

# Baby Diaper Development with Hemp and Kenaf

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## Abstract

Disposable diapers produce an incredible amount of environmental waste. In the United States, 4 million tonnes are disposed every year, 80% of which buried in landfills (EPA, United States). In Australia an estimate of 3.75 million of disposable diapers are used every day that highly contributes to waste production. Our project investigated the potential use of blended hemp and kenaf fibres in the development of baby cloth diapers. Why blended hemp and kenaf fibres? Because both Hemp and Kenaf are good absorbent than cotton. We developed cloth diapers inserts by blended hemp and kenaf. Why cloth diapers? There is a reason disposable diapers clog landfills in every country, but by using cloth diapers we can reduce the Medi waste. It is a sensitive matter that must be properly investigated now. Bamboo, hemp, cotton, and flax among other natural fibre species, would be employed as mixes in these smart textiles. Because these things would be more ecologically friendly, their value would increase. Biodegradable fibres made from them are attractive as a potential solution to throwaway issues. In a world with finite resources and numerous environmental consequences, it is clear that sustainable lifestyles and industrial styles are becoming increasingly crucial. With these issues in mind, we develop the cloth baby diaper that is not harmful to both environment and newborns. This diaper that can washable at procter and gamble, safety assurance is a vital aspect of the diaper development process, with the purpose of ensuring the safety of both carers and newborns.

**Keywords:** Diaper • Medi waste • Fibres • Procter • Safety

## Introduction

In recent years, there has been growing interest in developing sustainable and eco-friendly alternatives to traditional disposable baby diapers, which are known to generate significant waste and contribute to environmental pollution. It is crucial to assess the environmental effects of every product over its entire life cycle, including raw material extraction, production, consumption, and reusable components. Reusable diapers are sometimes referred to as "cloth diapers," and are mostly constructed of many layers of fabric made of cotton, bamboo, hemp, polyester, or polyurethane. Natural fibres such as cotton, bamboo, or hemp can be used to make reusable diapers. When single-use diapers first hit the market, cloth diapers were produced using only 100% cotton materials. One promising approach is the use of natural fibres, such as hemp and kenaf, which have been shown to offer a range of benefits, including biodegradability, renewability, and low environmental impact. This paper presents an investigation into the development of blended hemp and kenaf baby diapers, with the aim of evaluating the feasibility and effectiveness of this approach. Specifically, we will explore the properties of hemp and kenaf fibres, the blending and

processing techniques used to create the diaper material, and the performance characteristics of the final product, including absorbency, breath ability, and comfort [1]. By delivering more value with less impact on the environment, eco-efficiency encourages businesses to seek environmental improvements.

## Cloth diapers

Cloth diapers are a reusable alternative to disposable diapers. They are typically made from cotton, hemp, bamboo, or a combination of these materials. Cloth diapers come in many styles, including prefolds, fitted, pocket, and all-in-one. Cloth diapers require regular washing, which can be done using a washing machine or by hand. In the United States, 15% of diapers are cloth diapers. However, it is a long-standing practice to use a device to cover a baby and collect excrement [2]. Originally, a fabric having a woven design was referred to as a "diaper." British phrase "nappie," or napkin. Cloth diapers may be reused, which means they do not contribute to the creation of waste or the subsequent accumulation of it in landfills. It is important to note that the making and washing of disposable diapers could cause environmental damage. For instance, to fulfil their demands for energy, they usually need non-renewable resources.

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## Advantages of cloth diapers

Cloth diapers have several advantages over disposable diapers. One of the most significant benefits is their environmental friendliness. Cloth diapers are reusable and can be used for years, reducing the amount of waste that ends up in landfills. Cloth diapers are reusable and can be used for years, reducing the amount of waste that ends up in landfills. Additionally, cloth diapers are generally less expensive in the long run than disposable diapers, which can save parents thousands of dollars over the course of their child's diapering years. Cloth diapers are also free from the chemicals and fragrances found in some disposable diapers, which can be irritating to a baby's sensitive skin. They also allow for better air circulation and are less likely to cause diaper rash. Cloth diapers can be customized by using different inserts or adding layers to the diaper, which can be helpful for overnight or heavy wetting. Finally, cloth diapers come in a wide range of colors and patterns, allowing parents to choose a style that suits their personal preferences. Despite the advantages, it's important to note that cloth diapers require more work and time than disposable diapers, as they need to be washed and dried regularly [3]. Natural fabrics, such as those manufactured from plants or animals, are often costlier but clean easier and hold odorless.

## MATERIALS and METHODS

### Materials

- Hemp
- Kenaf
- Cotton
- Bamboo cotton fleece
- TPU fabric (Thermoplastic Polyurethane laminate)
- Starch based SAP

### Hemp

Hemp is a typical fibre-producing plant and is essential to it because of its antibacterial characteristics. Hemp is less commonly used in research than other fibre plants since it is believed to be an important and active medicinal herb. Natural hemp, sometimes referred to as "*Cannabis sativa*," is a fine; glossy solid-based fibre made from the hemp plant. It is also known as "*Cannabis sativa*." It was developed in several nations and is a jute product that resembles a plant. Although it is thicker and coarser, it spins quite similarly to flax. Hemp fibre is a natural fibre derived from the stems of the hemp plant. It is known for its strength, durability, and versatility, and has been used for centuries to make a variety of products, including clothing, textiles, paper, and construction materials. Hemp fibre is considered to be one of the strongest and most durable natural fibres available, and is often compared to other fibres such as cotton, linen, and jute. Hemp is a fast-growing plant that requires minimal water and pesticides, making it a more sustainable and eco-friendly alternative

to other fibres [4]. Another advantage of hemp fibre is its versatility. Hemp fibre can be processed into a variety of different products, from clothing and textiles to paper and construction materials. It can be blended with other fibres to create stronger, more durable fabrics, and can be used to make everything from t-shirts and jeans to bed linens and curtains. Hemp fibre offers a number of advantages over other natural and synthetic fibres, including its strength, durability, sustainability, and versatility. As consumers become more interested in eco-friendly and sustainable products, the demand for hemp fibre is likely to continue to grow.

Hemp fibre is a versatile natural material that has many properties that make it a great option for use in various applications, including in the production of diapers. Due to the fact that green hemp fibres have more soluble components than retted fibres, which have a disproportionately higher wax content, green hemp fibres are more hydrophilic.

The distinctive aseptic features, high absorbency and hygroscopicity, strong thermal and electrostatic properties, protection from UV radiation, and lack of any allergic reactions make hemp fibres, a historically important raw material for textiles; stand out from other fibres. In addition, hemp fibre is a durable material that can withstand frequent washing and use without losing its shape or strength. This makes it a practical choice for use in diapers that need to hold up over time. Hemp plants require less water and fewer pesticides to grow than other crops, making it a more eco-friendly option for diaper production. Furthermore, hemp fibre can be produced with minimal environmental impact and can be recycled or composted at the end of its lifecycle, making it a more sustainable choice for diaper production. The properties of hemp fibre make that a great material for use in diapers [5,6].

### Hemp diapers

Hemp produces the best diapers on the planet. Washable diapers do not pollute landfills the same way that plastic diapers. And hemp diapers are considerably more absorbent than cotton diapers, keeping the baby and parents dry. These items are good for the environment and absorb moisture better than cotton diapers. One of the key properties of hemp fibre is its high absorbency. Hemp fibres can absorb up to four times their weight in liquid. Hemp fibre is also naturally antimicrobial and odour-resistant, which can help prevent bacteria growth and keep diapers smelling fresh. Additionally, hemp is a breathable material that allows air to circulate, which can help reduce the risk of diaper rash and other skin. Hemp fibre has a natural ability to resist bacterial growth, which can help prevent diaper rash and other skin irritations. Hemp is also a sustainable material that is better for the environment than traditional disposable diapers. Hemp fibre can be produced with minimal environmental impact and can be recycled or composted at the end of its lifecycle, making it a more sustainable choice for diaper production. The advantages of hemp baby diapers include high absorbency, durability, antimicrobial properties, and sustainability. By using hemp

baby diapers, parents can provide a comfortable and eco-friendly option for their babies while also reducing the environmental impact of diaper production [7].

## Kenaf

Similarly to cotton and jute, kenaf is an annual warm-season fibre crop. To make twine, rope, and sackcloth in the past, kenaf was utilised as a cordage crop. Kenaf crops are a type of rapidly growing plant that may reach heights of up to 12 feet and are dependent upon cultivation, seeding season, harvesting method, water retting treatments, and fibre preparation. However, kenaf may be used for a variety of different things, such as goods, construction equipment, absorbents, and fodder. Kenaf seems to have a single, branchless stalk that is straight and unbranched. The interior woody core of a kenaf stalk is surrounded by an outer fibrous bark. The fibre has a density of  $1.2 \text{ g/cm}^3$ , a breaking strength of 100.64 MPa, an elastic modulus of 23 GPa, a yarn breaking load of 79 N, a tensile strength of 283-800 MPa, an elongation of 17.3 percent, and a moisture absorption rate of 8.3 percent.

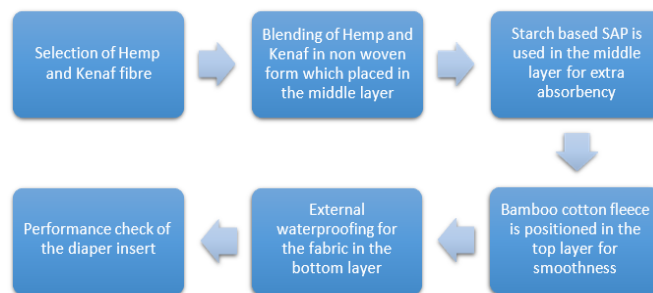
## Advantages of kenaf fiber

Kenaf fibres have been found to have several advantages when used in baby diapers. Kenaf fibres are very soft and comfortable, which makes them ideal for use in baby diapers. Unlike synthetic materials that can be rough and abrasive, kenaf fibres are gentle on a baby's delicate skin. Kenaf fibres have high absorbency, which means they can hold a lot of moisture. Kenaf is a sustainable and renewable crop that requires less water and pesticides than other crops. Using kenaf fibres in baby diapers is an eco-friendly choice that reduces the environmental impact of diaper production. Kenaf fibres have natural antibacterial properties that can help to prevent the growth of harmful bacteria in a baby's diaper. Kenaf fibres are highly breathable, which allows air to circulate and keep a baby's skin dry and comfortable [8,9]. Using kenaf fibres in baby diapers provides several advantages, including softness, absorbency, eco-friendliness, antibacterial properties, and breathability. These properties make kenaf an ideal material for use in baby diapers, as they can help to keep a baby's skin dry, comfortable, and healthy.

## Methodology

- In this project, natural fibre Hemp will be used to create baby diapers.
- It is achieved by blending the Kenaf fiber which makes the diaper more absorbent and adding the water repellent coating.
- First, the Hemp fibre is treated with hot water for better performance like absorption.
- Then the Hemp is blended with the Kenaf fibre in the non-woven form.
- Thermoplastic polyurethane laminate fabric is placed in the bottom layer of the diaper inserts.

Below we have mentioned the process flow of the project (Figure 1).



**Figure 1.** The process flow of the project

## Hot water treatment

Hot water treatment is a process in which hemp fibre is boiled in hot water for a specific period of time to remove impurities and increase its absorbency. During the hot water treatment process, the high temperature causes the fibres to expand, which opens up the pores in the fibre and increases its surface area. This, in turn, increases the fibre's ability to absorb moisture. Additionally, hot water treatment can remove waxes and other impurities from the fibre, which can further improve its absorbency [10].

The process involves preparation, boiling, cooling, and drying. The process can be done on a small scale at home or on a larger scale in a manufacturing facility. One study found that hot water treatment increased the water absorption capacity of hemp fibre by up to 45%.

- First, we cut the hemp fibres into small pieces using a pair of sharp scissors. This will make it easier for the fibres to absorb water during the boiling process.
- Then we added the cut hemp fibres to the pot and stir them using a spoon to make sure they are evenly distributed and fully submerged in the water.
- Then we added the cut hemp fibres to the pot and stir them using a spoon to make sure they are evenly distributed and fully submerged in the water.
- Then we boiled the hemp fibres for approximately 1 hour at a temperature at  $60^\circ\text{C}$ .
- After boiling, we removed the pot from the heat and carefully strain the hemp fibres to remove excess water.
- Then we rinse the fibres thoroughly with cold water to remove any remaining impurities or residues.
- Finally, we dry the fibres by hanging them in a well-ventilated area.

## Blending of hemp and kenaf

To blend Hemp and Kenaf we used mechanical blending method. We made the blend ratio in three different propositions (Table 1).

Hemp	Kenaf	Cotton
40%	40%	20%
60%	20%	20%
20%	60%	20%

**Table 1.** The blend ratio in three different propositions.

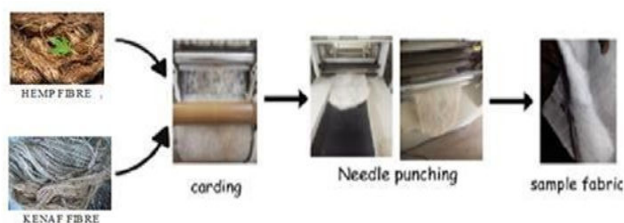
The process sequence for mechanical blending of hemp and kenaf fibres is listed below:

- **Cleaning and preparation:** We cleaned hemp, kenaf and cotton fibres and aligned by removing any dirt or debris and then carded to create a more consistent blend.
- **Loading the fibres:** We prepared fibres and then loaded into the blending machine.
- **Mechanical blending:** The blending machine is turned on, and the fibres are mechanically blended using rollers, combs, or other mechanisms. The machine mixes and aligns the fibres together, creating a more homogeneous blend.
- **Monitoring the process:** We closely monitored the blending process to ensure that the fibres are blending properly and that the blend ratio is consistent.
- **Collecting the blended fibres:** Once the blending process is complete, we collected the blended fibres and then transferred to the carding machine.

### Making of non-woven

Needle punching method is a commonly used method for making non-woven fabrics, and it can be used to create cloth diaper inserts. Needle punching can create a fabric with high density and good absorbency, but the type of fibres used also play a crucial role.

- After finalizing the blending ratio we card the blended fibres to create a uniform web of fibre.
- Then we feed the web through a needle punching machine that uses a series of barbed needles to entangle the fibres and create a non-woven fabric.
- After needle punching, non-woven fabric is then cut into the desired shape and size for use as a cloth diaper insert (Figure 2).



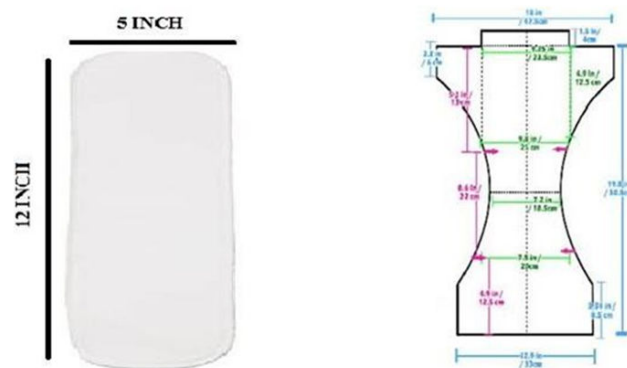
**Figure 2.** After needle punching, non-woven fabric is then cut into the desired shape and size for use as a cloth diaper insert.

Nonwoven fabrics are increasingly being used for water filtration due to their excellent filtering properties [11]. The manufacturing process for nonwoven fabrics involves bonding together fibres using various techniques such as mechanical, thermal, or chemical methods.

### Structure of cloth diaper

**Top layer (washable):** Bamboo cotton fleece is a type of fabric that is commonly used for towels and washcloths. Bamboo cotton fleece is known for its absorbency, which makes it a popular choice for cloth diapers. Because of this Bamboo cotton fleece is utilized in the top layer. Using Bamboo cotton fleece makes the skin smooth and comfortable, and liquids can easily pass through it.

**Middle layer as removable inserts:** Hemp and Kenaf are combined in the middle layer. This layer holds and absorbs the liquid. Moreover, in the middle layer starch based super absorbent (natural SAP) is used because to improve the absorbency. Additionally, it is biodegradable (use and throw) (Figure 3).



**Figure 3.** Structure of cloth diaper.

**Bottom layer (washable):** Thermoplastic polyurethane is a fabric commonly used in cloth diaper inserts as a waterproof and breathable barrier layer. The role of TPU in cloth diaper inserts is to prevent leaks and keep moisture contained within the diaper. Additionally, it is biodegradable which reduce the environmental impacts. So the Thermoplastic polyurethane fabric is used in the bottom layer (Figure 4).



**Figure 4.** Process from top layer to bottom layer.

Here, both top and bottom layer can be washable so, it can be reused multiple times, and the middle layer which act as the core layer can be removable which can be disposed after use. In the middle layer both Hemp and Kenaf are natural fibre and Starch based

SAP is also biodegradable so, the environmental impact is very low compared to disposable diapers [12].

After this we arranged the layers in order and attached the layers by zigzag stitch. The zigzag stitch allows for flexibility and durability. Additionally, the zigzag stitch can provide a good seal to prevent leaks (Figure 5).



**Figure 5.** Images of diaper.

## Results

### Testing methods

The following are some of the testing methods that can be used to evaluate the development and characteristics of cloth diaper insert using Hemp and Kenaf.

**Absorption test:** An absorption test for cloth diaper inserts is a test that measures the ability of the insert material to absorb and hold moisture.

**Moisture regain test:** Moisture Regain (MR) is a measure of the amount of moisture that a fabric can absorb and hold, expressed as a percentage of the dry weight of the fabric.

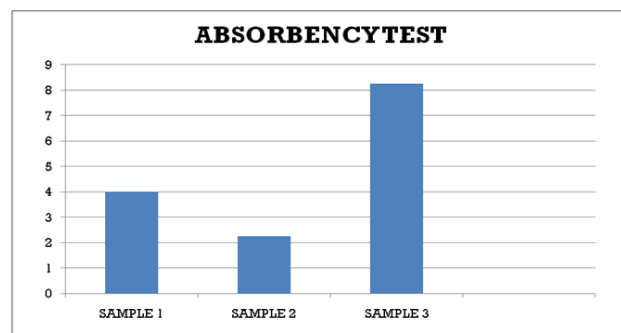
**Wicking test:** A wicking test is a test performed on a cloth diaper or diaper insert to determine how quickly it can absorb moisture and move it away from the baby's skin [13].

### Absorbency test

Absorbency test is a standard test method for determining the liquid strike-through time of a fabric. This method can be adapted to test the absorbency of baby cloth diaper inserts.

- Cut a piece of the diaper insert material to a standard size (usually 4 inches by 4 inches).
- Place the insert on a flat surface and pour a specific volume of water (usually 100 mL) onto the centre of the insert.
- Watch the insert closely and note the time when the water has completely penetrated through the insert.
- Repeat the test in different areas.
- Here, the absorbency test repeated in different areas for three different samples (Figure 6).

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**Figure 6.** Absorbency test repeated in different areas for three different samples.

Here,

Sample 1: Hemp 40%, Kenaf 40%, Cotton 20%

Sample 2: Hemp 60%, Kenaf 20%, Cotton 20%

Sample 3: Hemp 20%, Kenaf 60%, Cotton 20%

### Moisture regain test

Moisture Regain (MR) is a measure of the amount of moisture that a fabric can absorb and hold, expressed as a percentage of the dry weight of the fabric. This test can be used to determine the absorbency of baby cloth diaper inserts [14].

- Cut a piece of the diaper insert material to a standard size (usually 10 cm × 10 cm).
- Weigh the dry insert and record its weight.
- Soak the insert in distilled water for 30 minutes.
- Remove the insert from the water and gently squeeze out any excess water.
- Weigh the wet insert and record its weight.
- Place the wet insert in an oven set to a specific temperature (usually 105°C) for a specific amount of time (usually 1 hour) to dry.
- Remove the insert from the oven and allow it to cool to room temperature.
- Weigh the dry insert and record its weight.

Calculate the moisture regain using the following formula:

$$MR = \frac{(W2 - W1)}{W1} \times 100\%$$

Where,

W1=Weight of the dry insert

W2=Weight of the wet insert after soaking

Repeat the test on different ratio inserts to compare their absorbency (Table 2).

Sample	Moisture content	Moisture regain
Sample 1	6.00%	5.49%
Sample 2	8.01%	7.03%

Sample 3

5.05%

4.52%

**Table 2.** Moisture regain test result.

### Wicking test

The wicking test is used to determine how well a cloth baby diaper insert can distribute moisture across its surface.

- Cut a piece of the diaper insert material to a standard size (usually 4 inches by 4 inches).
- Weigh the dry insert and record its weight.
- Apply a specific volume of water (usually 5 mL) to the center of the insert.
- Allow the insert to sit undisturbed for 5 minutes.
- Place a piece of dry blotter paper on top of the insert.

- Apply a weight (usually 1000 grams) on top of the blotter paper.
- Leave the weight and blotter paper on the insert for 10 minutes.
- Remove the blotter paper and weigh it.
- Calculate the wicking height using the following formula:

Wicking height=(weight of the wet blotter paper-weight of the dry blotter paper)/ area of the insert

Where, Area of the insert=length × width of the insert

- Repeat the test on several inserts to compare their wicking ability (Table 3).

	Sample 1		Sample 2		Sample 3	
Specifications	Length	Width	Length	Width	Length	Width
After 5 min	03.5 cm	03 mm	07.5 cm	04.5 mm	02.5 cm	02.0 mm
After 10 min	08.5 cm	05.2 mm	09.7 cm	07.1 mm	06.5 cm	04.5 mm
After 25 min	11.4 cm	10.2 mm	13.4 cm	11.8 mm	10.8 cm	06.2 mm
After 60 min	12.5 cm	11.2 mm	14.5 cm	13.8 mm	11.3 cm	10.2 mm

**Table 3.** Wicking test results.

## Discussion

The test results show good absorbency, wicking, and moisture regain for the Hemp-60%, Kenaf-20%, Cotton-20%(sample 2) blended diaper inserts, it is likely to be a high-quality and effective diaper insert. The medium results for the Hemp-40% kenaf-40% Cotton-20% (sample 1) blended diaper inserts may indicate that they are still effective, but may not perform as well as sample 2 [15,16]. The poor results for the Hemp-20% kenaf-60% Cotton-20% (sample 3) blended diaper inserts suggest that they may not be suitable for use as a diaper insert. However, it's important to note that the comfort of the diaper insert is also an important factor to consider. A comfortable diaper insert can make a significant difference in the overall experience of wearing a diaper, and can help prevent discomfort and irritation for the baby [17]. In thatHemp-20% kenaf-60% Cotton-20% (sample 3) blended diaper inserts are more comfortable than the other blends; this may be an important factor to consider when selecting a diaper insert. Hemp-40% kenaf-40% Cotton-20% (sample 1) blended diaper inserts has good results in both absorbency and comfort ability. So, it would be the best diaper inserts among these blends. However, further testing and evaluation may be necessary to ensure that the inserts hold up over time and under various usage conditions [18,19].

## Conclusion

In conclusion, Hemp kenaf blended insert shows that it is a promising material for cloth diapers due to its unique characteristics such as absorbency, durability, and good mechanical properties. The use of Hemp in combination with kenaf in the development of diaper insert for cloth diaper has been found to improve the absorption efficiency.

Disposable diapers take hundreds of years to decompose in a landfill, due to the lack of oxygen and other environmental factors that slow down the decomposition process. However, these diaper inserts are biodegradable. Starch based super absorbent are natural SAP made from corn and potatoes.

The use of bamboo cotton fleece in the top layer, hemp kenaf blended non-woven with starch-based super absorbent in the middle layer, and TPU fabric in the bottom layer appears to be a well-thought-out design that could potentially provide effective and comfortable diaper insert. Blended hemp and kenaf materials have shown promising results, making them a potentially suitable alternative to traditional disposable diaper inserts. The testing results that have obtained so far are promising and suggest that the diaper inserts could have good absorption rates, minimal leakage, and a comfortable fit for the baby. In general, the blend of hemp and kenaf fibres presents a promising opportunity for the development of new, sustainable, and high-performance materials for the production of diapers. However, further testing and evaluation may be necessary to ensure that the inserts hold up over time and under various usage conditions.

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