sample on GSM cutter and weighing it on electronic weighing balance. The GSM of non-woven fabric tested with ASTM D 3776-96 standard. EPI and PPI measured on one inch pick glass. The crease recovery angle of fabrics tested on Shirley crease recovery tester. The rectangular specimen of size 50.8 mm × 25.4 mm prepared and crease recovery angle in degrees measured. The bending length of fabrics tested on Eureka stiffness tester. The stiffness of non-woven fabric tested according to ASTM D 5732-95 standard. The air permeability of the fabric measured on FX 3300 Air permeability tester. The air permeability of non-woven fabric tested in accordance with ASTM D 737-96 standard. The bursting strength of fabric measured on Eureka bursting strength tester. The bursting strength is tested in accordance with ASTM D 3786-87 standard for non-woven fabric.

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3 Results and discussion

3.1 Tensile properties of parallel laid nonwoven fabric

Figure 1 and 2 exhibits the breaking load and extension at break of different banana fibre needle punched nonwoven fabric. It is evident from Figure 1 that tensile strength of Shrimanti parallel laid (P.L.) nonwoven fabric is higher in comparison with Graint Naine and Mahalaxmi nonwoven fabric in both machine direction (MD) and cross direction (CD). This may be due to the higher tenacity of Shrimanti fibres (Table 1) compared to Graint Naine and Mahalaxmi banana fibres which contributing for greater tensile strength of Shrimanti non-woven fabric, while Graint Naine parallel laid banana non-woven fabric shows higher tensile strength than Mahalaxmi non-woven fabric.

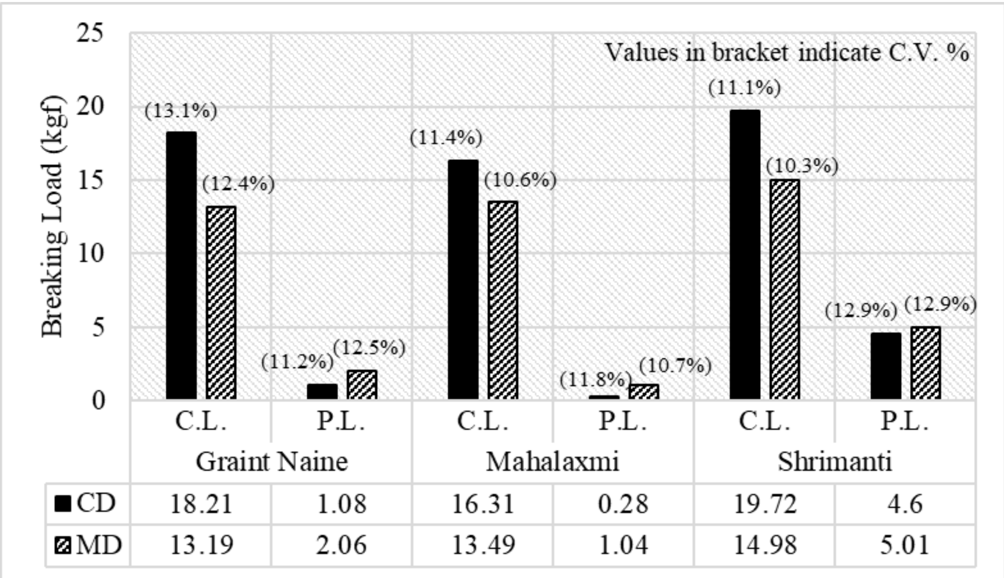

Figure 1 Breaking load

Parallel laid Mahalaxmi nonwoven banana fabric shows higher elongation % compared to Graint Naine and Shrimanti nonwoven banana fabric in cross direction. Whereas parallel laid Graint Naine nonwoven banana fabric shows higher elongation percentage than Mahalaxmi and Shrimanti nonwoven banana fabric in machine direction. Higher tensile strength in the machine direction observed compared to cross direction for all three varieties of parallel laid nonwoven fabric. In parallel laid non-woven fabric majority of fibres are oriented in machine direction of fabric. Hence, for the tensile test in machine direction of the fabric, the fibres can easily be reoriented much closer to the test direction, but if the testing carried out in cross direction the majority of the fibres cannot be oriented in the test direction. Hence the contribution of fibres towards the load bearing is much higher in the testing of machine direction than in the cross direction.

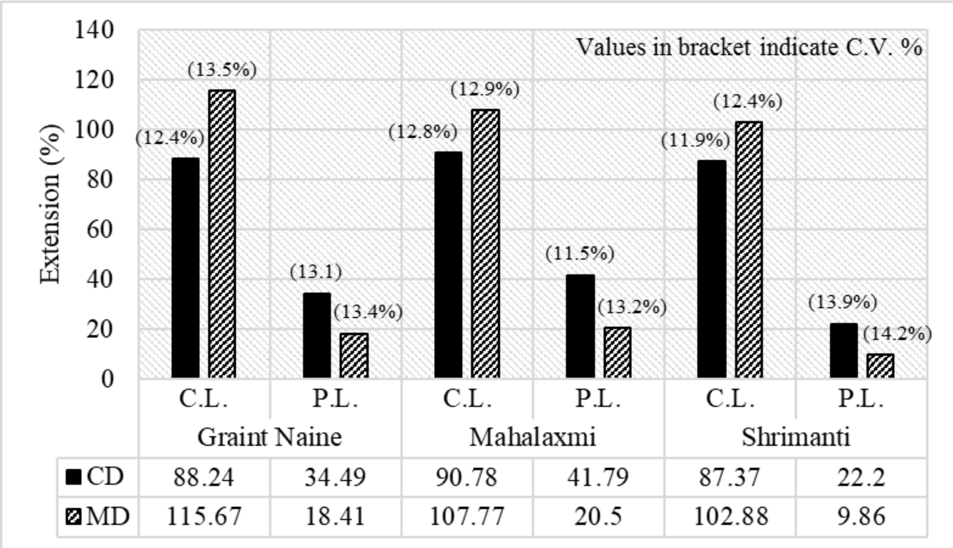

Figure 2 Extension (%)

Statistical analysis (Table 4) reveals that there is no significant effect of variety of banana fibre as well as direction of test on breaking load as well as elongation of 100% parallel laid nonwoven banana fabric. However, there is significant effect on type of fabric i.e. type of layup (parallel laid or cross-laid fabric) on tensile properties of 100% parallel laid nonwoven banana fabric.

Table 4 – Statistical analysis for parallel laid and cross laid non-woven fabric

		Breaking load		**Elongation %**		**Air permeability**	**Bursting strength**	**Thickness**	**Bending length**	**Areal density**
Source	Level	P-Value (PL)	P-Value (CL)	P-Value (PL)	P-Value (CL)	P-Value	P-Value	P-Value	P-Value	P-Value
Banana fibre variety	3	0.075	0.087	0.530	0.471	0.383	0.004	0.281	0.023	0.301
Fabric type	2	0.000	NA	0.000	NA	0.167	0.058	0.301	0.000	0.340
Test direction	2	0.129	0.026	0.823	0.033	0.000	0.016	0.701	0.661	0.239

If P-Value < 0.05 then it is statistically significant

3.2 Tensile properties of cross laid (60:40) nonwoven fabrics

Figure 3 and 4 displays the tensile properties of cross laid (C.L.) banana/polypropylene (60:40) needle punched nonwoven fabric. It can be easily seen from Figure 3 that tensile strength of

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Shrimanti cross laid nonwoven fabric is higher than Graint Naine and Mahalaxmi nonwoven fabric in both direction i.e. machine direction as well as in cross direction, this may be because of the stronger behaviour of Shrimanti banana fibres compared to Graint Naine and Mahalaxmi fibres (Table 1). Graint Naine nonwoven fabric shows higher elongation (%) than Mahalaxmi and Shrimanti nonwoven fabric in the machine direction, while Mahalaxmi nonwoven banana fabric shows higher elongation % than Graint Naine and Shrimanti nonwoven banana fabric in the cross direction.

Higher tensile strength in the cross direction is observed than in machine direction for all cross laid nonwoven fabric samples. This happens mainly because in cross laid nonwoven fabric, majority of fibres are oriented in cross direction than in machine direction and due to orientation of fibre in the direction of application of load, the contribution of fibres towards the load bearing is much higher in the cross direction than in machine direction for cross laid nonwovens.

As shown in Figure 1, the tensile strength of cross laid, banana/polypropylene non-woven fabric were higher compared to parallel laid (P.L.) 100% banana non-woven fabric for all three varieties of banana fibres, this may be due to the combine contribution of polypropylene fibres with banana fibres in load bearing capacity of non-woven fabric, resulting in higher tensile strength for cross laid (C.L) structure than parallel laid (P.L.) structure.

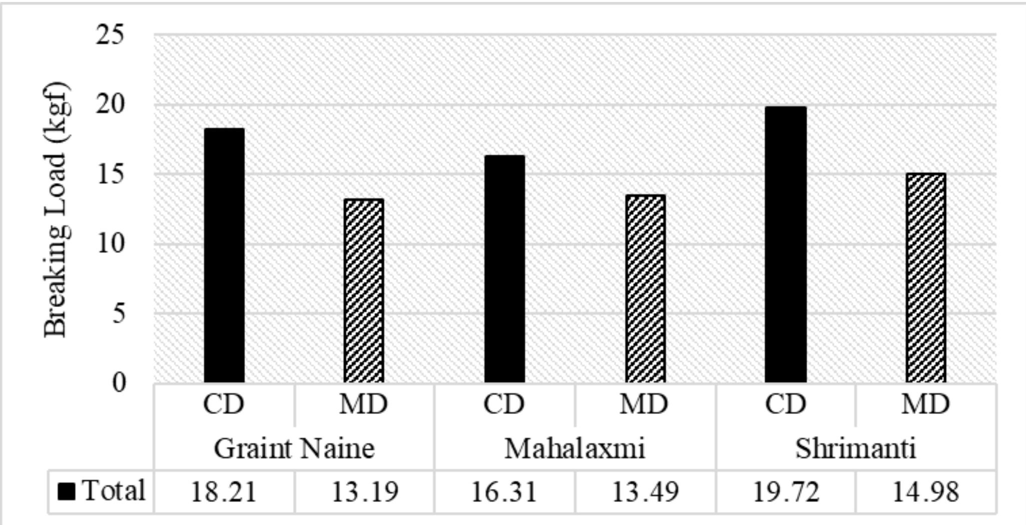

Figure 3 Tensile strength of cross laid (60:40) banana nonwoven fabric

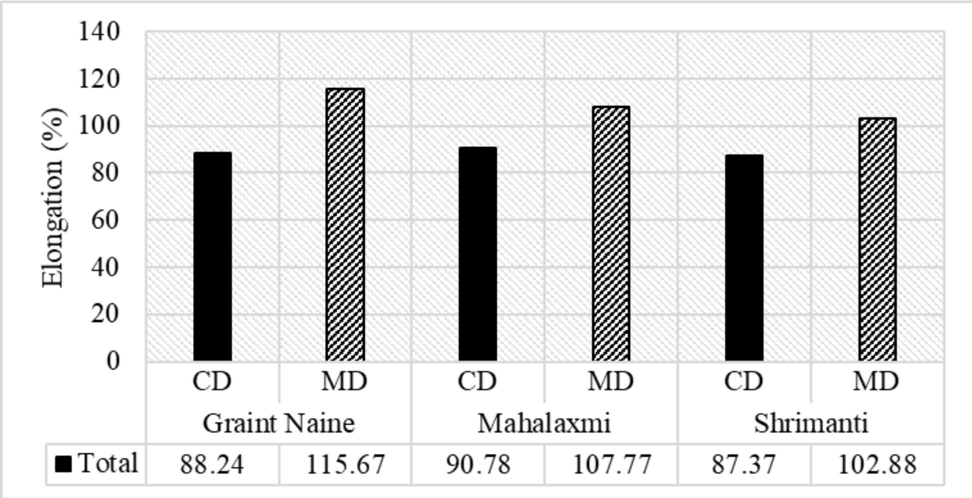

Figure 4 Elongation of cross laid (60:40) banana nonwoven fabric

Statistical analysis (Table 4) reveals that there is no significant effect of variety of banana fibre on tensile properties of cross laid banana/polypropylene (60:40) needle punched nonwoven fabric. Whereas there is significant effect of test direction on tensile properties of cross laid banana/polypropylene (60:40) needle punched nonwoven fabric.

3.3 Air permeability of nonwoven fabrics

Air permeability of parallel laid as well as cross laid banana nonwoven fabric is exhibited in Figure 5.

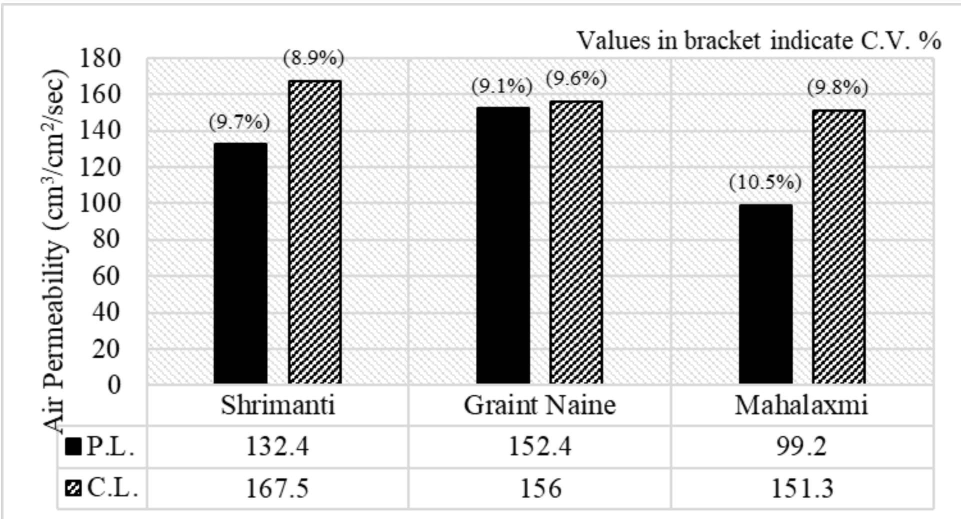

Figure 5 Air permeability

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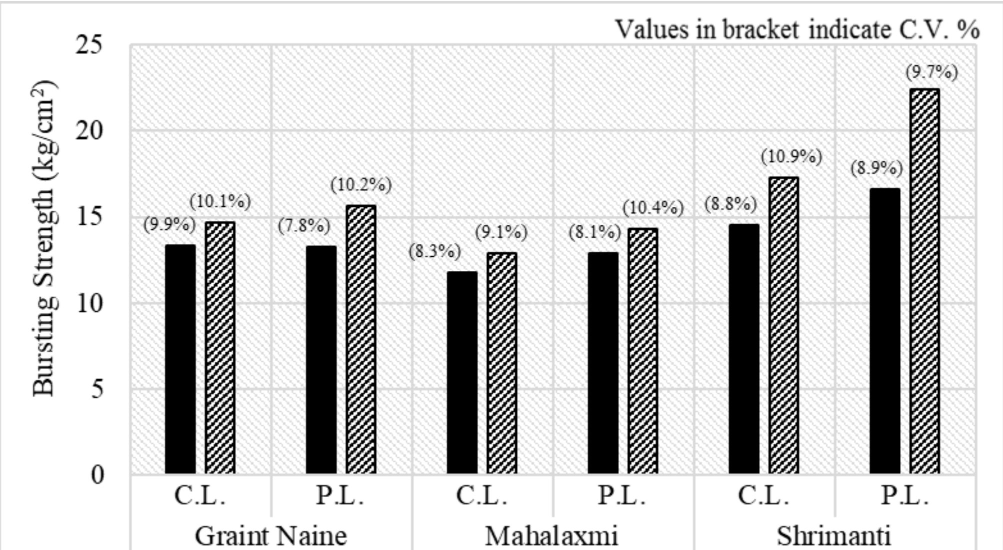
It can be observed from Figure 5 that parallel laid Graint Naine nonwoven banana fabric shows higher air permeability compared to Shrimanti and Mahalaxmi parallel laid nonwoven banana fabric. While for cross laid structure Shrimanti non-woven fabric shows higher air permeability. This may happen because of the more variation in the linear density of the banana fibres (Table 1). Cross laid (C.L.) nonwoven fabric shows higher air permeability compared to parallel laid (P.L.) nonwoven banana fabric for all three varieties of banana fibres. Parallel laid fabrics have lower values of air permeability than cross laid fabrics because the arrangement of fibres in parallel laid fabrics make the fabric structure more compact so that it holds less air and offers more resistance to the flow of air.

3.4 Bursting strength of nonwoven fabrics



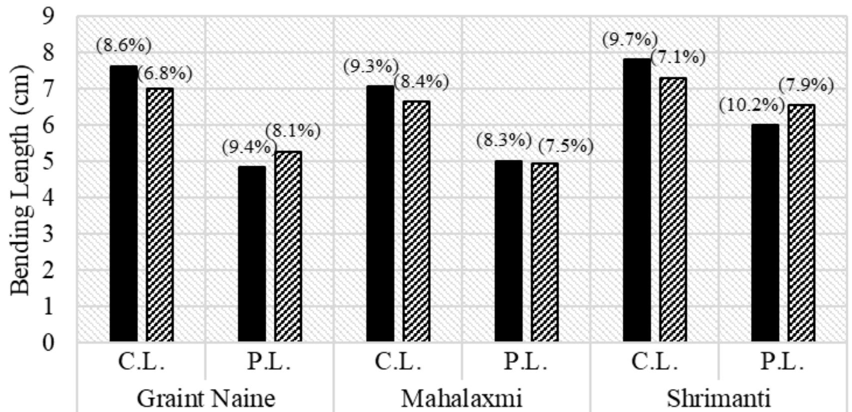
	C.L.	P.L.	C.L.	P.L.	C.L.	P.L.
	Graint Naine		Mahalaxmi		Shrimanti	
CD	13.32	13.25	11.76	12.92	14.53	16.6
MD	14.7	15.67	12.88	14.31	17.28	22.41

Figure 6 Bursting strength

Figure 6 shows bursting strength for parallel laid (P.L.) and cross laid (C.L.) of all three varieties of banana fibre nonwoven fabrics. It can be observed that Shrimanti banana nonwoven fabric shows higher bursting strength in the machine direction than Graint Naine and Mahalaxmi for both parallel laid and cross laid nonwoven fabric. This may be due to the incorporation of stronger behaviour of Shrimanti banana fibres (Table 1) in comparison with Graint Naine and Mahalaxmi fibres. The cross laid nonwoven fabric shows lower bursting strength compared to parallel laid fabric for all three varieties of banana fibre nonwoven fabric in the machine as well as in cross direction. Parallel laid (P.L.) non-woven fabrics are more regular than cross laid (C.L.) structure and may be contributing for higher bursting strength of parallel laid structure than cross laid structure. From the statistical analysis (Table 4) it can be observed that banana fibre variety have a significant effect on bursting strength of non-woven fabric. Banana fabric type (parallel laid structure and cross laid structure) have a significant effect on bursting strength of non-woven fabric and test direction i.e. machine direction and cross direction have a significant effect on bursting strength of non-woven fabric.

3.5 Bending length of nonwoven fabric

Figure 7 displays the bending length of banana nonwoven fabric. It can be seen from Figure 7 that bending length of parallel laid as well as cross laid Shrimanti banana nonwoven fabric is higher compared to Graint Naine and Mahalaxmi both in machine direction as well as in cross direction. This may be due to the stiff nature of Shrimanti banana fibres than Graint Naine and Mahalaxmi fibres. While Graint Naine non-woven fabric shows higher bending length values compared to Mahalaxmi non-woven fabric.



	Graint Naine C.L.	Graint Naine P.L.	Mahalaxmi C.L.	Mahalaxmi P.L.	Shrimanti C.L.	Shrimanti P.L.
CD	7.61	4.83	7.05	5	7.8	5.99
MD	7.01	5.26	6.63	4.92	7.29	6.54

Figure 7 Bending length

Cross laid (C.L.) fabric shows higher bending length for all three varieties of banana fibre nonwoven fabric than parallel laid (P.L.) fabric. As fibre orientation is more in the cross direction and high compactness of cross laid structure are responsible for giving higher bending length in cross direction than in machine direction. From the statistical analysis (Table 4) it can

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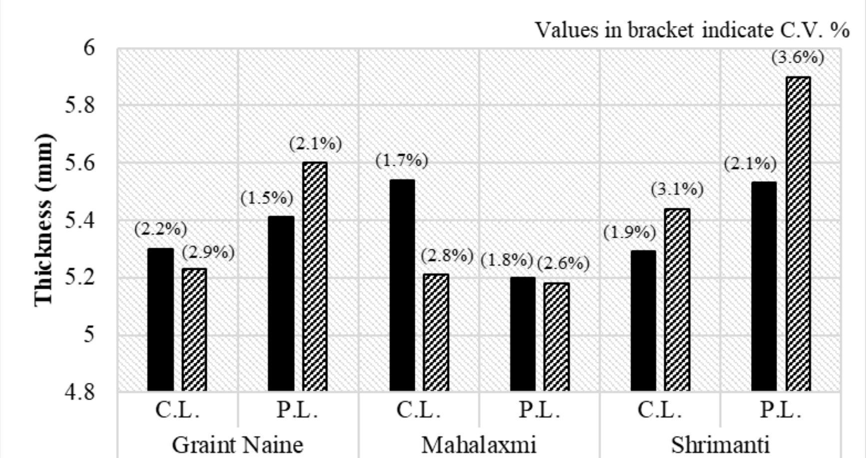
be observed that banana fibre variety does not have significant effect on bending length of non-woven fabric. Fabric type has a significant effect on bending length of non-woven fabric.

3.6 Thickness of nonwoven fabric

Figure 8 exhibits the thickness of different varieties banana nonwoven fabric for parallel laid and cross laid structures.



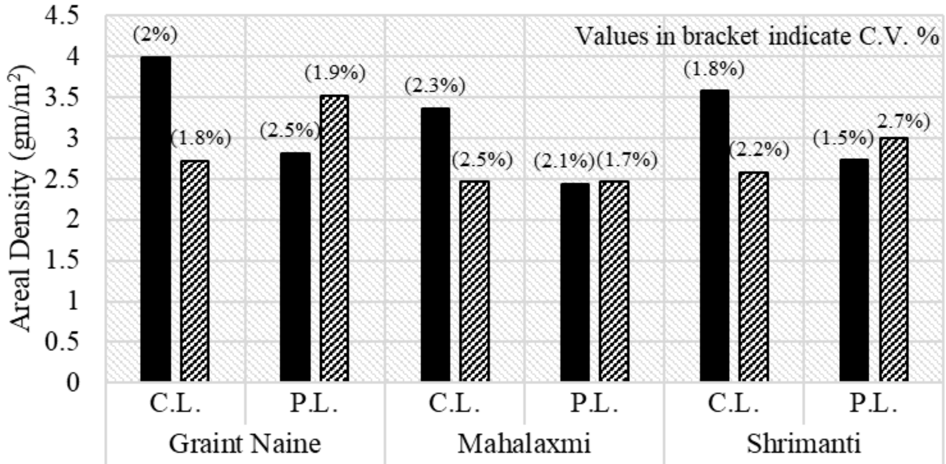
	Graint Naine C.L.	Graint Naine P.L.	Mahalaxmi C.L.	Mahalaxmi P.L.	Shrimanti C.L.	Shrimanti P.L.
CD	5.3	5.41	5.54	5.2	5.29	5.53
MD	5.23	5.6	5.21	5.18	5.44	5.9

Figure 8 Thickness

Higher thickness for parallel laid (P.L.) fabric in the machine direction (M.D.) than in cross direction (C.D.) is observed for Shrimanti and Graint Naine nonwoven fabric, but a reverse trend is observed for Mahalaxmi fibre nonwoven fabric, this may be happened because of the higher variation of linear density (Table 1) for all three varieties of the banana fibres. It can also be observed from Figure 8 that the parallel laid (P.L.) structure non-woven fabric shows higher thickness than cross laid (C.L.) structure non-woven fabric, this may be due to the more regular structure of parallel laid non-woven fabric making it thicker than cross laid non-woven fabric.

3.7 Areal density of nonwoven fabric

Areal density of parallel laid and cross laid structure for three varieties of banana fibre can be observed from Figure 9. Areal density of all the fabric samples measured in g/m^2 (GSM). However, it shows from Figure 9 that there is no much significant difference for areal density of all three varieties of banana non-woven fabric for parallel laid and cross-laid structure.



	C.L.	P.L.	C.L.	P.L.	C.L.	P.L.
	Graint Naine		Mahalaxmi		Shrimanti	
CD	3.99	2.81	3.36	2.44	3.57	2.73
MD	2.72	3.52	2.46	2.46	2.58	3

Figure 9 Areal density

Statistical analysis (Table 4) reveals that there is no significant effect of variety of banana fibre, type of nonwoven fabric and direction of test on areal density of banana needle punched nonwoven fabric.

Conclusion

Irrespective of variety of banana fibre, cross laid (C.L) nonwoven fabric shows superior tensile properties as compared to parallel laid (P.L.) nonwoven fabric. Shrimanti fibre nonwoven fabric is stronger than Graint Naine and Mahalaxmi fibre nonwoven fabric for both the parallel laid and cross laid structure. Parallel laid Mahalaxmi banana nonwoven fabric and cross laid Graint Naine banana nonwoven fabric gives higher elongation% for machine and cross direction. Increased air permeability of cross laid (60:40) banana/polypropylene blend non-woven fabric observed than parallel laid 100% banana non-woven fabric. Parallel laid Graint Naine non-woven fabric showed higher air permeability than Shrimanti and Mahalaxmi parallel laid non-woven fabric. Shrimanti cross laid (60:40) banana/polypropylene non-woven fabric showed higher air permeability than Graint Naine and Mahalaxmi cross laid non-woven fabric. Bursting strength of parallel laid nonwoven fabric is higher, both in the machine as well as in cross direction than cross laid nonwoven fabric for three varieties of banana fibres. Shrimanti banana non-woven fabric showed higher bursting strength for parallel laid and cross laid structure than Graint Naine and Mahalaxmi parallel laid and cross laid structure. Parallel laid (P.L.) structure non-woven fabric shows higher thickness than cross laid (C.L.). Areal densities remain same for all the nonwoven fabric samples. Bending length of the cross laid banana nonwoven fabric is higher than the parallel laid nonwoven fabric. Parallel as well as cross laid Shrimanti fibre nonwoven fabric samples have more bending length than Graint Naine and Mahalaxmi nonwoven fabric. Cross laid (C.L.) nonwoven fabric shows higher air permeability compared to parallel laid (P.L.) fabric.

Roles of author

The author (V.S.S.) confirms sole responsibility of the manuscript.

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Conflict of interest

The author declares that there are no conflicts of interest.

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