Analysing and Evaluation of The Reusable and Sustainable Textile Materials for A Lactation Leakproof Nursing Pad

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Keywords—reusable nursing pad, one way transport, wicking-layer, moisture management, PU coating

I. Introduction

Lactation Leaking is a common problem that many nursing mothers face, and while it is mostly resolved in the initial weeks of nursing, many mothers discover that the leaking remains throughout their feeding time period [1]. Mothers who combine breastfeeding and working should also be concerned about this problem [2]. Within the first six months after giving birth, 66% of women informed leaking in first few month [1]. Throughout the first few months of breastfeeding, the majority of mothers use an absorbent pad. According to some research papers, leaking is a "little problem"[3] and something that happens when "your body is somewhat out of shape [1]. For nursing mothers, disposable nursing pads are a need because they offer convenience, security, and discretion. Breastfeeding pads are available in a biodegradable format, but because of the high material consumption, they are not sustainable enough. Therefore, there is a growing need for reusable nursing pads that provide excellent leak protection while having minimal adverse environmental effects due to the growing demand for eco-friendly and sustainable products. In order to create a reusable, innovative nursing pad, this research will concentrate on three layers: the leakage prevention layer, which will be located near the bra, for breathability and molding, the wicking layer, which will be located near the skin for unidirectional transport, wicking, and molding and absorbent layer.

II. Literature Review

The design and construction of reusable nursing pads are the main topics of the literature study, which highlights the significance of three essential layers: the outer leak-proof layer, the absorbent core, and the inner wicking layer. Because of their superior wicking, breathability, and antibacterial qualities, materials like recycled polyester and nylon are used in the inner layer, which is intended to regulate moisture. The long-term performance of the absorbent layer is ensured by its high absorbency, durability, and washability, which are designed materials such as cotton, hemp, bamboo, banana or lyocell. [4, 5]

Using polyethylene, polypropylene, or polyurethane, the outer layer creates an impermeable barrier that keeps leaks from happening while yet allowing for breathability. The characteristics of each layer, such as breathability, durability, antibacterial qualities, and wicking capacity, are carefully chosen and ranked to maximize overall performance, comfort, and dependability, meeting the hygienic and comfort needs of nursing mothers. Recent studies conducted for the market analyzing, pad manufacturing processes and requirements of the nursing mothers[2]. Pad structure was engineered considering the market research via comfort of the nursing mothers[3].

III. Material And Methodology

A. Materials

TABLE I. MATERIAL LIST FOR WICKING AND LEAK PREVENTION LAYERS

Fabric Layer	Fabric Types
Wicking layer	Fleece, terry, Single jersey, sueded terry, plated option 1, plated option 2 fabrics
Leak prevention layer	PU coated – Terry, PU coated – Single jersey fabrics

B. Methodology

1) Analyzing a suitable wicking layer in knitted fabrics: A comparative investigation of six different knitted fabric structures was done to determine the most suited structure for the wicking layer of nursing pad. The materials chosen, namely single jersey, terry, fleece, sueded terry, and plating, were selected considering the weight, structure compatibility, materials of the fabrics. The table below displays the fabric structures discussed earlier along with their corresponding physical properties.

TABLE II. PHYSICAL PARAMETERS OF WICKING LAYER FABRICS

Fabric Structure	Composition	GSM	Yarn Count	Thickness (mm)	WPI/CPI
Fleece	100%RE-Polyester	260 ±5	170D/80D	1 ±0.1	30/42
Terry	100% Cotton	260 ±5	30S/20S	1 ±0.1	36/46
Single Jersey	60% Cotton/ 30% Polyester/ 10% Spandex	190 ±5	40S/85D	0.9 ±0.1	44/42
Plated Option 1	65% Cotton / 35% Polyester	163 ±5	40S/60D	0.5 ±0.1	33/52
Sueded Terry	50% Cotton/ 30% Modal/ 20% Polyester	253 ±5	30S/70D	1.2 ±0.1	30/32
Plated Option 2	65% Modal/ 35% Polyester	195 ±5	40S/85D	0.5±0.1	37/58

2) Analyzing a suitable leakage prevention layer in knitted fabrics: The analysis of a suitable outer layer fabric for the lactation leak-proof nursing pad involves a dual approach including evaluating the properties of the material and assessing its moldability. The fabrics were subsequently assessed for its breathability and moisture management using an Air permeability tester and a moisture management tester, respectively. In order to preserve the structural integrity of the outer layer during the shaping process, the fabric with a polyurethane coating was molded, and any subsequent adaptations were examined.

TABLE III. PHYSICAL PARAMETERS OF LEAK PREVENTION LAYER

Fabric	Finishing Layer	GSM	Thickness
Terry	PU coated	135 ±5	0.9 ±0.1
Single jersey	PU coated	120 ±5	0.7 ±0.1

3) Analyzing absorbent layer : This study assessed the absorbent layer of nursing pads through literature review and experimentation. Four non-woven web samples—100% viscose, 100% lyocell, viscose-polyester, and lyocell-polyester blends—were selected for their absorbency and durability. Needle punching, involving barbed needle interlocking, was applied to enhance the structural integrity, strength, and uniform thickness of the webs. This method is particularly effective for short fibers with a denier per filament (dpf) of 1.5–3.0, ensuring rapid moisture absorption and distribution..

4) Check the mouldability : Moulding technology use to shape nursing bra cups, providing efficient support and customization. It enhances comfort and functionality, increases the cup's lifespan, and reduces discomfort during breastfeeding. The following table presents the molding conditions utilized in the production of 3D nursing pad.

TABLE IV. MOULDING CONDITIONS

Temperature	165°C
Processing time	2min
Mould shape	Contoured

5) Conducting the testing: The chosen fabrics have been tested for its properties, including wicking, one-way transport, spreading time, and absorption rate. Leakage prevention layer fabrics are used to prevent liquid leakage.

IV. RESULTS AND DISCUSSIONS

A. Wicking Layer Fabrication

TABLE V. MMT TEST RESULTS OF WICKING LAYER

Testing Parameters	Single Jersey	Sueded Terry	Fleece	Terry	Plated Op1	Plated Op2
Top wetting time (s)	3.5	3.5	3.5	1.0	5.0	3.5
Top Absorption ate (%/s)	2.5	2.5	2.5	1.0	3.0	3.5
Top spreading speed (mm/s)	3.0	2.0	1.5	1.0	5.0	3.5
Bottom Wetting time(s)	3.5	3.5	3.5	3.5	4.5	3.5
Bottom Absorption rate (%/s)	3.5	3.0	3.0	4.0	3.5	4.0
Bottom spreading speed(mm/s)	2.5	2.0	2.5	1.0	4.5	3.5
Overall Moisture management	1.0	1.0	3.5	3.5	2.5	2.5

The wicking layer focuses on the fabric's better wicking capabilities, one-way transport, and breathability. The most important attribute is vertical wicking, followed by one way transport and finally air permeability.

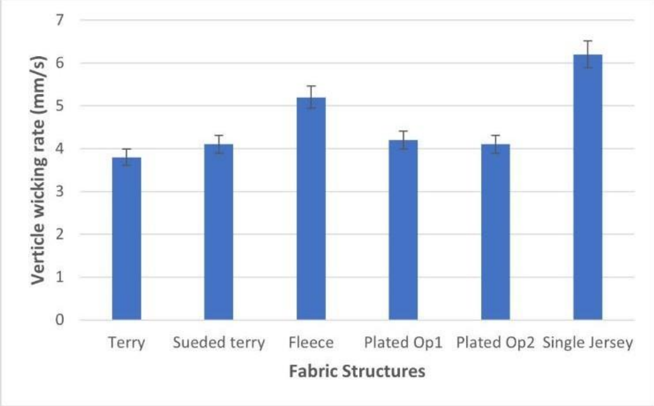

Fig. 1. Vertical wicking testing results (error precentage±*0.1*)

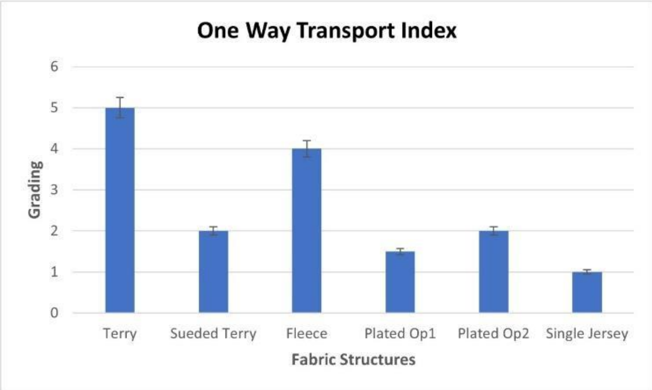

Fig. 2. One-way transport index results

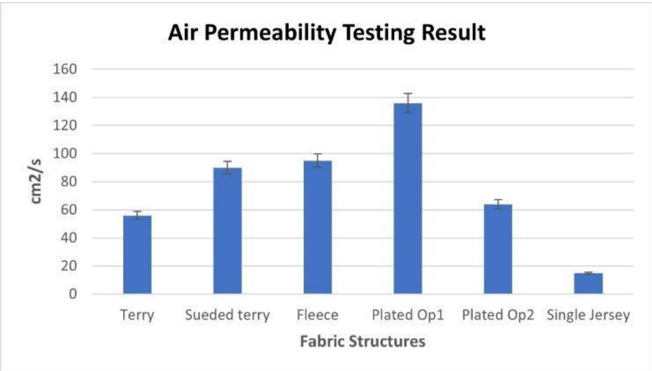

Fig. 3. Air permeability testing results

The wicking layer is the most important property because it guarantees that breast milk is efficiently transferred from the skin to the fabric, reducing leaks. The second most prioritized quality is one-way transport, which directs leaky milk to the cloth rather than the skin. Furthermore, air permeability is critical for the fabric's breathability, reducing skin irritation and perspiration collection while increasing overall comfort.

Figure 1 shows that single jersey fabric exhibits the highest vertical wicking, followed by fleece and plated fabrics. Figure 2 indicates that terry fabric has the highest one-way transport index, followed by fleece and sueded terry fabrics.

As shown in Figure 3, terry fabric also demonstrates the highest air permeability, with single jersey fabric ranking second. A weighted analysis of these properties reveals that fleece fabric achieves the highest overall performance, making it ideal for applications requiring effective moisture management and breathability. As shown in Tables V and VI, while fleece initially exhibited strong one-way transport and breathability, molding increased porosity but reduced transport efficiency. To address this, an 85-90% polyester and 10-15% spandex blend is recommended, leveraging polyester's moisture-wicking properties and spandex's structural reinforcement to maintain performance post-molding.

TABLE VI. AIR PERMEABILITY RESULT BEFORE AND AFTER

Structure	Before Moulding	After Moulding
Terry	95.9	105.9

TABLE VII. ONE WAY TRANSPORT INDEX BEFORE AND AFTER

Structure	Before Moulding	After Moulding
Terry	4	3

B. *Leakage Prevention Layer*

Strong water-repellent qualities are displayed by the PU-coated materials of the upper layer, and MMT results reveal little moisture transport. The efficacy of single jersey and terry fabrics in water resistant applications was confirmed by their low grades for bottom-side moisture transport and high grades for top wetting and absorption.

The increased breathability of the single jersey PU-coated fabric over terry cloth made it the preferred choice for ventilation in nursing pads. Techniques including putting gum at the edges, enclosing the fabric in a water-repellent membrane, and using high pressure when molding were found to be effective in addressing edge leaks. These approaches guarantee the nursing pads' efficacy and dependability in stopping leaks, together with exclusive procedures from cup molding companies. To achieve the desired fabric characteristics, incorporating 10%-15% spandex content is essential. Additionally, a denser weave is necessary to attain the required flexibility and water-repellent properties. In cases where issues arise with the PU coating, alternative materials such as TPU-coated yarn fabric or Teflon-coated fabrics should be considered for the outer layer. These adjustments ensure optimal performance and meet the stringent requirements for fabric durability and functionality.

C. *Absorbent Layer*

Analysis showed that 100% lyocell and 100% viscose non-woven webs quickly degraded after washing and had trouble keeping their shape after molding. On the other hand, non-woven webs mixed with 20% polyester showed better resilience and form preservation. The stiffness of the viscose-polyester blend, however, was observed, compromising user comfort. On the other hand, the blend of lyocell and polyester provided the best durability and comfort, which made it the ideal material for nursing pads that could be reused.

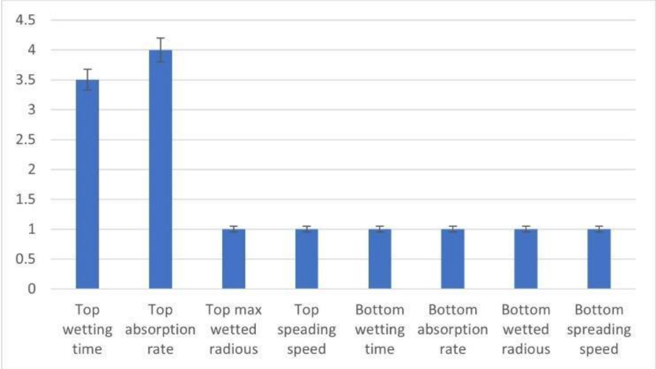

Fig. 4. Moisture management PU coated single jersey fabric

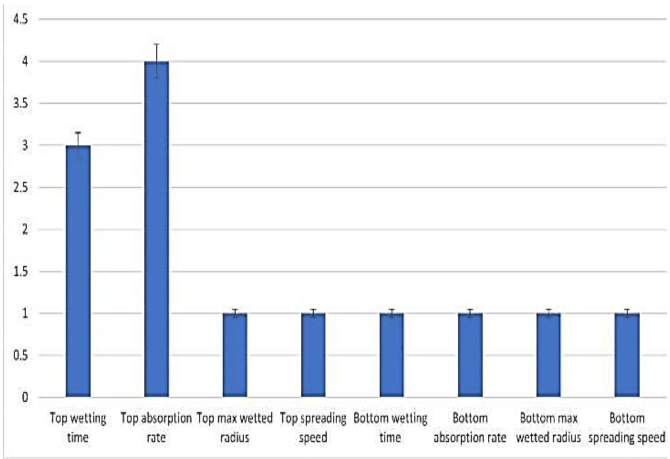

Fig. 5. Moisture management PU coated single Terry fabric

V. ACKNOWLEDGMENT

The department of Textile and Apparel Engineering, University of Moratuwa, Sri Lanka provided support and guidance for this project.

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