CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

The present study aims to enhance the performance characteristics of various types of sanitary napkins. The different types of napkin samples as mentioned in Table 3.7 have been prepared using commercial facility on sanitary napkin machine as details given in Section 3.3.4. These napkin samples have been designated in to three main categories depending on the type of constituent materials used for its construction viz. Maxi, Ultra-thin and Skiny-thin. In each of these categories two different sizes of sanitary napkins have been made: Large and Extra-large designated as SN_L and SN_{XL}.

The evolution of various characteristics such as physical and mechanical properties and general performance properties of these napkin samples have been carried out using test methods described in Section 3.3.5. The various nonwoven fabrics, polymeric cast films and wood pulp sheets etc. are the main raw materials of these napkins. The final characteristics of the napkin are influenced by the properties of these constituent materials. Therefore before the napkin manufacture various properties of these materials have been first evaluated. The various test results have been presented and analysed in the following sections.

4.2 Constituent Materials of Sanitary Napkin

As par the designs of various napkins, different types of raw materials have been procured from the market and/or manufacturers. These are various types of nonwoven fabrics, perforated plastic sheets, laminated sheets (film coated nonwoven), super absorbent powder, wood pulp sheets, tissue papers, adhesive materials etc. The characteristics of these raw materials affect the performance of the final napkin products. Hence the acquired raw materials have been evaluated for basic physical and mechanical properties such as wood pulp fibre length, mass density, tensile strength, breaking elongation. Certain performance characteristics also have been measured such as strike through and wet back. For some materials certain specifications also have been provided by the supplier.

4.2.1 Physical and Mechanical Characteristics

(a) Fibre Length: For Sanitary napkins it is necessary to take into consideration the properties of constituent fibres such as staple length, fibre fineness etc. It comprises of wood pulp fluff up to seventy percent by the weight of the pad; fibre length of the pulp is crucial, particularly in the case of pulp sheet. Its main purpose is to maintain the uniform distribution of liquids over the whole length of the pad. An ideal fluff pulp must possess certain specific characteristics viz. high bulk and absorption capacity, minimal absorption time, and sufficient tensile strength. Longer fibres will lead to a corresponding increase in SAP attraction, resulting in more water absorption. For evaluation of the fibre length of untreated wood pulp fluff and bamboo pulp sheets total of 20 SEM pictures have been obtained (Fig. 4.1 and Fig. 4.2).

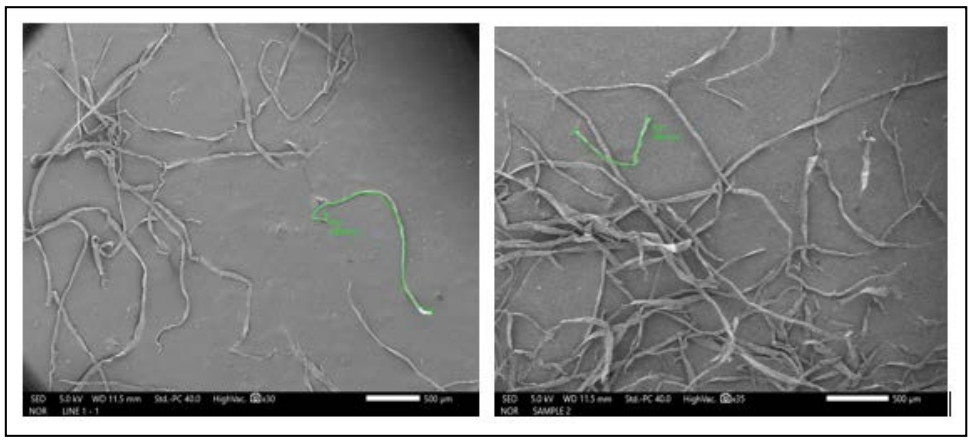

Fig. 4.1 SEM images of untreated pine wood pulp

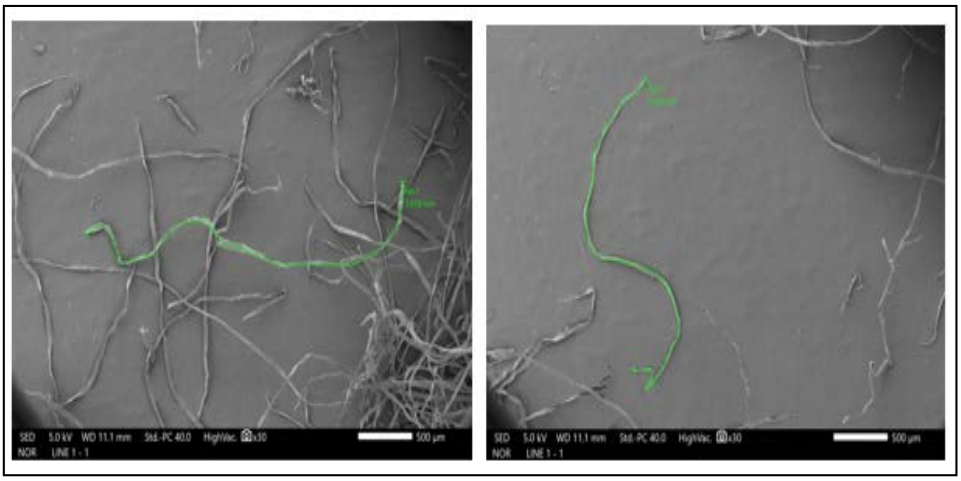

Fig. 4.2 SEM images of bamboo wood pulp

Table 4.1 Fibre length of pine and bamboo wood pulp used in pulp sheet

Sr. No.	Fibre length (mm)			Standard deviation	Coefficient of variation (%)
	Average	Minimum	maximum		
Untreated pine wood pulp	2.62	0.90	5.25	3.08	44
Bamboo wood pulp	3.08	2.94	3.98	0.5	16

The pine pulp sheet and bamboo pulp sheet both are natural cellulosic fibrous materials. The fibre length in both cases has been measured from pulp fluff prepared from the pulp sheets. The average fibre length found much shorter than cotton fibre length. However main property requirement from the pulp is to absorb fluid providing high absorbency to the napkin. In case of bamboo pulp measured fibre length is about 3mm which is marginally longer than that of pine pulp.

(b) Fabric Mass Density: Nonwoven fabrics are commonly used in disposable hygiene products to provide a more comprehensive solution. The mass density of these non-woven fabrics typically ranges from 10 gsm to 60 gsm suitable for medical and hygiene items, including masks, diapers, sanitary pads, and adult incontinence products. For the study, we manufactured sanitary napkins using a wide range of nonwoven fabric types: eight different top sheet materials, three acquisition distribution layers, various core layer materials and two back sheets. Mass of 20cm x25cm size samples (absorbent core was cut into the largest rectangular piece) have been weighed using electronic weighing machine. Average mass per unit area have been calculated from 20 samples in each case and expressed in gsm.

(c) Tensile Properties: A wide range of nonwoven fabrics have been utilised in preparing the samples of sanitary napkins for the study. The fabric samples have been cut into 20 mm x150 mm strips and conditioned at 26°C and 50% relative humidity for 24 hours before the test. An INSTRON 5944 tensile testing machine model 2580107 has been used with a traverse speed of 300 mm/min. Total 20 tests of each fabric sample have been carried out both in machine and cross-machine direction. Average tensile strength in N/50mm and elongation at break (extension %) results have been recorded.

4.2.2 Hydraulic Properties

(a) Strike Through: EDANA test method have been used to measure the strike-through time, i.e. time taken for a known volume of liquid (simulated urine) applied to the surface of a test portion of nonwoven in contact with an underlying standard absorbent pad, to pass through the nonwoven. The strike-through rate is measured for a single droplet of liquid penetrates the pad. A little amount of the test solution is applied to the sample, and the amount of time it takes for the solution to travel from the top layer of the serviette to the layers beneath inside the sample is measured by carefully examining the drop in order to locate the dull wet area on the wet portion of the sample.

Test samples have been conditioned for a period of 24 hours before test. To measure rate of penetration of a single drop of liquid through samples, 5ml of 0.9% saline solution was used. A drop of the liquid was permitted to fall on the pad sample and the penetration rate of the liquid was thoroughly observed. The pad was assessed by measuring the time taken for the blood substitute to be absorbed from the upper layer of the pad to the inner layer. The drop was monitored closely until the drop of the test liquid appeared on the pad sample like a dull spot, the pad being observed over the same period of time.

(b) Wet Back: In order to ensure that the liquid is distributed evenly throughout the coverstock and absorbent material, a typical weight is applied to both of these components. Then, a blotter paper that has already been pre-weighed is placed on top of the coverstock, and the weight is then placed on top of it. For the purpose of determining whether or not a sanitary napkin is capable of preventing liquid that has leaked through the cover material from being transferred back to the skin. The word "wetback" (or "rewet") refers to a unique characteristic that is used to assess the amount of liquid that is ejected by a product after it has absorbed liquid and is subjected to pressure. This involved pouring 5 ml of a 0.9% saline solution over the centre of the napkin and allowing it to set for 1 minute. Subsequently, a 3 gram dry filter paper is placed at the centre for duration of 15 seconds, carefully take out and measure the weight of the first filter paper (w_1). Repeating this method will yield the weight of the second filter paper (w_2). The difference of weight of the second filter weight and first filter paper ($w_2 - w_{1)}$ was measured for each sample at controlled test conditions.

Napkin samples have been designed in layered structure using Top Sheet (TS), Acquisition Distribution Layer (DL), Absorbing Core layer (AC) and Back Sheet (BS). The various test results of these materials have been presented in Table 4.2, Table 4.3, Table 4.4 and Table 4.5 respectively.

Table 4.2 Detail specifications of various Nonwoven Top Sheets

Sr. No	Type of top sheet	Top sheet code	Mass density (gsm)	Tensile strength (N/50mm)		Elongation (%)		Strike through (s)	Wet back (g)
				MD	CD	MD	CD		
1	PP spunbond	TS_1	18.1	39.6	21.1	73.9	74.9	1.8	0.9
2	PP hot air through	TS_2	18.2	31.1	6.4	41.2	84.4	2.4	0.8
3	PE single perforated	TS_3	20.0	27.6	8.3	140	218	3.6	0.0
4	PE double perforated	TS_4	20.0	24.0	7.6	110	160	3.3	0.1
5	PE:PP Laminated composite	TS_5	30.0	28.0	9.0	50.0	90.0	2.5	0.1
6	Organic cotton spunlace	TS_6	30.0	54.0	19.0	21.0	85.0	1.8	0.6
7	Mulberry silk spunlace	TS_7	30.0	42.0	12.0	32.0	46.0	2.0	0.4
8	Corn -PLA spunlace	TS_8	30.0	35.0	12.0	60.0	90.0	1.7	0.1

Table 4.3 Detail specifications of various type of Acquisition Distribution Layer (ADL) (a and b)

a)

Sr. No	Type of ADL	Code	Mass density (gsm)	Tensile strength (N/50mm)		Elongation (%)		Strike through	Wet back
				MD	CD	MD	CD	(s)	(g)
1	PP hot air through NW	DL_1	25.2	33.4	7.02	49.7	74.6	2.78	0.86
2	PLA hot air through NW	DL_2	30.4	45.3	8.43	15.5	60.7	1.58	0.03

b)

Sr. No	Type of ADL	Code	Mass density (gsm)	Tensile strength (mN/ 15mm)	Elon-gation (%)	Mois-ture %	Longitudinal wet tension (mN/15mm)	Lateral water absorption (mm/ 100s)
3	Tissue paper	DL_3	16.1	4072	21	6.37	1050	23

Table 4.4 Detail specifications of various types of materials used for core layer (a, b, c, and d)

a)

Sr. No	Core layer Material	Code	Golden isles fluff, grade 4881, wood species southern pine, fibre length (mm)				Moisture (%)	Supply roll	
			FQA Length weighted	FQA Weight weighted	Kajaani Length weighted	Kajaani Weight weighted		width (cm)	dia. (cm)
2	Wood Pulp	AC_1	2.4	2.8	2.7	3.4	8	25	152

Sr. No	Core layer Material	Code	Mass Density (g/ml)	Centrifugal Retention Capacity (g/g)	Moisture Content (%)	pH	Particle Size µm	Absorption against pressure (g/g)
1	SAP powder	AC_1	0.63	37.5	1.1	6	80% above 300um	18 (at 0.7 psi)

b)

c)

Sr. No	Core layer material	Code	Mass density (gsm)	Thickness (mm)	Mass of material (g)	Proportion of material (%)	Absorption in 60mm x 100mm (ml)
3	SAP paper (SAP powder + wood pulp)	AC_2	144	0.8	SAP 45	SAP (30)	88
4	Biodegradable absorbent material (bamboo pulp + corn starch powder)	AC_3	152	0.98	Corn starch 60	Corn Starch (45)	48

d)

Sr. No	Core layer material	Code	Mass density (gsm)	Thickness (mm)	Tensile strength (N/50mm)	Strike through (s)	Wet back (g)

5	Pulp fluff air-laid nonwoven	AC_2	50	0.75	21.98	2.78	0.86
6	Bamboo pulp air-laid nonwoven	AC_3	55	0.8	23.32	2.65	0.78

Table 4.5 Detail specifications of various types of back sheet

Sr. No	Type of back sheet	Code	Mass density	Tensile strength (N/50mm)		Elongation (%)	
				MD	CD	MD	CD
1	Polyethylene back sheet	BS_1	16.00	31.60	17.20	377.00	766.00
2	PBAT and PLA back sheet	BS_2	18.00	27.43	12.65	423.00	823.00

4.3 Specifications of Sanitary Napkin Samples

After manufacturing the napkin samples various physical parameters have been measured in the laboratory. The specifications of Maxi, Ultra-thin and Skiny- thin sanitary napkins have been given in Table 4.6, Table 4.7 and Table 4.8 respectively.

Table 4.6 Specifications of Maxi napkin (Large and Extra-large) samples

Sr. No.	Specification	$\mathbf{SN_{L1}}$	$\mathbf{SN_{L2}}$	$\mathbf{SN_{L3}}$	$\mathbf{SN_{L4}}$	$\mathbf{SN_{XL1}}$	$\mathbf{SN_{XL2}}$	$\mathbf{SN_{XL3}}$	$\mathbf{SN_{XL4}}$
1	Weight (g)	7.5	7.5	7.5	7.6	10.4	10.4	10.4	10.4
2	Length (mm)	240	240	240	240	280	280	280	280
3	Thickness (mm)	7.5	7.5	7.5	7.5	13	13	13	13
4	Width at wings (mm)	160	160	160	160	160	160	160	160
5	Width at front (mm)	100	100	100	100	105	105	105	105
6	Width at back (mm)	100	100	100	100	113	113	113	113
7	Wing length (mm)	100	100	100	100	100	100	100	100
8	End seal length at front (mm)	6.5	6.5	6.5	6.5	70	70	70	70
9	End seal length at back (mm)	6.5	6.5	6.5	6.5	105	105	105	105
10	Core weight (g)	5.0	4.9	5.0	5.0	6.5	6.32	6.5	105
11	Core length (mm)	205	205	205	205	250	250	250	250
12	Core width at centre (mm)	65	65	65	65	70	70	70	70
13	Core width front (mm)	72	72	72	72	75	75	75	75
14	Core width back (mm)	72	72	72	72	80	80	80	80

15	MRP length (mm)	185	185	185	185	230	230	230	230
16	MRP width (mm)	55	55	55	55	55	55	55	55
17	WRP length (mm)	70	70	70	70	70	70	70	70
18	WRP width (mm)	55	55	55	55	55	55	55	55

Table 4.7 Specifications of Ultra-thin napkin (Large and Extra-large) samples

Sr. No.	Specification	SN_{L5}	SN_{L6}	SN_{L7}	SN_{XL5}	SN_{XL6}	SN_{XL7}
1	Weight (g)	6.90	6.90	6.90	8.2	8.2	8.2
2	Length (mm)	240	240	240	280	280	270
3	Thickness (mm)	6.5	6.5	6.5	6.5	6.5	6.5
4	Width at wings (mm)	158	158	158	158	158	158
5	Width at front (mm)	100	100	100	100	100	100
6	Width at back (mm)	100	100	100	110	110	110
7	Wing length (mm)	100	100	100	100	100	100
8	SAP paper length (mm)	170	170	170	200	200	200
9	SAP paper width (mm)	60	60	60	60	60	60
10	ADL length (mm)	50	50	50	80	80	80
11	ADL width (mm)	35	35	35	35	35	35
12	Core /Airlaid length (mm)	210	210	210	250	250	250
13	Core /Airlaid width centre (mm)	65	65	65	65	65	65
14	Core width front/back (mm)	70	70	70	75/80	75/80	75/80
15	MRP length (mm)	190	190	190	235	235	235
16	MRP width (mm)	53	53	53	53	53	53
17	WRP length (mm)	50	50	50	70	70	70
18	WRP width (mm)	53	53	53	53	53	53

Table 4.8 Specifications of skiny-thin napkin (Large and Extra-large) samples

Sr. No.	Specification	SN_{L8}	SN_{L9}	SN_{L10}	SN_{XL8}	SN_{XL8}	SN_{XL10}
1	Weight (g)	7.17	7.15	7.15	8.4	8.4	8.4
2	Length (mm)	240	240	240	280	280	275
3	Thickness (mm)	6.1	6.0	6.1	6.1	6.0	6.0
4	Width at wings (mm)	158	158	158	158	158	158
5	Width at front (mm)	100	100	100	100	100	100
6	Width at back (mm)	100	100	100	110	110	110
7	Wing length (mm)	100	100	100	100	100	100
8	SAP paper length (mm)	170	170	170	200	200	200
9	SAP paper width (mm)	60	60	60	60	60	60
10	ADL length (mm)	50	50	50	80	80	80
11	ADL width (mm)	35	35	35	35	35	35
12	Core /Airlaid length (mm)	210	210	210	250	250	250
13	Core /Airlaid width centre (mm)	65	65	65	65	65	65
14	Core width front/back (mm)	70	70	70	75/80	75/80	75/80
15	MRP length (mm)	190	190	190	235	235	235
16	MRP width (mm)	53	53	53	53	53	53
17	WRP length (mm)	50	50	50	70	70	70
18	WRP width (mm)	53	53	53	53	53	53

4.4 Absorption and Rewet Test

The study aims to develop 10 different types of sanitary napkins in each variety of large and extra-large. The reason of making large and extra-large sanitary napkins is on the bases of their consumption, which is approximately 80 to 85% in India. These 10 samples are divided into three categories. The first type is thick Maxi-sanitary napkins, which is ranging in thickness from 7.5 to 13 mm and four samples are made with different top sheets (TS_1, TS_2, TS_3, and TS_4). The absorption core, which is composed of AC_1 and the back sheet BS1, which are kept same for all Maxi type samples. The consumption of AC_1 materials in all the four varieties of sanitary napkins is 0.2 g and 4.2 g respectively. The second type is ultra-thin sanitary napkins, having 6.5 mm thickness and three samples are made with different top sheets (TS_3, TS_4, and TS_5). The absorption core, which is composed of AC_2 and the back sheet BS1, which are kept same for all ultra-thin samples. The consumption of AC_2 materials in all the three varieties of sanitary napkins is 1.98 g and 1.88 g respectively. And the last one is skiny-thin with eco-friendly sanitary napkins having 6.0 mm thickness and three samples are made with different top sheets (TS_6, TS_7, and TS_8). The absorption core, which is composed of AC_3 and the back sheet BS_2, which are kept same for all skiny-thin samples. The consumption of AC_3 materials in all the three varieties of sanitary napkins is 1.98 g and 1.76 g respectively. The ISO 5405-1980 standards were used to evaluate these sanitary napkins.

The findings for the absorption and rewet tests for all the four maxi samples of large and extra-large size sanitary napkins are presented in Table 4.9 and Table 4.10 respectively. For this test, five napkins of each size were evaluated and the average results are given in each table. The Fig. 4.23 shows the graphical presentation for different maxi type of large size sanitary napkins for absorption and rewet character. The average absorption time for the synthetic blood by various Maxi large sanitary napkins varied between 17.14 and 24.74 s in first cycle and between 23.08 and 39.32 s in second cycle. The average rewet varied between 0.53 and 1.53 g in first cycle and 2.13 and 5.14 g in second cycle. The test images are shown for all eight samples of Maxi type, which include 4 samples of large and 4 samples of extra-large sanitary napkins in Fig. 4.3 to Fig. 4.10 respectively.

Table 4.9 Absorption, rewet, and distribution length for the maxi large sanitary napkins

Sr. No	Napkin code	Napkin type	1st cycle absorbent time for 15ml (s)	1st cycle rewet (g)	2nd cycle absorbent time for 15ml (s)	2nd cycle rewet (g)	Distribution length (mm)
1	SN_{L1}	Maxi	17.14	1.53	23.08	5.14	150.4
2	SN_{L2}	Maxi	23.12	0.82	36.40	3.00	165.2
3	SN_{L3}	Maxi	24.74	0.53	39.32	2.13	162.6
4	SN_{L4}	Maxi	21.88	0.68	36.10	2.92	172.9

From Table 4.9 it is observed that the average absorption time for both the cycles each of 15ml is minimum i.e. 17.14 s and 23.08 s respectively for SN_{L1} sample and the maximum average absorption time taken for both the cycles i.e. 24.74 s and 39.32 s respectively by SN_{L3} sample. The minimum average rewet property is observed in SN_{L3} sample in both the cycles i.e. 0.53 g and 2.13 g respectively among all the samples and the maximum average rewet property is observed in SN_{L1} sample in both the cycles i.e. 1.53 g and 5.14 g respectively. The blood distribution length at the end of test is observed highest in SN_{L4} i.e. 172.9 mm and lowest in SN_{L1} sample i.e. 150.4 mm.

Fig. 4.23 Absorption time and rewet for large size of maxi type sanitary napkins. (SN_{L1}, SN_{L2}, SN_{L3} and SN_{L4})

The SN_{L1} sample has shown the minimum absorption time in both the cycles as compare to the other samples (SN_{L2}, SN_{L3}, and SN_{L4}). SN_{L1} has shown 30.72% reduction in first cycle and 41.30% reduction in second cycle in absorption time than SN_{L3} sample which has shown the highest time of absorption both the cycles i.e. 24.74 and 39.32 seconds respectively. The other samples SN_{L2} and SN_{L4} have shown the 6.55% and 11.56% reduction in first cycle and 7.43% and 8.19% reduction in second cycle in absorption time than SN_{L3} sample as shown in table 4.9. This may be due to hydrophilic nature and more open structure of the SN_{L1} sample which has contributed to its shorter absorption time. On the other hand, the SN_{L3} sample has shown the longer absorption time, this may be due to its hydrophobic nature and the fluid passing through only the perforations of the sheet. The hydrophobic nature of the top sheet may contribute to the lowest rewet character of the SN_{L3} sample. When fluid passes through the perforated structure of the top sheet and reaches the core material, the top sheet remains dry due to its hydrophobic property. The hydrophilic nature of the top sheet contributes to the high rewet character of the SN_{L1} sample. The hydrophilic property of the top sheet causes the release of some fluid from the top sheet when it passes through and reaches the core material during wet back, resulting in a high rewet.

In sample SN_{L1} and SN_{L2}, the top sheets were made by using polypropylene fibres with distinct nonwoven technologies. SN_{L1} was made by using spunbond nonwoven technology, while SN_{L2} was made by using hot air-through nonwoven technology. The main distinction is the greater presence of pore structure in spunbond nonwoven as compared to hot air nonwoven as shown in Fig. 3.1(b). SN_{L2} has a soft and fluffy texture that resembles a cottony top sheet as shown in Fig. 3.2. The SN_{L1} top layer allows fluid to move through more rapidly compared to the SN_{L2}.

In SN_{L3} and SN_{L4} samples, both the top sheets were manufactured using polyethylene material using the cast film technique. Both of these materials originate from the same source but have different structural characteristics. The production of SN_{L3} involves a solitary perforated framework, while SN_{L4} was produced using a dual perforated framework. The pore structure of a single-perforated top sheet is lesser than that of a double-perforated top sheet. This is the primary differentiation between the two types of top sheets. Both sheets possess an inherent hydrophobic property. The SN_{L4} top layer has a higher permeability than the SN_{L3} layer, resulting in an increased fluid flow rate and reduced absorption time compared to SN_{L3}.

Table 4.10 Absorption, rewet, and distribution length for the maxi extra-large sanitary napkins

Sr. No	Napkin code	Napkin type	1st cycle absorbent time for 15ml (s)	1st cycle rewet (g)	2nd cycle absorbent time for 15ml (s)	2nd cycle rewet (g)	Distribution length (mm)
1	SN_{XL1}	Maxi	15.46	1.14	21.86	3.31	194.20
2	SN_{XL2}	Maxi	18.76	0.99	20.92	3.22	183.80
3	SN_{XL3}	Maxi	22.44	0.45	31.50	1.66	203.40
4	SN_{XL4}	Maxi	20.38	0.65	29.10	1.46	191.70

The absorption and rewet property of Maxi extra-large samples i.e. SN_{XL1}, SN_{XL2}, SN_{XL3} and SN_{XL4} are shown in Table 4.10 and the graphical representation of these samples is given in Fig. 4.24. The average absorption time for the synthetic blood by various Maxi extra-large sanitary napkins varied between 15.46 and 22.44 s in first cycle and between 21.86 and 31.50 s in second cycle. The average rewet varied between 0.45 and 1.14 g in first cycle and 1.46 and 3.31 g in second cycle. It can be seen that the results are in similar trend as maxi large size sanitary napkins. The extra-large sanitary napkins took lesser absorption time than large sanitary napkin. The rewet range has also reduced in extra-large samples as compare to large one. It may be due to the more volume of absorbent material used for extra-large samples than large sanitary napkins, which can be seen from Table 4.18 The percentage reduction in absorption time observed in SN_{XL1} is 31.11% and 30.60% in cycle 1 and cycle 2 respectively as compared to SN_{XL3} sample which has shown the highest absorption time, i.e. 22.44 s and 31.50 s in cycle 1 and cycle 2 respectively.

Fig. 4.24 Absorption time and rewet for extra-large size of maxi type sanitary napkins. (SN_{XL1}, SN_{XL2}, SN_{XL3} and SN_{XL4})

The Fig. 4.3 to 4.10 show that there is no leakage observed in any of the eight samples of maxi large and extra-large sanitary napkins.

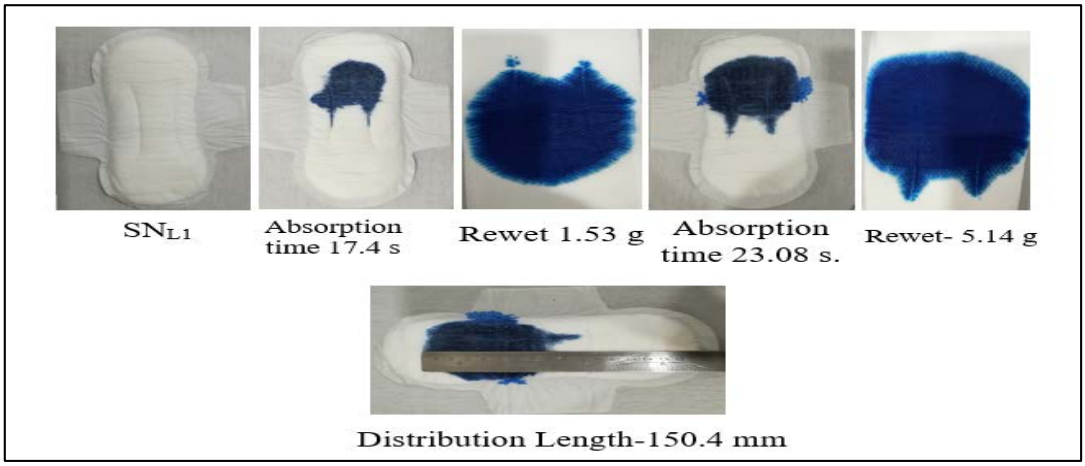

Fig. 4.3 Absorbency, rewet, and distribution length of sanitary napkin (SN_{L1}).

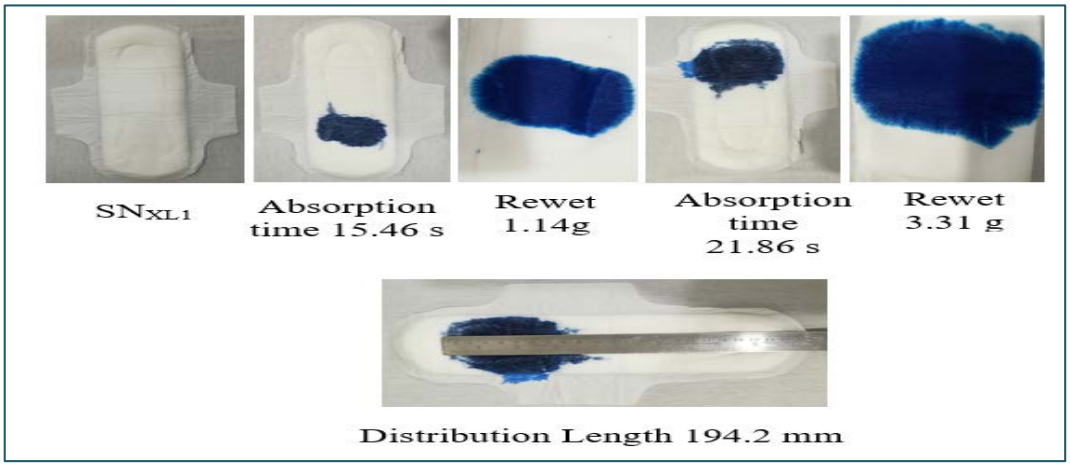

Fig. 4.4 Absorbency, rewet, and distribution length of sanitary napkin (SN_{XL1}).

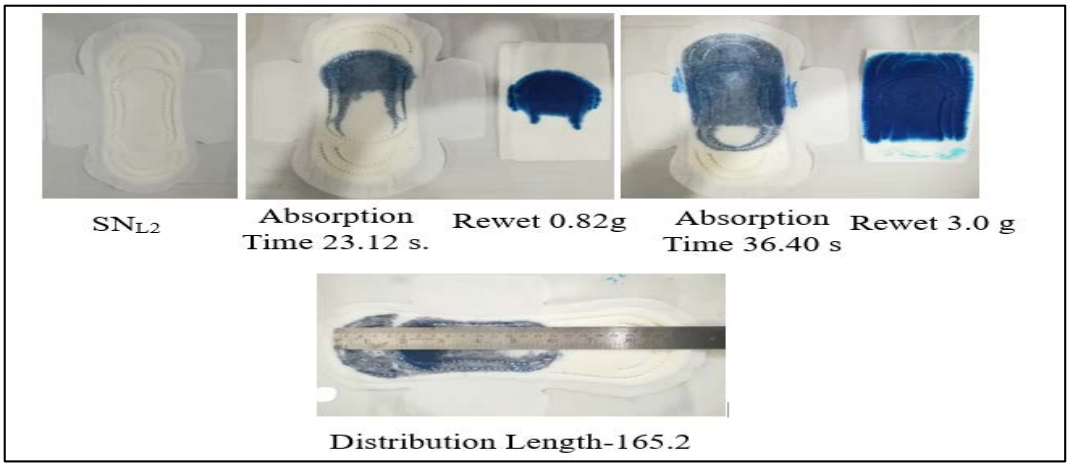

Fig. 4.5 Absorbency, rewet, and distribution length of sanitary napkin (SN_{L2}).

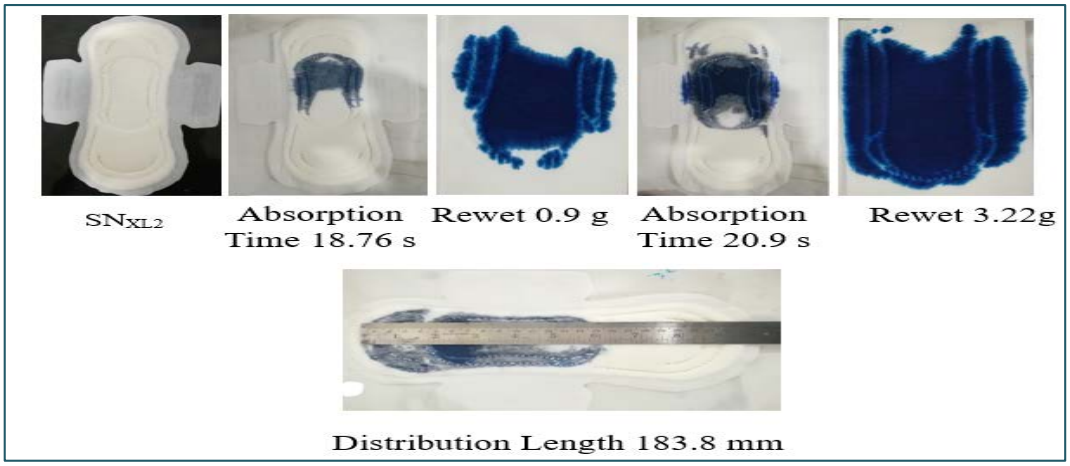

Fig. 4.6 Absorbency, rewet, and distribution length of sanitary napkin (SN_{XL2}).

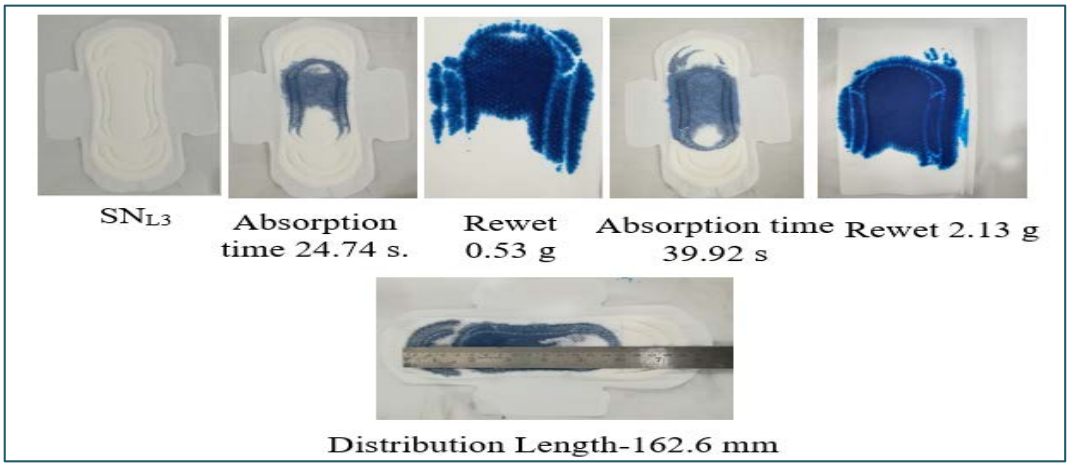

Fig. 4.7 Absorbency, rewet, and distribution length of sanitary napkin (SN_{L3}).

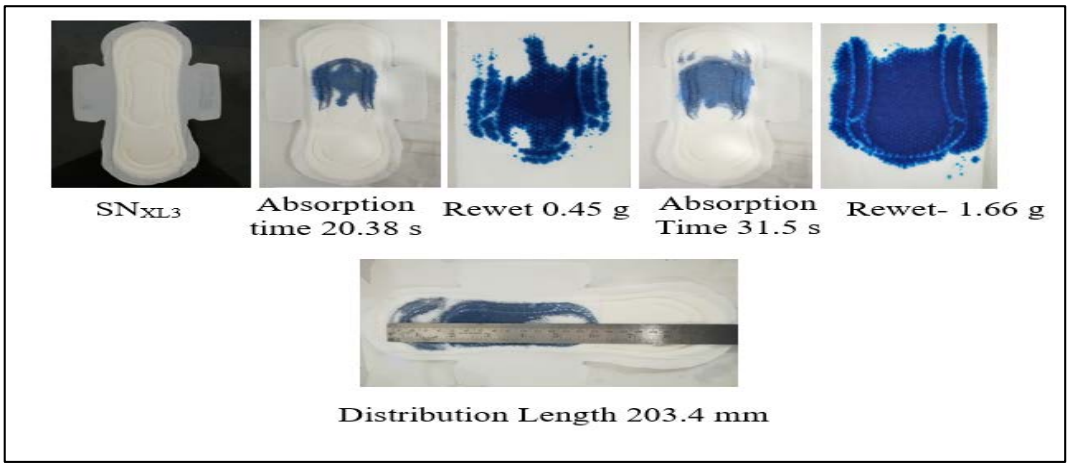

Fig. 4.8 Absorbency, rewet, and distribution length of sanitary napkin (SN_{XL3}).

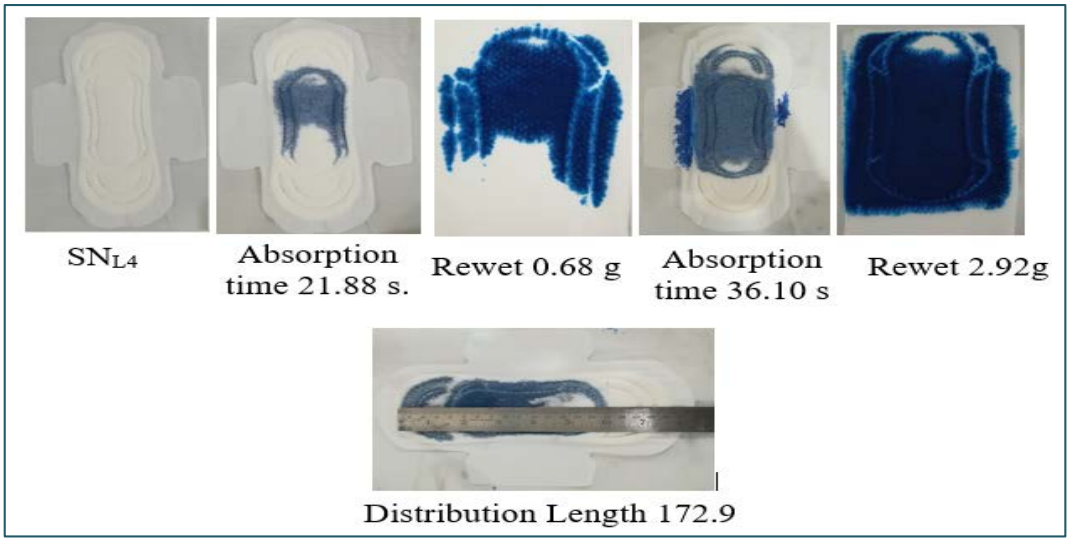

Fig. 4.9 Absorbency, rewet, and distribution length of sanitary napkin (SN_{L4}).

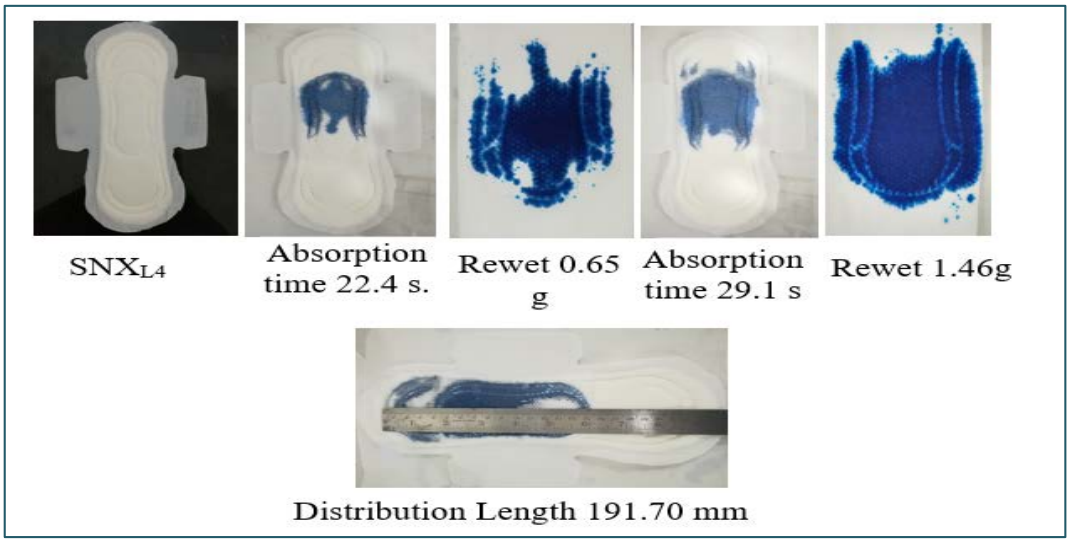

Fig. 4.10 Absorbency, rewet, and distribution length of sanitary napkin (SN_{XL4}).

The absorption and rewet test results for the three ultra-thin samples of large and extra-large size sanitary napkins are presented in Table 4.9 and 4.10, respectively. Additionally, the test images for all six samples, consisting of three large and three extra-large sanitary napkins, are shown in Figures 4.11 to 4.16. The Figure 4.29 displays a graphical representation of various ultra-thin, large-sized sanitary napkins, highlighting their absorption and rewet characteristics. The absorption time for the synthetic blood by different ultra large sanitary napkins showed some variation, ranging from 24.86 to 30.14 seconds in the first cycle and from 37.32 to 44.16 seconds in the second cycle. In the first cycle, the average rewet ranged from 0.72 to 0.92 g, whereas in the second cycle, it ranged from 2.81 to 3.00 g.

Table 4.11 Absorption, rewet, and distribution length for the Ultra-thin large sanitary napkins

Sr. No	Napkin code	Napkin type	1st cycle absorbent time for 15ml (s)	1st cycle rewet (g)	2nd cycle absorbent time for 15ml (s)	2nd cycle rewet (g)	Distribution length (mm)
1	SN_{L5}	Ultra-thin	30.14	0.72	44.16	2.81	163.3
2	SN_{L6}	Ultra-thin	28.92	0.90	43.76	3.00	166.4
3	SN_{L7}	Ultra-thin	24.86	0.97	37.32	3.35	169.6

Fig. 4.25 Absorption time and rewet for large size of ultra-thin type sanitary napkins. (SN_{L5}, SN_{L6}, and SN_{L7})

In this study, a total of five napkins of each size were assessed, and the average results are given in Table 4.11 and Table 4.12. It can be seen from Table 4.11 that the SN_{L7} sample has the shortest average absorption time for both cycles, which is 24.86 seconds and 37.32 seconds respectively. On the other hand, the SN_{L5} sample has the longest average absorption time for both cycles, which is 30.14 seconds and 44.16 seconds respectively. Among all of the samples, the SN_{L5} sample has the lowest average rewet property, which is measured at 0.72 g and 2.81 g respectively, in both cycles. On the other hand, the SN_{L7} sample has the highest average rewet property, which is measured at 0.97 g and 3.35 g respectively, in both cycles. The blood distribution length at the end of test is observed highest in SN_{L7} i.e. 169.63 mm and lowest in SN_{L1} sample i.e. 163.32 mm.

A comparative analysis is being conducted between the ultra-thin napkins SN_{L5} and SN_{L6}. Both napkins were made from polyethylene top sheet with distinct structures. SN_{L5} is equipped with a top sheet that has a single perforation characteristic (TS_3), whereas SN_{L6} has double perforations (TS_4). SN_{L7} features a combination of double perforated polyethylene (TS_4) and polypropylene spun bond nonwoven (TS_1) top sheet, which are seamlessly fused together.

In both cycles, the SN_{L7} sample exhibited the least amount of absorption time in comparison to the SN_{L5} and SN_{L6} samples. The absorption time of the SN_{L7} sample was found to be 17.5% lower in the first cycle and 15.5% lower in the second cycle, in contrast to the SN_{L5} sample, which showed a prolonged absorption duration in both cycles at 30.14 s and 44.16 s, respectively. According to the data presented in Table 4.9, it can be observed that the SN_{L6} sample showed a decrease in absorption time of 4.0% during the first cycle and 0.9% during the second cycle, in comparison to the SN_{L5} sample.

The top sheets of both SN_{L5} and SN_{L6} samples were produced using polyethylene material. The construction of SN_{L5} utilised a singular perforated structure. In contrast, SN_{L6} was manufactured using a dual perforated framework, results in a double perforated structure. The pore structure of a top sheet with a single perforation is lower than that of a top sheet with double perforations. Both sheets contain an inherent hydrophobic characteristic. The SN_{L6} top sheet exhibits greater permeability than the SN_{L5} top sheet, leading to an enhanced fluid flow rate and decreased absorption time in comparison to SN_{L5}.

The SN_{L7} sanitary napkin showed the shortest absorption time, potentially attributed to the dual nature of its specially designed top sheet. This top sheet is double perforated on one side and hydrophilic on the other. In contrast, the SN_{L5} sample exhibited a prolonged absorption period, which can be attributed to its hydrophobic nature and the presence of a single perforated structure of the top sheet. The hydrophobic feature of the top sheet ensures that it does not become wet when fluid travels through the perforated structure of the top sheet and reaches the core material.

The SN_{L5} demonstrated the least rewet characteristic when compared to other ultra-thin sanitary napkins. The observed phenomenon may be explained by the hydrophobic properties and decreased porosity caused by a single perforated surface. The SN_{L6} sanitary napkin has shown a higher level of rewet compared to the SN_{L5} sanitary napkin. The increased openness of SN_{L6} can be attributed to its dual perforated surface. The rewet property of SN_{L7} is high

compared to other ultra-thin sanitary napkins. This may be attributed to the unique combination of hydrophobic and hydrophilic characteristics in its top sheet. Ultra-thin sanitary napkins have equivalent or greater absorption compared to traditional Maxi-type napkins while providing increased sensitivity.

Table 4.12 Absorption, rewet, and distribution length for the Ultra-thin large sanitary napkins

Sr. No	Napkin code	Napkin type	1st cycle absorbent time for 15ml (s)	1st cycle rewet (g)	2nd cycle absorbent time for 15ml (s)	2nd cycle rewet (g)	Distribution length (mm)
1	SN_{XL5}	Ultra-thin	26.66	0.31	44.58	2.21	184.20
2	SN_{XL6}	Ultra-thin	26.38	0.67	42.20	2.58	185.10
3	SN_{XL7}	Ultra-thin	25.54	0.78	33.78	3.19	186.20

The absorption and rewet property of ultra-thin extra-large samples, specifically SN_{XL5}, SN_{XL6}, and SN_{XL7}, are displayed in Table 4.12. Additionally, a graphical representation of these samples can be seen in Fig. 4.30. The mean absorption duration of the synthetic blood by different ultra-thin extra-large sanitary napkins ranged from 25.54 to 26.66 s in the first cycle and from 33.78 to 44.58 s in the second cycle. In the first cycle, the average rewet ranged from 0.31 to 0.78 g, whereas in the second cycle it ranged from 2.21 to 3.19 g. The findings show a similar pattern to those of ultra-thin large sanitary napkins. In SN_{XL7}, the absorption time decreased by 4.2% in cycle 1 and by 24.2% in cycle 2, compared to the SN_{XL5} sample which had the longest absorption duration of 26.66 s in cycle 1 and 44.58 s in cycle 2. The Fig. 4.11 to 4.16 show that there is no leakage observed in any of the six samples of ultra-thin large and extra-large sanitary napkins.

Fig. 4.26 Absorption time and rewet for extra-large size of ultra-thin type sanitary napkins. (SN_{XL5}, SN_{XL6}, and SN_{XL7})

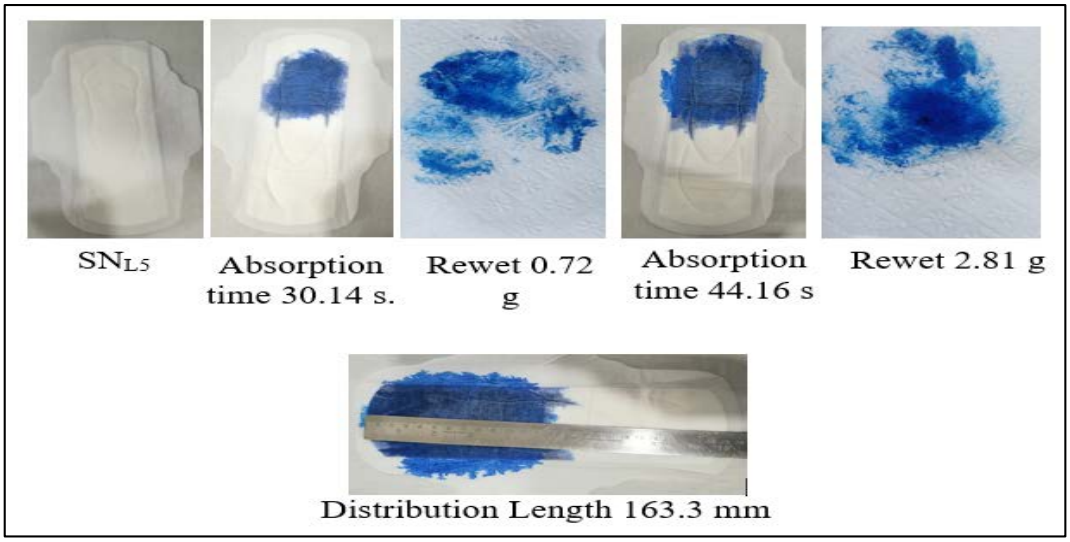

Fig. 4.11 Absorbency, rewet, and distribution length of sanitary napkin (SN_{L5}).

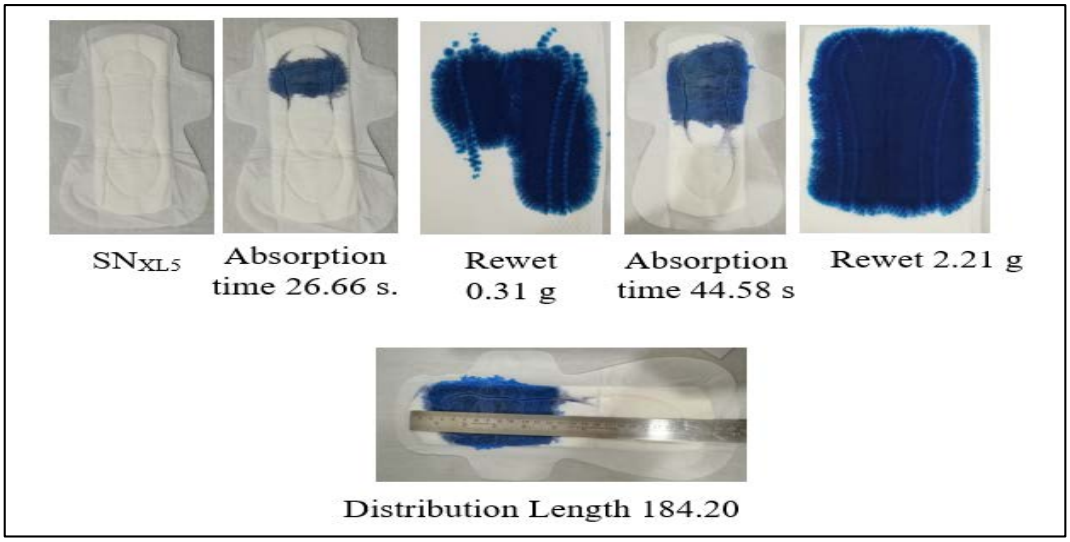

Fig. 4.12 Absorbency, rewet, and distribution length of sanitary napkin (SN_{XL5}).

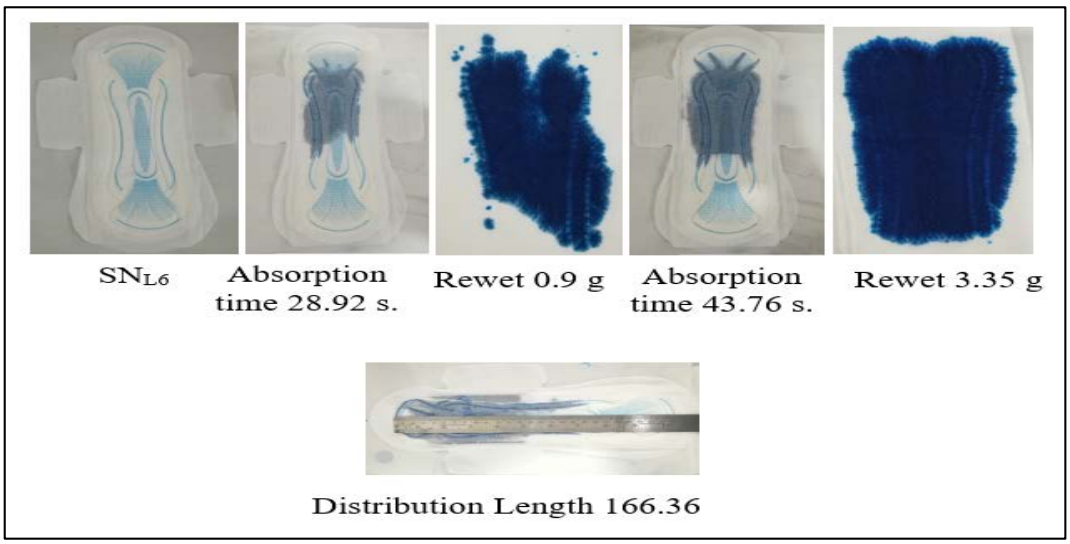

Fig. 4.13 Absorbency, rewet, and distribution length of sanitary napkin (SN_{L6}).

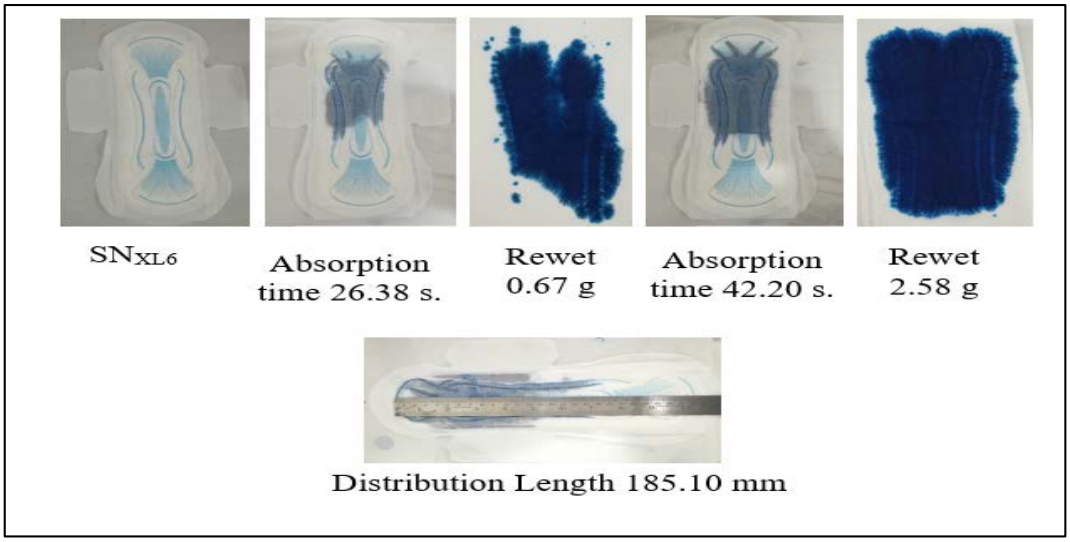

Fig. 4.14 Absorbency, rewet, and distribution length of sanitary napkin (SN_{XL6}).

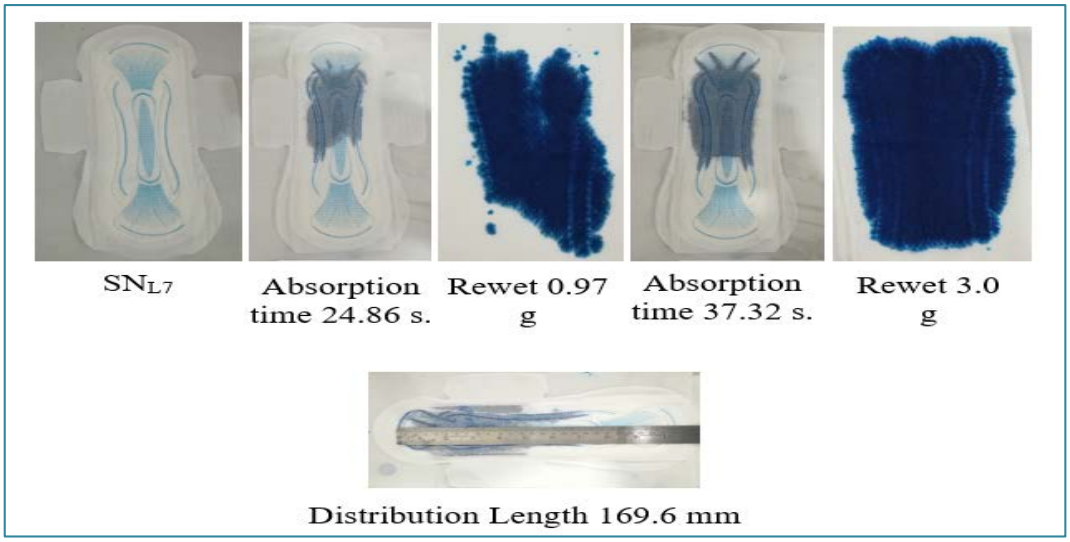

Fig. 4.15 Absorbency, rewet, and distribution length of sanitary napkin (SN_{L7}).

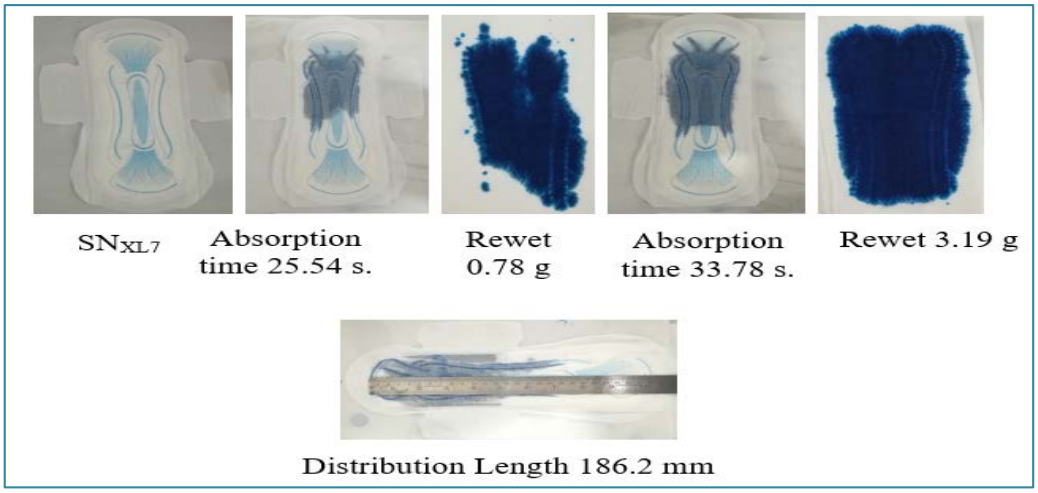

Fig. 4.16 Absorbency, rewet, and distribution length of sanitary napkin (SN_{XL7}).

Table 4.13 Absorption, rewet, and distribution length for the skiny-thin large sanitary napkins

Sr. No	Napkin code	Napkin type	1st cycle absorbent time for 15ml (s)	1st cycle rewet (g)	2nd cycle absorbent time for 15ml (s)	2nd cycle rewet (g)	Distribution length (mm)
1	SN_{L8}	Skiny-thin	11.50	1.48	20.14	3.53	171.0
2	SN_{L9}	Skiny-thin	14.82	1.85	21.96	3.40	168.6
3	SN_{L10}	Skiny-thin	12.00	1.46	20.48	3.41	173.8

The skiny-thin sanitary napkins are made from environmental friendly and biodegradable materials. Both the absorption and rewet test results for the three skiny-thin samples of large and extra-large size sanitary napkins are provided in Table 4.13 and 4.14, respectively. These tables summarise the findings of the tests. For this investigation, a total of five napkins of each size were evaluated and its average is represented in all tables. The material selected for the top sheet of skiny-thin sanitary napkins are organic cotton for SN_{L8} and SN_{LX8}, corn-PLA material for SN_{L9} and SN_{LX9} and silk fibres for SN_{L10} and SN_{LX10}. Furthermore, the test images for all six samples, which include three large and three extra-large sanitary napkins, are shown in Figures 4.17 to 4.22. These figures include the whole set of sanitary napkins. A graphical representation of the various skiny-thin types of large-sized sanitary napkins according to their absorption and rewet characteristics is shown in Figure 4.31. In the first cycle, the average absorption time for synthetic blood by a variety of skiny-thin large sanitary napkins ranged from 11.50 to 14.82 s, and in the second cycle, it ranged from 20.14 to 20.48 s. During the first cycle, the average rewet ranged from 1.46 to 1.85 g, whereas during the second cycle, it ranged from 3.40 to 3.53 g.

.Fig. 4.27 Absorption time and rewet for large size of skiny-thin type sanitary napkins. (SN_{L8}, SN_{L9}, and SN_{L10})

The test images are shown for each of the six samples of the skiny-thin type, which included three samples of large sanitary napkins and three samples of extra-large sanitary napkins, respectively, and can be found in Figure 4.17 and Figure 4.22. The blood distribution length at the end of test is observe highest in SN_{L10} i.e. 173.8 mm and lowest in SN_{L2} sample i.e. 168.56 mm.

From Table 4.13 it is observed that the average absorption time for both the cycles each of 15ml is minimum i.e. 11.5 s and 20.14 s respectively for SN_{L8} sample and the maximum average absorption time taken for both the cycles i.e. 14.82 s and 21.96 s respectively by SN_{L9} sample. The minimum average rewet property is observed in SN_{L10} sample in both the cycles i.e. 1.46 g and 3.41 g respectively among all the samples and the maximum average rewet property is observed in SNL9 sample in both the cycles i.e. 1.85 g and 3.4 g respectively.

The SN_{L8} sample has shown the minimum absorption time in both the cycles as compare to the other samples (SN_{L9} and SN_{L10}). SN_{L8} has shown 22.40% reduction in first cycle and 8.30% reduction in second cycle in absorption time than SN_{L9} sample which has shown the highest time of absorption both the cycles i.e. 14.82 and 21.96 seconds respectively. The other sample SN_{L10} has shown the 19.0% reduction in first cycle and 6.7% reduction in second cycle in absorption time than SN_{L9} sample as shown in table 4.11.

Due to the structural feature of the selected polymers, the absorbency property also differ as per their polymeric nature. The SN_{L8} sanitary napkin, the top sheet is made up of organic cotton has shown the least time in fluid absorbency among all samples, it may be due to the cellulosic in nature of organic cotton and is having highly amorphous and random structure of polymers i.e. open structure. In polymer matrix, there is high open space due to random arrangement of the cellulosic polymer chains. So, it can absorb the fluid faster and also can absorb high quantity of fluid.

In SN_{L9} sanitary napkin, the top sheet is made up case of Corn-PLA material, and it has shown the moderate reduction in absorption of fluid. This may be due to the corn belongs to the cellulosic category and the PLA belongs to the protein category. So, corn material will have highly amorphous and random structure of polymer chains i.e. open structure. In polymer matrix, there is high open space due to random arrangement of the cellulosic/polymeric chains. So, it can absorb the fluid faster and also high quantity. The PLA is a protein material and the protein is hydrophobic in nature and also the structural feature of

polymer matrix is uniformly arranged as compare to the cellulosic amorphous open structure, therefore the absorbency of PLA is less as compare to the cellulosic material. So, the combination of cellulosic and protein materials i.e. corn and PLA has given a moderate absorbency character of fluid.

The SN_{L10} sanitary napkin top sheet is made up of silk fibres, which is a protein fibre and the protein is in the form of fibroin and sericin and also having polyamide group. The polymeric structure of silk fibre is also well organized and well oriented. Protein is hydrophobic in nature as compare to cellulose. Therefore, silk has exhibited comparatively slower absorbency than cellulosic materials.

The Fig. 4.17 to 4.22 show that there is no leakage observed in any of the six samples of skiny-thin large and extra-large sanitary napkins.

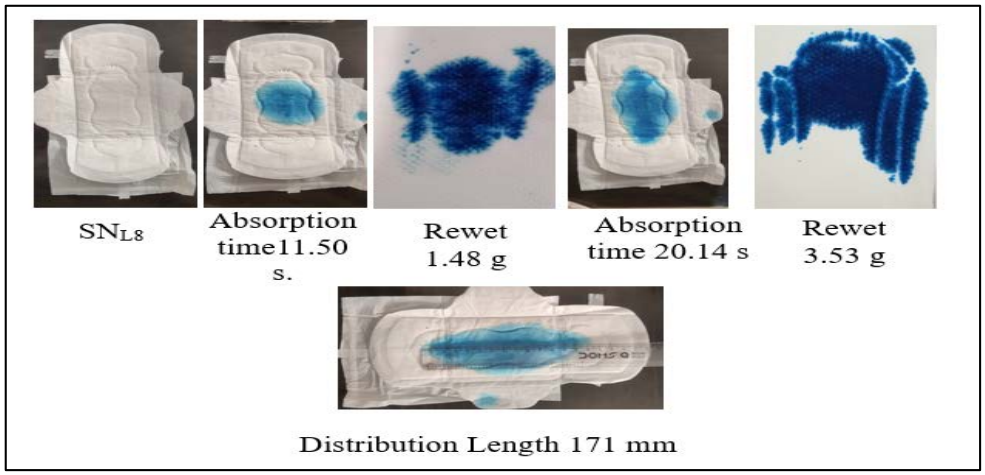

Fig. 4.17 Absorbency, rewet, and distribution length of sanitary napkin (SN_{L8}).

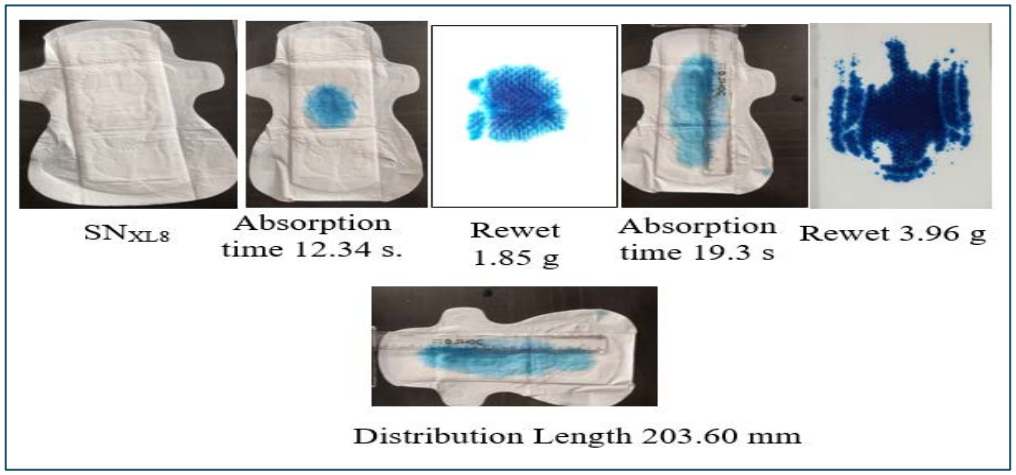

Fig. 4.18 Absorbency, rewet, and distribution length of sanitary napkin (SN_{XL8}).

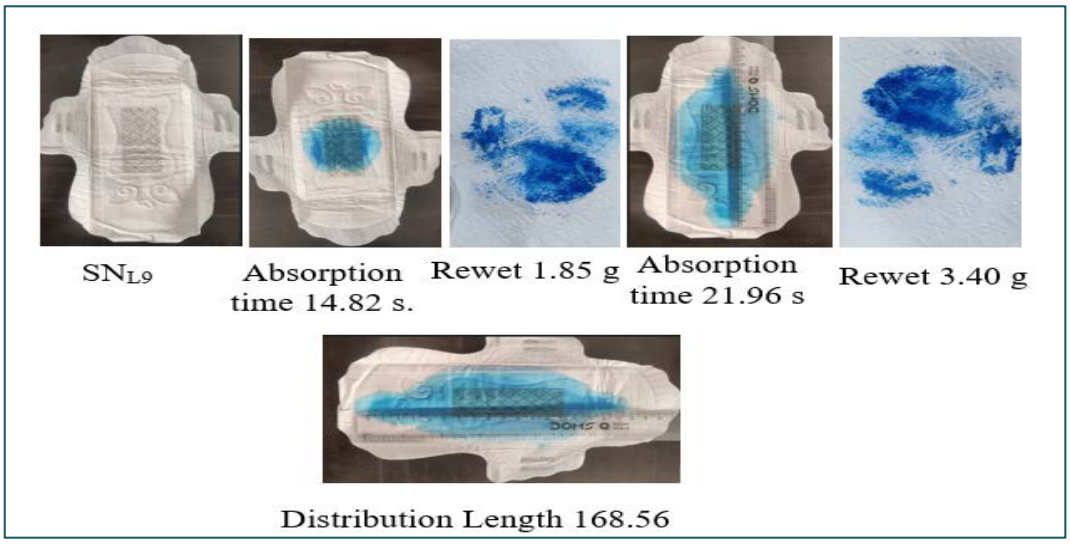

Fig. 4.19 Absorbency, rewet, and distribution length of sanitary napkin (SN_{L9}).

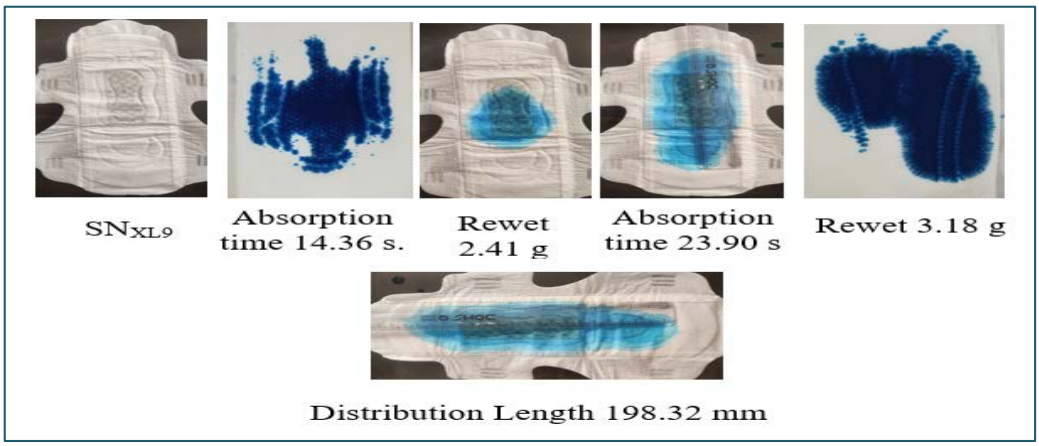

Fig. 4.20 Absorbency, rewet, and distribution length of sanitary napkin (SN_{XL9}).

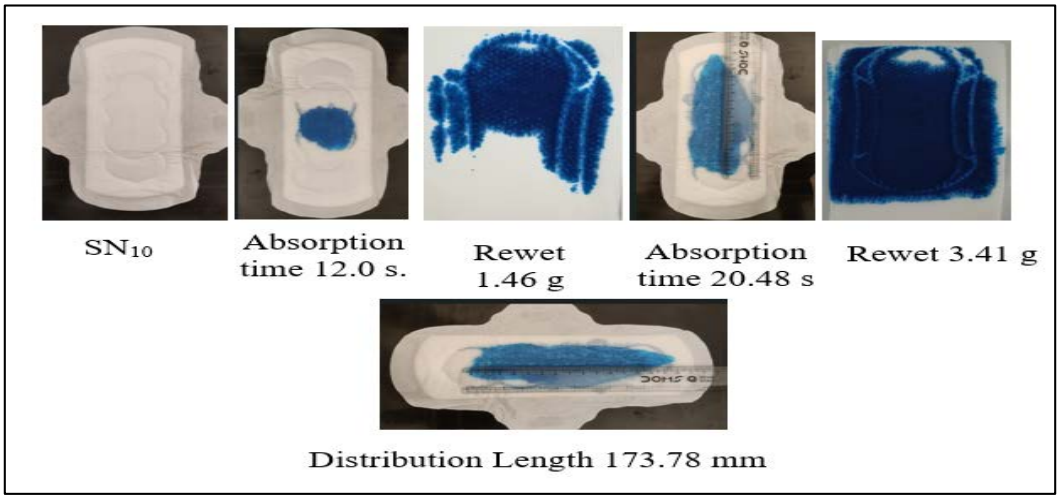

Fig. 4.21 Absorbency, rewet, and distribution length of sanitary napkin (SN_{X10}).

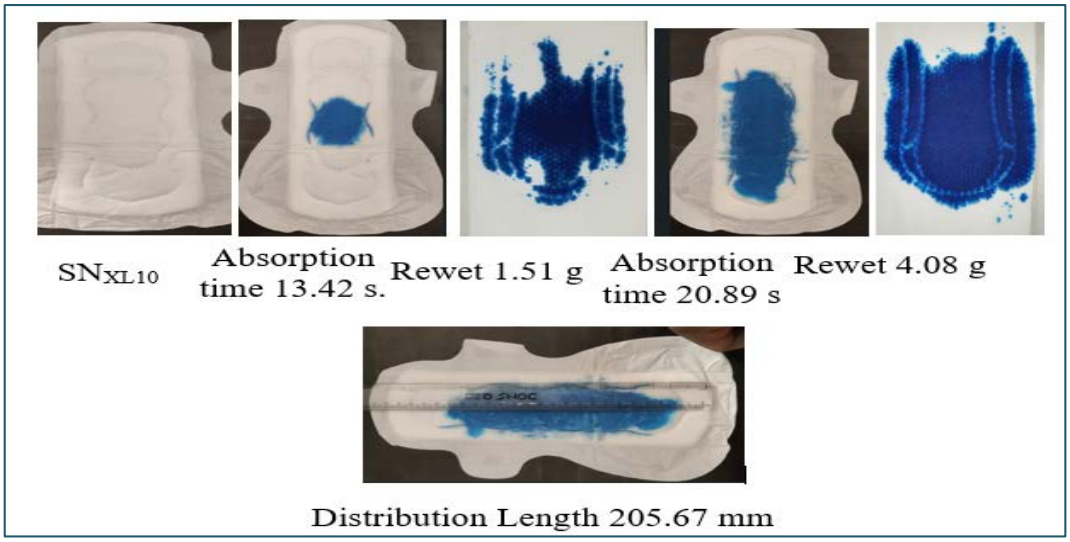

Fig. 4.22 Absorbency, rewet, and distribution length of sanitary napkin (SN_{X10}).

Table 4.14 Absorption, rewet, and distribution length for the skiny-thin extra-large sanitary napkins

Sr. No	Napkin code	Napkin type	1st cycle absorbent time for 15ml (s)	1st cycle rewet (g)	2nd cycle absorbent time for 15ml (s)	2nd cycle rewet (g)	Distribution length (mm)
1	SN_{XL8}	Skiny-thin	12.34	1.85	19.30	3.96	203.60
2	SN_{XL9}	Skiny-thin	14.36	2.41	23.90	3.18	198.32
3	SN_{XL10}	Skiny-thin	13.42	1.51	20.89	4.08	205.67

The absorption and rewet property of skiny-thin extra-large samples, specifically SN_{XL8}, SN_{XL9}, and SN_{XL10}, are displayed in Table 4.14. Additionally, a graphical representation of these samples can be seen in Fig. 4.32. The mean absorption duration of the synthetic blood by various skiny-thin extra-large sanitary napkins ranged from 12.34 to 14.36 s in the first cycle and from 19.30 to 23.90 s in the second cycle. In the first cycle, the average rewet ranged from 1.51 to 2.41 g, whereas in the second cycle it ranged from 3.18 to 4.08 g. The findings show a similar pattern to those of skiny-thin large sanitary napkins. In SN_{XL8}, the absorption time decreased by 14.1% in cycle 1 and by 19.2% in cycle 2, compared to the SN_{XL9} sample which has the longest absorption duration of 14.36 s in cycle 1 and 23.90 s in cycle 2. The Fig. 4.17 to Fig. 4.22 show that there is no leakage observed in any of the six samples of ultra-thin large and extra-large sanitary napkins.

Fig. 4.28 Absorption time and rewet for extra-large size of skiny-thin type sanitary napkins. (SN_{XL8}, SN_{XL9}, and SN_{XL10})

Fig. 4.29 Comparison of absorption time for large size maxi, ultra-thin and skiny-thin sanitary napkins for cycle 1 and cycle 2

Fig. 4.30 Comparison of absorption time for extra-large size maxi, ultra-thin and skiny-thin sanitary napkins for cycle 1 and cycle 2

From Fig. 4.29 and Fig. 4.30 shows the comparison of absorption time for the large size maxi, ultra-thin and skiny-thin sanitary napkins for cycle 1 and cycle 2. It is observed that the ultra-thin sanitary napkins which are made up of biodegradable materials have shown the least absorption time among all samples in both the cycles. After skiny-thin sanitary napkins, the maxi sanitary napkins shown the higher absorption time and the ultra-skin has shown the highest absorption time among all the sanitary napkins. The reason for lowest absorption time for skiny-thin sanitary napkin may be due to its hydrophilic nature of top sheets among all the samples. The increase in absorption time of ultra-thin sanitary napkin may be due to its hydrophobic nature.

Fig. 4.31 Comparison of rewet for large size maxi, ultra-thin and skiny-thin sanitary napkins for cycle 1 and cycle 2

Fig. 4.32 Comparison of rewet for extra-large size maxi, ultra-thin and skiny-thin sanitary napkins for cycle 1 and cycle 2

From Fig. 4.34 and Fig. 4.35 shows the comparison of rewet property for the large and extra-large size maxi, ultra-thin and skiny-thin sanitary napkins for cycle 1 and cycle 2.

It is observed that the SN_{L3}, SN_{XL3} samples have shown the lower rewet property in first and second cycle. It may be due to their hydrophobic nature and lower pore structure of top sheets. The SN_{L1} and SN_{XL8} sanitary napkins have shown the highest rewet property in cycle 1 and cycle respectively.

4.5 Peel adhesion

The present study focuses on the preparation of disposable sanitary napkins, which are classified on the basis of their thickness property and are named as maxi (7.5 to 13 mm), ultra-thin (6.5 mm), and skiny-thin (6.0 mm), and each category has different sizes of sanitary napkins. An adhesive is coated at the back sheet of a sanitary napkin. The adhesive area is usually covered by the release paper, which is typically applied to the adhesive attachment point. The function of the release paper is to protect the adhesive from impurities. Before sticking the sanitary napkin to their undergarment, it needs to pull-out the release paper. Hot melt adhesives, which are made up of polymers like polyolefin, are used as positioning adhesives in absorbent materials. As the market shifting towards fashionable undergarments produced from microfiber materials, which provide a smooth, flexible, and comfortable feeling, adhesive materials used for positioning must possess the capability to adhere to microfiber fabrics as well as other types of fabrics, including cotton and other fibres. Furthermore, these adhesives should securely hold absorbent articles in place without leaving any adhesive residue on the undergarment after removal. The materials are peeled apart at a constant speed, and the strength of the force needed to separate the materials from bonded surface is measured to determine the peel strength. The positioning glue (adhesive) is applied on the back side and wings of the napkins. The peel strength test measures the strength of the glue by testing materials that are stuck together. The amount of force needed to separate two surfaces joined together by an adhesive is known as peel adhesion. Adequate peel strength is necessary to guarantee a strong adhesion between the surfaces of a disposable item. In severe instances, inadequate peeling might cause the disposition of the napkin. The higher peel strength, on the other hand, may cause the back side to get detached from the napkin. It is crucial to comprehend the manner in which the disposable product will be utilised and the external pressures it will withstand during its usage. These parameters will help in the selection of the appropriate adhesive to fulfil the need.

In order to achieve the goal of the research, each and every one of the product samples, which included Maxi, Ultra-thin, and Skiny-thin, were both analysed concurrently in the 240 mm and 280 mm size configurations i.e. large and extra-large size of sanitary napkins. The adhesion properties of the produced samples were analysed by measuring the peeling force required to separate the two surfaces of the sanitary napkin that were glued together.

Table 4.15 Peel adhesion of 240 mm large size of sanitary napkins

Sr. No	Product Code	Napkin Type	Peel force (gf)	
			Front	Back
1	SN_{L1}	MAXI	134.2	131.1
2	SN_{L2}	MAXI	128.4	131.4
3	SN_{L3}	MAXI	134.2	137.6
4	SN_{L4}	MAXI	132.8	133.6
5	SN_{L5}	Ultra-thin	133.8	133.4
6	SN_{L6}	Ultra-thin	141.4	142.8
7	SN_{L7}	Ultra-thin	150.2	154.6
8	SN_{L8}	Skiny-thin	144.3	154.7
9	SN_{L9}	Skiny-thin	153.6	155.8
10	SN_{L10}	Skiny-thin	147.0	140.2

A thorough study was conducted on the maxi, ultra-thin, and skin-thin sanitary napkins, each measuring 240 mm in size which is known as the large size of the napkin. The results of peel adhesion tests performed on large and extra-large variants of sanitary napkins are shown in Table 4.15 and Table 4.16. The bar chart in Fig. 4.33 displays the peel strength results for different types of sanitary napkins with 240 mm large size.

The peel adhesion test is used to quantify the force required for the detachment of two bonded components. The test result, referred to as peel force, is often quantified in gf (the amount of force needed for deboning).

Fig. 4.33 Peel strength of 240 mm large size of sanitary napkins

Table 4.16 Peel adhesion of 280 mm extra-large size of sanitary napkins

Sr. No	Product Code	Napkin type	Peel force (gf)	
			Front	Back
1	SN_{XL1}	MAXI	126.00	123.60
2	SNx_{L2}	MAXI	128.40	137.60
3	SNx_{L3}	MAXI	144.80	147.40
4	SNx_{L4}	MAXI	138.64	140.60
5	SNx_{L5}	Ultra-thin	141.40	142.80
6	SNx_{L6}	Ultra-thin	133.00	136.80
7	SNx_{L7}	Ultra-thin	144.40	147.40
8	SNx_{L8}	Skiny-thin	153.60	148.80
9	SNx_{L9}	Skiny-thin	153.20	152.20
10	SNx_{L10}	Skiny-thin	148.00	155.00

The peel adhesion force of sanitary napkins typically falls within the range of 80 gf to 200 gf, as per industrial standard. According to Table 4.15, among the maxi large size sanitary napkins (SNL1, SNL2, SNL3, and SNL4), SNL3 has the greatest peel adhesion strength. Additionally, among the category of ultra-thin large sanitary napkins (SNL5, SNL6, and SNL7), SNL7 has the highest peel adhesion strength. Out of the three skiny-thin large-sized sanitary napkins (SNL8, SNL9, and SNL10) SNL9 has the highest peel adhesion strength. All the napkins met the standard range for peel strength.

Fig. 4.34 Peel strength of 280mm extra-large size of sanitary napkins

A study was carried out on the maxi, ultra-thin, and skin-thin sanitary napkins, all of which have a size of 280 mm, referred to as the extra-large size. The bar chart shown in Figure 4.34 illustrates the peel strength results for several categories of sanitary napkins, namely those with an extra-large size of 280 mm. The peel adhesion property of several 280mm extra-large size maxi, ultra-thin, and skiny-thin kinds of sanitary napkins is shown in Table 4.16. Among the maxi extra-large size sanitary napkins (SN_{XL1}, SN_{XL2}, SN_{XL3}, and SN_{XL4}), SN_{XL3} has the highest peel adhesion strength. Furthermore, among the ultra-thin extra-large sanitary napkin category (SN_{XL5}, SN_{XL6}, and SN_{XL7}), SN_{XL7} has the greatest peel adhesion strength. Among the three skiny-thin sanitary napkins of extra-large size, namely SN_{XL8}, SN_{XL9}, and SN_{XL10}, SN_{XL10} has the greatest peel adhesion strength. All the napkins complied with the specified range of peel strength.

4.6 Seal Strength

A sanitary napkin (pad) consists of multiple layers which are sealed with a glue called as construction glue. The defective sealing of the layers can result in leakage of the sanitary napkin. Such leakage pad is never been accepted by the user. The different methods available to seal various layers of the napkin are:

(a) Adhesive sealing
(b) Ultrasonic technology
(c) Heat sealing

Out of these three methods of sealing in this research, the heat sealing method is used to produce all the samples.
In Adhesive sealing method uses glue as a sealing agent in which two types of adhesives are used namely (i) cold-melt adhesive and (ii) hot-melt adhesive. In Ultrasonic technology, the sealing process uses an acoustic vibration to generate heat and cause the thermoplastic fibres to bond together for sealing the pad. The Heat sealing method, glue hot melt is sprayed across the whole back sheet and on the border of the core material. Then the sealing of all the layers is done by hot die pressure which will help in avoiding the risk of leakage of napkin. This process causes the sealing of top sheet, back sheet, and absorbent core materials.

In the present study, the sealing of the sanitary napkin is done by the heat sealing, boundary sealing, and adhesive hot melt sealing. The findings of seal strength tests that were carried out on different categories of sanitary napkins like maxi, ultra-thin and skiny-thin with large and extra-large sizes. The test results for these sanitary napkins and the graphical bar chart presentation of various types of large and extra-large samples is done in Table 4.17, Table 4.18, Fig. 4.35 and Fig. 4.36 respectively. The seal strength refers to the amount of force required to break the seal at room temperature, as per ASTM F88. The sample were tested for seal strength on a Universal Testing Machine with the model no. I050322496 and the make of Hemtech pvt. ltd. The test result, referred to as seal strength, is quantified in gf (gram force). According to industry standards, the seal strength of sanitary napkin should be greater than 300 gf. Below limit seal strength may lead to an increased risk of napkin leakage. The seal strength is measured for the front side, back side, left side and right side i.e. for all four sides of sanitary napkins for all large and extra-large sanitary napkins.

Table 4.17 Seal strength of 240 mm large size sanitary napkins

Sr. No	Product Code	Napkin type	Seal strength (g)			
			Front	Back	Operator side	Driver side
1	SN_{L1}	MAXI	591	580	423	449
2	SN_{L2}	MAXI	525	514	445	404
3	SN_{L3}	MAXI	484	528	524	519
4	SN_{L4}	MAXI	552	582	476	485
5	SN_{L5}	Ultra-thin	637	571	410	351
6	SN_{L6}	Ultra-thin	627	545	392	368
7	SN_{L7}	Ultra-thin	579	540	451	483
8	SN_{L8}	Skiny-thin	540	476	523	534
9	SN_{L9}	Skiny-thin	510	535	565	530
10	SN_{L10}	Skiny-thin	475	490	503	524

From table 4.17, it can be observed that all the sanitary napkins are having seal strength above the standard limit i.e. 300 gf. The highest seal strength for front side of the napkin is observed in SN_{L5} i.e. 637 gf. The seal strength of napkin on back side, sample SN_{L1} has shown the lead i.e. 580 gf. The SN_{L9} sanitary napkin has shown the highest seal strength i.e. 565 gf for left side wing which is also known as operator side wing of napkin. In right side wing which is also known as the drive side wing, the seal strength property is shown highest by SNL8 napkin i.e. 534 gf.

Fig. 4.35 Seal strength of 240 mm large size sanitary napkins

Table 4.18 Seal strength of 280 mm extra-large size sanitary napkins

Sr. No	Product Code	Napkin type	Seal strength (g)			
			Front	Back	Operator side	Driver side
1	SN_{XL1}	MAXI	636	618	467	423
2	SN_{XL2}	MAXI	531	490	438	435
3	SN_{XL3}	MAXI	538	537	541	549
4	SN_{XL4}	MAXI	579	499	470	483
5	SN_{XL5}	Ultra-thin	644	573	372	358
6	SN_{XL6}	Ultra-thin	612	538	385	378
7	SN_{XL7}	Ultra-thin	582	569	483	461
8	SN_{XL8}	Skiny-thin	476	510	534	564
9	SN_{XL9}	Skiny-thin	523	527	539	521
10	SN_{XL10}	Skiny-thin	480	526	563	512

Table 4.18 shows the seal strength for extra-large size sanitary napkins measuring 280 mm, whereas Fig 4.36 provides a graphical depiction of these results in the form of a bar chart. Table 4.18 shows that all the sanitary napkins have a seal strength above the regulatory limit of 300 gf. It has been observed that SN_{XL5} has the maximum seal strength for the front side of the napkin, which is 644 gf. The napkin's seal strength on back side, as shown by sample SN_{L1}, had a leading value of 618 gf. The left side wing of the SN_{L10} sanitary napkin, which is also referred to as the operator side wing of the napkin, has shown the greatest seal strength; specifically, it has a value of 563 gf. In the right side wing, which is also referred to as the drive side wing, the SN_{L8} napkin has the greatest seal strength characteristic, which is measured at 564 gf.

Fig. 4.36 Seal strength of 280 mm extra-large size sanitary napkins

4.7 Adhesive residue Test

The sanitary napkin is consists of a body-contacting top sheet, ADL (Acquisition Distribution Layer), an absorbent material (core material) for menstrual blood and other fluids, a leak-proof layer at the bottom called as back sheet, and an adhesive coating on the back of the back sheet for secure attachment to undergarments, preventing displacement during use. The pad should be equipped with wings to facilitate attachment to the undergarments. A coated paper known as a release paper, which is made of silicone-coated paper. The glue of the adhesive release liner needs to be sticky enough and should be firmly stuck the mounted pad to the fabric surface of the underwear's crotch area.

Adhesive residue refers to the degree of stability shown by a sanitary napkin when it is detached from an undergarment after being used. The adhesive residue is examined by measuring the amount of time needed to detach the adhesive from the cloth commonly used in the production of undergarments. According to Industrial standards the time required to separate the napkin from the undergarment should be less than three seconds.

The primary goal of removing adhesive tape from a temporary application is to ensure that the surface is left completely clean and free of any residue. The left hand is used to grasp the end of the cotton fabric, and the right hand is used to make a continuous motion in order to peel the product away from the cotton fabric. The whole separation process takes around three seconds to complete.

The adhesive residue test was carried out for different categories of sanitary napkins like maxi, ultra-thin and skiny-thin with large and extra-large sizes. The test results for the sanitary napkins and the graphical bar chart presentation of various types of large and extra-large samples is done in Table 4.19, Table 4.20, Fig. 4.37 and Fig. 4.38 respectively. This adhesive residue indicates the nature of the napkin whether it will get separated easily without any tresses of the adhesive on the undergarment where it is adhered. The results of adhesive residue property for large size of sanitary napkins of different categories are shown in Table 4.19. From this table it can be observed that adhesive residue property of all the large size napkins is within the standard time limit i.e. less than three seconds. The SN_{L10} skiny-thin napkin and SN_{L1} maxi napkin have shown the 2.80 s, which is the highest among all the napkins while SN_{L9} skiny-thin napkin has shown 1.54 s, which is the lowest among all

the napkins, but both these values are less than three seconds, which are within standard time limit.

Table 4.19 Adhesive residue property of 240 mm large size sanitary napkins

Sr. No	Product Code	Napkin type	Time (s)
1	SN_{L1}	MAXI	2.80
2	SN_{L2}	MAXI	1.62
3	SN_{L3}	MAXI	1.58
4	SN_{L4}	MAXI	2.24
5	SN_{L5}	Ultra-thin	2.32
6	SN_{L6}	Ultra-thin	2.68
7	SN_{L7}	Ultra-thin	2.52
8	SN_{L8}	Skiny-thin	2.38
9	SN_{L9}	Skiny-thin	1.54
10	SN_{L10}	Skiny-thin	2.80

It indicates that the achieved adhesive residue property is safe for the user. It will not cause any kind of distortion or damage to the napkin during its separation from undergarment after use.

Fig. 4.37 Adhesive residue property of 240 mm large size sanitary napkins

Table 4.20 displays the adhesive residue property values for extra-large sanitary napkins of various types. Upon examination of the table, it is evident that the adhesive residue characteristic of all the napkins of extra-large dimensions adheres to the prescribed time limit, specifically, less than three seconds.

Table 4.20 Adhesive residue property of 280 mm extra-large size sanitary napkins

Sr. No	Product Code	Napkin type	Time (s)
1	SN_{XL1}	MAXI	2.84
2	SNx_{L2}	MAXI	2.34
3	SNx_{L3}	MAXI	2.58
4	SNx_{L4}	MAXI	2.50
5	SNx_{L5}	Ultra-thin	2.32
6	SNx_{L6}	Ultra-thin	2.70
7	SNx_{L7}	Ultra-thin	2.68
8	SNx_{L8}	Skiny-thin	2.56
9	SNx_{L9}	Skiny-thin	2.44
10	SNx_{L10}	Skiny-thin	2.86

The SN_{XL10} napkin, the skiny-thin design, demonstrated a duration of 2.86 seconds, the longest among all napkins. On the other hand, the SN_{XL5} ultra-thin napkin recorded the shortest time of 2.32 seconds. However, it is important to note that all of these times fall inside the standard limits of three seconds. This signifies that the adhesive residue characteristic that has been attained is safe for the user. The removal of the pad from the undergarment after usage will not result in any deformation or damage.

Fig. 4.38 Adhesive residue property of 280 mm extra-large size sanitary napkins

4.7 pH Test

The sanitary napkin should have hygiene property as it remains in contact with the delicate skin of the body and the skin is a protein-rich material. So, the pH value of the sanitary napkin should be in the standard range. According to IS 1390 cold method, a sanitary napkin should have the pH value in the range of 5.5 to 8. This means that the pH value of sanitary napkin should neither be too acidic i.e. less than 5.5 nor be too alkaline i.e. higher than 8, it may cause degradation of the skin in terms of rashes, itching, etc. problems. These problems may lead to discomfort or irritation to the user.

Table 4.21 pH property of 240 mm large size sanitary napkins

Sr. No	Product Code	Napkin type	Time (s)
1	SN_{L1}	MAXI	6.16
2	SN_{L2}	MAXI	6.40
3	SN_{L3}	MAXI	6.44
4	SN_{L4}	MAXI	6.16
5	SN_{L5}	Ultra-thin	6.60
6	SN_{L6}	Ultra-thin	6.80
7	SN_{L7}	Ultra-thin	6.40
8	SN_{L8}	Skiny-thin	6.86
9	SN_{L9}	Skiny-thin	6.32
10	SN_{L10}	Skiny-thin	7.26

The pH test was carried out for different categories of sanitary napkins like maxi, ultra-thin and skiny-thin with large and extra-large sizes. The test results for the sanitary napkins and the graphical bar chart presentation of various types of large and extra-large samples is done in Table 4.21, Table 4.22, Fig. 4.39 and Fig. 4.40 respectively. The pH value indicates the nature of the napkin whether it is acidic or alkaline or neutral. The results of pH value for large size of sanitary napkins of different categories are shown in Table 4.21. From this table it can be observed that the pH value of all the large size napkins is within the standard range given in IS 1390 i.e. 5.5 to 8. The SN_{L10} skiny-thin napkin has shown the 7.26 pH value which is the highest among all the napkins while SN_{L1} maxi and SN_{L4} ultra-thin napkins have shown 6.16 pH value which is the lowest among all the napkins, but both these pH

values are within the range of acceptable limits of pH values. It indicates that the achieved pH value is safe for the user. It will not cause any kind of discomfort or irritation.

Fig. 4.39 pH property of 240 mm large size sanitary napkins

Table 4.22 pH property of 280 mm extra-large size sanitary napkins

Sr. No	Product Code	Napkin type	Time (s)
1	SN_{XL1}	MAXI	6.22
2	SNx_{L2}	MAXI	6.50
3	SNx_{L3}	MAXI	6.46
4	SNx_{L4}	MAXI	6.28
5	SNx_{L5}	Ultra-thin	6.62
6	SNx_{L6}	Ultra-thin	6.68
7	SNx_{L7}	Ultra-thin	6.50
8	SNx_{L8}	Skiny-thin	6.82
9	SNx_{L9}	Skiny-thin	6.28
10	SNx_{L10}	Skiny-thin	7.30

Table 4.22 displays the pH values of extra-large sanitary napkins in three categories, such as maxi, ultra-thin, and skiny-thin. Upon examination of the table, it is evident that the pH value of all the napkins of extra-large size falls within the specified range according to IS 1390, which is 5.5 to 8. The SN_{XL10} skiny-thin napkin has shown a pH value of 7.3, which is the highest among all napkins. Conversely, the SNL1 maxi napkin has shown a pH value of 6.22,

which is the lowest among all napkins. However, all of these pH values are within the permitted range. This signifies that the attained pH level is deemed safe for the user. It will not induce any kind of pain or inflammation.

Fig. 4.40 pH property of 280 mm extra-large size sanitary napkins

4.5 Costing for Sanitary Napkin

Sanitary napkins are feminine hygiene products engineered to absorb menstrual flow during the menstruation cycle. Layers of absorbent materials make up the sanitary napkin, allowing it to absorb and contain menstrual fluid, ensuring comfort, cleanliness, and preventing staining. Sanitary napkins are available in different sizes, shapes, and absorption levels to suit varying physical needs and flow levels. People extensively use sanitary napkins in various settings, including homes, schools, workplaces, and public facilities. The current study involves the manufacture of sanitary napkins through the investigation of various materials and configuration possibilities, resulting in the development of a disposable sanitary pad. In this study, the different types of materials use as per the three categories of sanitary napkins are; the first is, Maxi type ($TS_1/TS_2/TS_3/TS_4$ + DL_3 + AC_1 + AM_1+ AM_2+ RP_1 + BS_1), the Ultra-thin type ($TS_3/TS_4/TS_5$ + DL_1 + AC_2 + AM_1+ AM_2+ RP_1 + BS_1), and the Skiny-thin type ($TS_6/TS_7/TS_8$ + DL_2 + AC_3 + AC_6 + AM_3 + RP_1 + BS_2). Within the scope of this study, an examination is being carried out to investigate the utilisation of four various types of top sheets for maxi-type sanitary napkins, three types of top sheets for ultra-thin napkins, and three types for skiny-thin napkins. All the samples generated as a result of this research have characteristics and features comparable to those of the commercial products available in the market. These examples show that it is possible to make a pad that meets modern standards and also the cost. However, the products which are good for the environment may cost more. The escalating cost of sanitary napkin products can be attributed to the fact that manufacturers prioritise comfort and aesthetics over cost-effectiveness in their product development. The purpose of this research is to concentrate on the production of environmentally friendly products. In the current study, the manufacturing costs for the sanitary napkins were calculated, considering all available raw materials in the market. The Tables 4.18 to 4.22 below provides the cost breakup for various sanitary napkins of two sizes of 240 mm and 280 mm.

Table 4.23 Cost calculation of SN_{L1} and SN_{XL1} sanitary napkins

Raw Material Price						Cost of SNL1 (240mm)						Cost of SNXL1 (280mm)					
Raw Material (RM) code	R.M price (Rs/kg.)	GST (%)	Price with GST (Rs.)	Raw material (240 280) (GPP GSM)		Length (mm)	Width (mm)	AREA (m^2)	Consumption (gm)	(%)	Napkin Cost (Rs./Pcs)	Length (mm)	Width (mm)	AREA (m2)	Consumption (gm)	(%)	Napkin Cost (Rs./Pcs)
AC1	95	12%	106.40	0.2/0.3	GPP	NA	NA	NA	0.20	1.7%	0.02	NA	NA	NA	0.30	1.9%	0.03
AC1	130	12%	145.60	4.2/6.5	GPP	NA	NA	NA	4.20	49.1%	0.61	NA	NA	NA	6.50	55.8%	0.95
TS1	115	12%	128.80	18	GSM	240	180	0.043	0.78	8.0%	0.10	280	180	0.050	0.91	6.9%	0.12
DL3	160	12%	179.20	16	GSM	240	160	0.038	0.61	8.8%	0.11	280	160	0.045	0.72	7.6%	0.13
BS1	160	18%	188.80	16	GSM	240	180	0.043	0.69	10.5%	0.13	280	180	0.050	0.81	9.0%	0.15
RP1	210	12%	235.20	29	GSM	230	50	0.012	0.33	6.3%	0.08	270	50	0.014	0.39	5.4%	0.09
RP1	210	12%	235.20	29	GSM	50	55	0.003	0.08	1.5%	0.02	50	55	0.003	0.08	1.1%	0.02
AM1	240	18%	283.20	0.45/0.55	GPP	NA	NA	NA	0.45	10.2%	0.13	NA	NA	NA	0.55	9.2%	0.16
AM2	280	18%	330.40	0.14/0.16	GPP	NA	NA	NA	0.14	3.7%	0.05	NA	NA	NA	0.16	3.1%	0.05
GROSS WEIGHT									**7.49**						**10.41**		
TOTAL - Cost										100%	**1.24**					100%	**1.70**

Table 4.24 Cost calculation of SN_{L2} and SN_{XL2} sanitary napkins

Raw Material Price						Cost of SNL2 (240mm)						Cost of SNXL2 (280mm)					
Raw Material (R.M.)	R.M price (Rs.)	GST (%)	Price with GST (Rs.)	Raw material (240/280) (GPP/GSM)		Length (mm)	Width (mm)	AREA (m^2)	Consumption (gm)	(%)	Napkin Cost (Rs./Pcs)	Length (mm)	Width (mm)	AREA (m^2)	Consumption (gm)	(%)	Napkin Cost (Rs./Pcs)
AC1	95	12%	106.40	4.2/6.5	GPP	NA	NA	NA	0.20	1.6%	0.02	NA	NA	NA	0.30	1.7%	0.03
AC1	130	12%	145.60	4.2/6.5	GPP	NA	NA	NA	4.20	44.9%	0.61	NA	NA	NA	6.50	51.6%	0.95
TS2	250	12%	280.00	18	GSM	240	180	0.043	0.78	16.0%	0.22	280	180	0.050	0.91	13.9%	0.25
DL3	160	12%	179.20	16	GSM	240	160	0.038	0.61	8.1%	0.11	280	160	0.045	0.72	7.0%	0.13
BS1	160	18%	188.80	16	GSM	240	180	0.043	0.69	9.6%	0.13	280	180	0.050	0.81	8.3%	0.15
RP1	210	12%	235.20	29	GSM	230	50	0.012	0.33	5.8%	0.08	270	50	0.014	0.39	5.0%	0.09
RP1	210	12%	235.20	29	GSM	50	55	0.003	0.08	1.4%	0.02	50	55	0.003	0.08	1.0%	0.02
AM1	240	18%	283.20	0.45/0.55	GPP	NA	NA	NA	0.45	9.4%	0.13	NA	NA	NA	0.55	8.5%	0.16
AM2	280	18%	330.40	0.14/0.16	GPP	NA	NA	NA	0.14	3.4%	0.05	NA	NA	NA	0.16	2.9%	0.05
GROSS WEIGHT									**7.49**						**10.41**		
TOTAL - Cost											**1.36**					100%	**1.83**

Table 4.25 Cost calculation of SN_{L3} and SN_{XL3} sanitary napkins

Raw Material Price						Cost of SNL3 (240mm)						Cost of SNXL3 (280mm)					
Raw Material (RM) code	R.M price (Rs/kg.)	GST (%)	Price with GST (Rs.)	Raw material (240 (GPP	280) GSM)	Length (mm)	Width (mm)	AREA (m^2)	Consumption (gm)	(%)	Napkin Cost (Rs./Pcs)	Length (mm)	Width (mm)	AREA (m2)	Consumption (gm)	(%)	Napkin Cost (Rs./Pcs)
AC1	95	12%	106.40	4.2/6.5	GPP	NA	NA	NA	0.20	1.4%	0.02	NA	NA	NA	0.30	1.6%	0.03
AC1	130	12%	145.60	4.2/6.5	GPP	NA	NA	NA	4.20	41.2%	0.61	NA	NA	NA	6.50	48.0%	0.95
TS3	350	12%	392.00	20	GSM	240	180	0.043	0.86	22.8%	0.34	280	180	0.050	1.01	20.0%	0.40
DL3	160	12%	179.20	16	GSM	240	160	0.038	0.61	7.4%	0.11	280	160	0.045	0.72	6.5%	0.13
BS1	160	18%	188.80	16	GSM	240	180	0.043	0.69	8.8%	0.13	280	180	0.050	0.81	7.7%	0.15
RP1	210	12%	235.20	29	GSM	230	50	0.012	0.33	5.3%	0.08	270	50	0.014	0.39	4.7%	0.09
RP1	210	12%	235.20	29	GSM	50	55	0.003	0.08	1.3%	0.02	50	55	0.003	0.08	1.0%	0.02
AM1	240	18%	283.20	0.45/0.55	GPP	NA	NA	NA	0.45	8.6%	0.13	NA	NA	NA	0.55	7.9%	0.16
AM2	280	18%	330.40	0.14/0.16	GPP	NA	NA	NA	0.14	3.1%	0.05	NA	NA	NA	0.16	2.7%	0.05
GROSS WEIGHT									**7.57**						**10.51**		
TOTAL - Cost										100%	**1.48**					100%	**1.97**

Table 4.26 Cost calculation of SN_{L4} and SN_{XL4} sanitary napkins

Raw Material Price						Cost of SNL4 (240mm)						Cost of SNXL4 (280mm)					
Raw Material (R.M.)	R.M price (Rs.)	GST (%)	Price with GST (Rs.)	Raw material (240/280) (GPP/GSM)		Length (mm)	Width (mm)	AREA (m^2)	Consumption (gm)	(%)	Napkin Cost (Rs./Pcs)	Length (mm)	Width (mm)	AREA (m^2)	Consumption (gm)	(%)	Napkin Cost (Rs./Pcs)
AC1	95	12%	106.40	4.2/6.5	GPP	NA	NA	NA	0.20	1.4%	0.02	NA	NA	NA	0.30	1.6%	0.03
AC1	130	12%	145.60	4.2/6.5	GPP	NA	NA	NA	4.20	39.9%	0.61	NA	NA	NA	6.50	46.6%	0.95
TS4	400	12%	448.00	20	GSM	240	180	0.043	0.86	25.3%	0.39	280	180	0.050	1.01	22.2%	0.45
DL3	160	12%	179.20	16	GSM	240	160	0.038	0.61	7.2%	0.11	280	160	0.045	0.72	6.3%	0.13
BS1	160	18%	188.80	16	GSM	240	180	0.043	0.69	8.5%	0.13	280	180	0.050	0.81	7.5%	0.15
RP1	210	12%	235.20	29	GSM	230	50	0.012	0.33	5.1%	0.08	270	50	0.014	0.39	4.5%	0.09
RP1	210	12%	235.20	29	GSM	50	55	0.003	0.08	1.2%	0.02	50	55	0.003	0.08	0.9%	0.02
AM1	240	18%	283.20	0.45/0.55	GPP	NA	NA	NA	0.45	8.3%	0.13	NA	NA	NA	0.55	7.7%	0.16
AM2	280	18%	330.40	0.14/0.16	GPP	NA	NA	NA	0.14	3.0%	0.05	NA	NA	NA	0.16	2.6%	0.05
GROSS WEIGHT									**7.57**						**10.51**		
TOTAL - Cost											**1.53**						**2.03**

Table 4.27 Cost calculation of SN_{L5} and SN_{XL5} sanitary napkins

Raw Material Price						Cost of SNL5 (240mm)						Cost of SNXL5 (280mm)					
Raw Material (R.M.)	R.M price (Rs.)	GST (%)	Price with GST (Rs.)	Raw material (240/280) (GPP/GSM)		Length (mm)	Width (mm)	AREA (m^2)	Consumption (gm)	(%)	Napkin Cost (Rs./Pcs)	Length (mm)	Width (mm)	AREA (m^2)	Consumption (gm)	(%)	Napkin Cost (Rs./Pcs)
TS3	350	12%	392.00	20	GSM	240	90	0.022	0.43	9.0%	0.17	280	90	0.025	0.50	8.9%	0.20
TS1	115	12%	128.80	20	GSM	240	140	0.034	0.67	4.6%	0.09	280	140	0.039	0.78	4.6%	0.10
DL1	160	12%	179.20	25	GSM	80	40	0.003	0.08	0.8%	0.01	100	40	0.004	0.10	0.8%	0.02
AC2	230	12%	257.60	90	GSM	220	95	0.021	1.88	25.7%	0.48	260	95	0.025	2.22	25.8%	0.57
AC2	290	18%	342.20	150	GSM	220	60	0.013	1.98	36.0%	0.68	260	60	0.016	2.34	36.1%	0.80
BS1	190	18%	224.20	20	GSM	240	180	0.043	0.86	10.3%	0.19	280	180	0.050	1.01	10.2%	0.23
RP1	210	12%	235.20	29	GSM	230	50	0.012	0.33	4.2%	0.08	270	50	0.014	0.39	4.2%	0.09
RP1	210	12%	235.20	29	GSM	60	65	0.004	0.11	1.4%	0.03	60	65	0.004	0.11	1.2%	0.03
AM1	215	18%	253.70	0.45/0.55	GPP	NA	NA	NA	0.45	6.1%	0.11	NA	NA	NA	0.55	6.3%	0.14
AM2	230	18%	271.40	0.14/0.16	GPP	NA	NA	NA	0.14	2.0%	0.04	NA	NA	NA	0.16	2.0%	0.04
GROSS WEIGHT									**6.95**						**8.17**		
TOTAL - Cost										100%	**1.88**					100%	**2.22**

Table 4.28 Cost calculation of SN_{L6} and SN_{XL6} sanitary napkins

Raw Material Price						Cost of SNL6 (240mm)						Cost of SNXL6 (280mm)					
Raw Material (R.M.)	R.M price (Rs.)	GST (%)	Price with GST (Rs.)	Raw material (240/280) (GPP/GSM)		Length (mm)	Width (mm)	AREA (m^2)	Consumption (gm)	(%)	Napkin Cost (Rs./Pcs)	Length (mm)	Width (mm)	AREA (m^2)	Consumption (gm)	(%)	Napkin Cost (Rs./Pcs)
TS4	400	12%	448.00	20	GSM	240	90	0.022	0.43	10.3%	0.19	280	90	0.025	0.50	10.2%	0.23
TS1	115	12%	128.80	20	GSM	240	140	0.034	0.67	4.6%	0.09	280	140	0.039	0.78	4.6%	0.10
DL1	160	12%	179.20	25	GSM	80	40	0.003	0.08	0.8%	0.01	100	40	0.004	0.10	0.8%	0.02
AC2	230	12%	257.60	90	GSM	220	95	0.021	1.88	25.7%	0.48	260	95	0.025	2.22	25.8%	0.57
AC2	290	18%	342.20	150	GSM	220	60	0.013	1.98	36.0%	0.68	260	60	0.016	2.34	36.1%	0.80
BS1	190	18%	224.20	20	GSM	240	180	0.043	0.86	10.3%	0.19	280	180	0.050	1.01	10.2%	0.23
RP1	210	12%	235.20	29	GSM	230	50	0.012	0.33	4.2%	0.08	270	50	0.014	0.39	4.2%	0.09
RP1	210	12%	235.20	29	GSM	60	65	0.004	0.11	1.4%	0.03	60	65	0.004	0.11	1.2%	0.03
AM1	215	18%	253.70	0.45/0.55	GPP	NA	NA	NA	0.45	6.1%	0.11	NA	NA	NA	0.55	6.3%	0.14
AM2	230	18%	271.40	0.14/0.16	GPP	NA	NA	NA	0.14	2.0%	0.04	NA	NA	NA	0.16	2.0%	0.04
GROSS WEIGHT									**6.95**						**8.17**		
TOTAL - Cost										101%	**1.91**					101%	**2.25**

Table 4.29 Cost calculation of SN_{L7} and SN_{XL7} sanitary napkins

Raw Material Price						**Cost of SNL7 (240mm)**						**Cost of SNXL7 (280mm)**					
Raw Material (R.M.)	R.M price (Rs.)	GST (%)	Price with GST (Rs.)	Raw material (240/280) (GPP/GSM)		Length (mm)	Width (mm)	AREA (m^2)	Consumption (gm)	(%)	Napkin Cost (Rs./Pcs)	Length (mm)	Width (mm)	AREA (m^2)	Consumption (gm)	(%)	Napkin Cost (Rs./Pcs)
TS5	500	12%	560.00	30	GSM	240	90	0.022	0.65	19.3%	0.36	280	90	0.025	0.76	19.1%	0.42
TS1	115	12%	128.80	18	GSM	240	140	0.034	0.60	4.1%	0.08	280	140	0.039	0.71	4.1%	0.09
DL1	160	12%	179.20	25	GSM	80	40	0.003	0.08	0.8%	0.01	100	40	0.004	0.10	0.8%	0.02
AC2	230	12%	257.60	90	GSM	220	95	0.021	1.88	25.7%	0.48	260	95	0.025	2.22	25.8%	0.57
AC2	290	18%	342.20	150	GSM	220	60	0.013	1.98	36.0%	0.68	260	60	0.016	2.34	36.1%	0.80
BS1	190	18%	224.20	20	GSM	240	180	0.043	0.86	10.3%	0.19	280	180	0.050	1.01	10.2%	0.23
RP1	210	12%	235.20	29	GSM	230	50	0.012	0.33	4.2%	0.08	270	50	0.014	0.39	4.2%	0.09
RP1	210	12%	235.20	29	GSM	60	65	0.004	0.11	1.4%	0.03	60	65	0.004	0.11	1.2%	0.03
AM1	215	18%	253.70	0.45/0.55	GPP	NA	NA	NA	0.45	6.1%	0.11	NA	NA	NA	0.55	6.3%	0.14
AM2	230	18%	271.40	0.14/0.16	GPP	NA	NA	NA	0.14	2.0%	0.04	NA	NA	NA	0.16	2.0%	0.04
GROSS WEIGHT									**7.09**						**8.35**		
TOTAL - Cost											**2.07**						**2.43**

Table 4.20 Cost calculation of SN_{L8} and SN_{XL8} sanitary napkins

Raw Material Price						**Cost of SNL8 (240mm)**						**Cost of SNXL8 (280mm)**					
Raw Material (R.M.)	R.M price (Rs.)	GST (%)	Price with GST (Rs.)	Raw material (240/280) (GPP/GSM)		Length (mm)	Width (mm)	AREA (m^2)	Consumption (gm)	(%)	Napkin Cost (Rs./Pcs)	Length (mm)	Width (mm)	AREA (m^2)	Consumption (gm)	(%)	Napkin Cost (Rs./Pcs)
TS6	800	12%	896.00	35	GSM	240	180	0.043	1.51	39.0%	1.35	280	180	0.050	1.76	38.8%	1.58
DL2	260	12%	291.20	25	GSM	80	40	0.003	0.08	1.2%	0.02	100	40	0.004	0.10	1.3%	0.03
AC3	300	12%	336.00	50	GSM	220	160	0.035	1.76	17.0%	0.59	260	160	0.042	2.08	17.1%	0.70
AC3	400	18%	472.00	150	GSM	220	60	0.013	1.98	26.9%	0.93	260	60	0.016	2.34	27.1%	1.10
BS2	300	18%	354.00	20	GSM	240	180	0.043	0.86	8.8%	0.31	280	180	0.050	1.01	8.8%	0.36
RP1	210	12%	235.20	29	GSM	230	55	0.013	0.37	2.5%	0.09	270	55	0.015	0.43	2.5%	0.10
RP1	210	12%	235.20	29	GSM	60	55	0.003	0.10	0.6%	0.02	60	55	0.003	0.10	0.6%	0.02
AM3	215	18%	253.70	0.45/0.55	GPP	NA	NA	NA	0.45	3.3%	0.11	NA	NA	NA	0.55	3.4%	0.14
AM3	230	18%	271.40	0.14/0.16	GPP	NA	NA	NA	0.14	1.1%	0.04	NA	NA	NA	0.16	1.1%	0.04
GROSS WEIGHT									**7.25**						**8.53**		
TOTAL - Cost											**3.47**						**4.08**

Table 4.31 Cost calculation of SN_{L9} and SN_{XL9} sanitary napkins

Raw Material Price						Cost of SNL9 (240mm)						Cost of SNXL9 (280mm)					
Raw Material (R.M.)	R.M price (Rs.)	GST (%)	Price with GST (Rs.)	Raw material (240/280) (GPP/GSM)		Length (mm)	Width (mm)	AREA (m^2)	Consumption (gm)	(%)	Napkin Cost (Rs./Pcs)	Length (mm)	Width (mm)	AREA (m^2)	Consumption (gm)	(%)	Napkin Cost (Rs./Pcs)
TS7	1200	12%	1344.00	35	GSM	240	180	0.043	1.51	49.0%	2.03	280	180	0.050	1.76	48.7%	2.37
DL2	260	12%	291.20	25	GSM	80	40	0.003	0.08	1.2%	0.02	100	40	0.004	0.10	1.3%	0.03
AC3	300	12%	336.00	50	GSM	220	160	0.035	1.76	14.3%	0.59	260	160	0.042	2.08	14.4%	0.70
AC3	400	18%	472.00	150	GSM	220	60	0.013	1.98	22.5%	0.93	260	60	0.016	2.34	22.7%	1.10
BS2	300	18%	354.00	20	GSM	240	180	0.043	0.86	7.4%	0.31	280	180	0.050	1.01	7.3%	0.36
RP1	210	12%	235.20	29	GSM	230	55	0.013	0.37	2.1%	0.09	270	55	0.015	0.43	2.1%	0.10
RP1	210	12%	235.20	29	GSM	60	55	0.003	0.10	0.5%	0.02	60	55	0.003	0.10	0.5%	0.02
AM3	215	18%	253.70	0.45/0.55	GPP	NA	NA	NA	0.45	2.8%	0.11	NA	NA	NA	0.55	2.9%	0.14
AM3	230	18%	271.40	0.14/0.16	GPP	NA	NA	NA	0.14	0.9%	0.04	NA	NA	NA	0.16	0.9%	0.04
GROSS WEIGHT									**7.25**						**8.53**		
TOTAL - Cost											**4.15**						**4.87**

Table 4.32 Cost calculation of SN_{L10} and SN_{XL10} sanitary napkins

Raw Material Price						Cost of SNL10 (240mm)						Cost of SNXL10 (280mm)					
Raw Material (R.M.)	R.M price (Rs.)	GST (%)	Price with GST (Rs.)	Raw material (240/280) (GPP/GSM)		Length (mm)	Width (mm)	AREA (m^2)	Consumption (gm)	(%)	Napkin Cost (Rs./Pcs)	Length (mm)	Width (mm)	AREA (m^2)	Consumption (gm)	(%)	Napkin Cost (Rs./Pcs)
TS7	1100	12%	1232.00	35	GSM	240	180	0.043	1.51	46.8%	1.86	280	180	0.050	1.76	46.5%	2.17
DL2	260	12%	291.20	25	GSM	80	40	0.003	0.08	1.2%	0.02	100	40	0.004	0.10	1.3%	0.03
AC3	300	12%	336.00	50	GSM	220	160	0.035	1.76	14.9%	0.59	260	160	0.042	2.08	15.0%	0.70
AC3	400	18%	472.00	150	GSM	220	60	0.013	1.98	23.5%	0.93	260	60	0.016	2.34	23.7%	1.10
BS2	300	18%	354.00	20	GSM	240	180	0.043	0.86	7.7%	0.31	280	180	0.050	1.01	7.6%	0.36
RP1	210	12%	235.20	29	GSM	230	55	0.013	0.37	2.2%	0.09	270	55	0.015	0.43	2.2%	0.10
RP1	210	12%	235.20	29	GSM	60	55	0.003	0.10	0.6%	0.02	60	55	0.003	0.10	0.5%	0.02
AM3	215	18%	253.70	0.45/0.55	GPP	NA	NA	NA	0.45	2.9%	0.11	NA	NA	NA	0.55	3.0%	0.14
AM3	230	18%	271.40	0.14/0.16	GPP	NA	NA	NA	0.14	1.0%	0.04	NA	NA	NA	0.16	0.9%	0.04
GROSS WEIGHT									**7.25**						**8.53**		
TOTAL - Cost											**3.98**						**4.67**

Table 4.33 Evaluation of product cost for large size and extra-large size

Sr. No	Napkin Category	Products		Napkin cost (Rs./piece)	
		Large size (240 mm)	Extra Large size (280 mm)	Large size (240 mm)	Extra Large size (280 mm)
1	Maxi	SN_{L1}	SN_{XL1}	1.24	1.70
2	Maxi	SN_{L2}	SN_{XL2}	1.36	1.83
3	Maxi	SN_{L3}	SN_{XL3}	1.48	1.97
4	Maxi	SN_{L4}	SN_{XL4}	1.53	2.03
5	Ultra-thin	SN_{L5}	SN_{XL5}	1.88	2.22
6	Ultra-thin	SN_{L6}	SN_{XL6}	1.91	2.25
7	Ultra-thin	SN_{L7}	SN_{XL7}	2.07	2.43
8	Skiny-thin	SN_{L8}	SN_{XL8}	3.47	4.08
9	Skiny-thin	SN_{L9}	SN_{XL9}	4.15	4.87
10	Skiny-thin	SN_{L10}	SN_{XL10}	3.98	4.67

The objective of this study, is to assess the comparative cost-effectiveness of different types of sanitary napkins, including maxi, ultra-thin, and skin-thin varieties of large and extra-large sizes. From Table 4.23 it can be observed that in large size, the price varies from 1.24 to 1.53 Rs. per piece, while in the extra-large size, the price varies from 1.70 to 2.03 Rs. per piece. In the present research, the raw materials used in the maxi type is same except top sheet. In maxi type of napkins, four types of top sheets are used. The price is varying is only due to the different prices of top sheets used. The top sheets used in SN_{L3}, SN_{L4}, SN_{XL3} and SN_{XL4} are costly because they are imported while other two top sheets used in SN_{L1}, SN_{L2}, SN_{XL1} and SN_{XL2} are Indian made.

There are three types of sanitary napkins available in ultra-thin size, namely SN_{L5}, SN_{L6}, and SNL_7, as well as three types in extra-large size, namely SN_{XL5}, SN_{XL6}, and SN_{XL7}. In the current study, the raw materials used in the ultra-thin variant remain consistent, with the exception of the top sheet. Three distinct varieties of top sheets were used in the production of ultra-thin napkins. The price fluctuates only owing to the various costs of the top sheets used. According to data from table 4.23, the SN_{L5} sanitary napkins in large size and SN_{XL5} sanitary napkins in extra-large size are the most cost-effective choices when compared to the

SN_{L6} and SN_{L7} sanitary napkins in large size and SN_{X6} and SN_{X7} sanitary napkins in extra-large size. The cost for large size is 1.88 Rs. per piece, while the cost for extra-large size is 2.22 Rs. per piece. In the large sizes of napkins, the cost varies from 1.88 to 2.07 Rs. per piece, while in the extra-large sizes of napkins, the price varies from 2.22 to 2.43 Rs. per piece. All the three top sheets are imported one. The costing of SN_{L7} and SN_{XL7} is high because it is laminated sheet along with double perforated feature.

Three kinds of eco-friendly sanitary pads are produced in skiny-thin large sizes: SN_{L8}, SN_{L9}, and SNL10. There are also three kinds of eco-friendly pads produced in extra-large sizes: SN_{XL8}, SN_{XL9}, and SN_{XL10}. The raw materials used in the skiny-thin variant are the same, except for the top sheet. There were three different kinds of top sheets used to make the skiny-thin napkins. The price only changes because the top sheets used cost different amounts. The cheapest options are the SN_{L8} large size and SN_{XL8} extra-large size sanitary napkins, as shown in Table 4.23. These are compared to the SN_{L9} and SN_{L10} large size and SN_{X9} and SN_{X10} extra-large size sanitary napkins. It costs 3.47 Rs. per piece for an SN_{L8} large size and 4.08 Rs. per piece for an SN_{LX8} extra-large size. As for prices, a large size napkins costs between 3.47 and 4.15 Rs. per piece, and an extra-large napkins costs between 4.08 and 4.87 Rs. per piece. The top sheet used in SN_{L8} is cheaper as it is Indian made while other two top sheet used in SN_{L9}, SN_{L10}, SN_{XL9} and SN_{XL10} are costly as they are imported one. The top sheet used in SN_{L9} and SN_{XL9} is made from silk waste, which is the costliest top sheet among all the top sheets used in all the categories of the sanitary napkins.

The aim of this study is to reduce the social effects that could occur when women in nations that are developing have the economic resources to acquire feminine hygiene products. The aim is to look into the requirements and capabilities for developing an environmentally friendly feminine hygiene product, and to suggest a theoretical design for a menstruation product that corresponds to the demands and capabilities of users and local producers in the particular context.

Table 4.34 Evaluation of product cost for large size and extra-large size

Sr. No	Napkin Category	Products		Napkin cost (Rs.)		Commercially Available Napkin (MRP) (Rs.)	
		Large size	Extra Large size	Large size (240mm)	Extra Large size (280mm)	Large size (240mm)	Extra Large size (280mm)
1	Maxi	SN_{L1}	SN_{XL1}	1.24	1.70	4.25	5.71
2	Maxi	SN_{L2}	SN_{XL2}	1.38	1.85	5.24	7.5
3	Maxi	SN_{L3}	SN_{XL3}	1.48	1.97	5.24	7.5
4	Maxi	SN_{L4}	SN_{XL4}	1.55	2.05	6.10	8.24
5	Ultra-thin	SN_{L5}	SN_{XL5}	1.88	2.22	8.23	10.0
6	Ultra-thin	SN_{L6}	SN_{XL6}	1.91	2.25	9.54	12.5
7	Ultra-thin	SN_{L7}	SN_{XL7}	2.07	2.43	12.32	14.3
8	Skiny-thin	SN_{L8}	SN_{XL8}	3.45	4.05	NA	NA
9	Skiny-thin	SN_{L9}	SN_{XL9}	4.12	4.84	NA	NA
10	Skiny-thin	SN_{L10}	SN_{XL10}	3.96	4.64	NA	NA

Note: NA: Not Available.

Table 4.24 presents a cost comparison between the sanitary napkins developed according to BIS requirements and commercially available napkins with similar qualities. The data indicates that the napkins developed through research have much lower rates compared to commercially available sanitary napkins. The biodegradable and environmentally friendly sanitary napkins are now unavailable in the commercial market in India, so their pricing remains unknown. It may be seen that the cost of biodegradable napkins is not significantly increasing despite their eco-friendly characteristics.