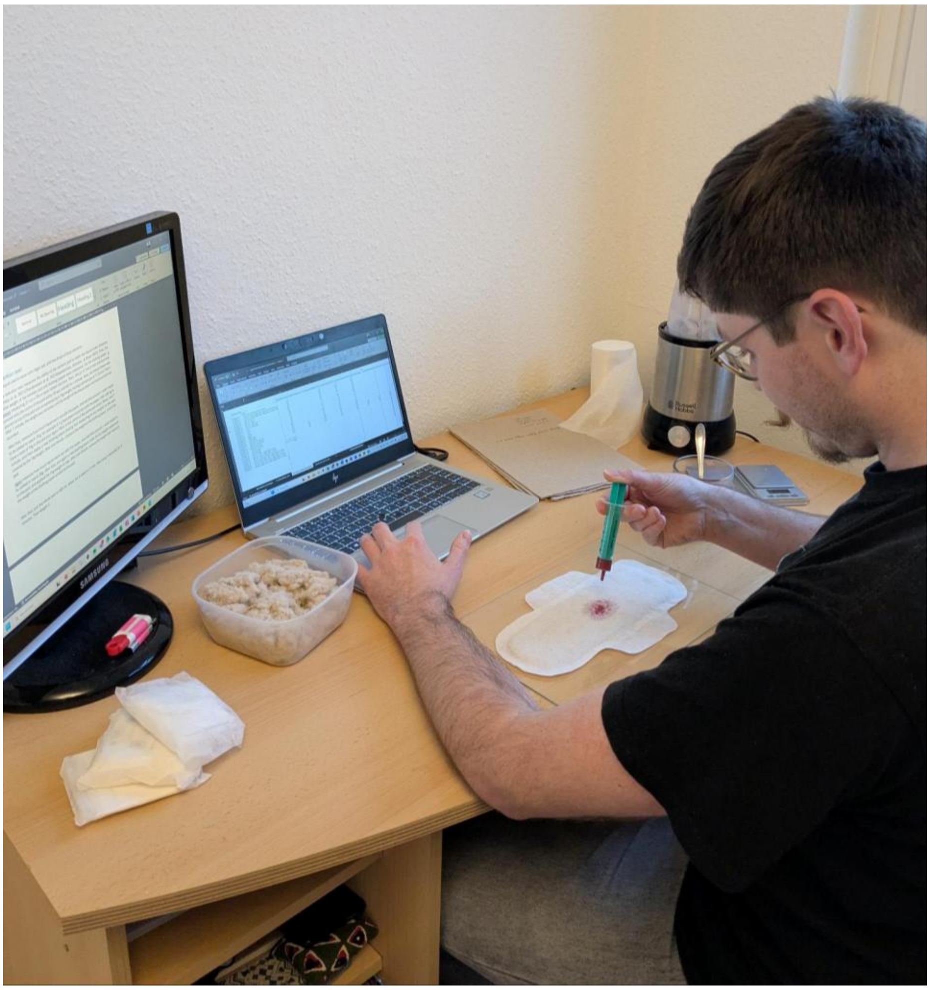
Research and Experimentation on the Sparsa Pad:

Focusing on Absorption and Retention



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Introduction

Since the menstrual pad has been invented in the XXth century, and especially in the last 30 years, a lot of research has been done by the private sectors to enhance the absorption and retention of their pad. Most of their inventions are however linked to the use of plastics, and other petrol-based polymers. By having a compostable sanitary pad, we have to use their research and adapt them to our product.

Most of those characteristics are using fossil-based polymer. The key here is to find solutions to get the same results while using cheap, available, and compostable materials. Or even better, by using the materials we already have in a better way. This document will focus on the transfer and absorbent layer, as it is here than we can hopefully have a great impact on our pad absorption and retention, by small adjustments.

Description of the different layers of a menstrual pad and their characteristics.

A menstrual pad, to be appreciated by its users, must fulfil several important characteristics, such as comfortability, leakage protection, absorbency, easy to use, etc. In this paper, the focus will be on the absorption and retention of the liquid by the pad. Therefore, only the characteristics linked to those areas will be discussed and detailed.

In terms of absorption, the 2 main characteristics are:

- No leakage is happening, even with pressure, which means that the menstruation blood is absorbed and kept inside the pad.
- The top layer gives a “dry feeling”, which means that it does not feel like wet, when in contact with the skin.

Now, to obtain a pad which fulfil those 2 characteristics, several points are important to follow, and to measure:

- The liquid must be quickly absorbed and not remain on the top layer. An easy test is to pour some drops on the pads, and measure how fast the drops are absorbed by the pad.
- The liquid must be spread all over the pad, to use all the capacity of the pad. The idea here is that the liquid, instead of staying on the surface of the pad, is distributed vertically and longitudinally in the pad, to use all the absorbent core, and so, increasing the absorption.
- The liquid must be locked inside the pad. This is important as otherwise the liquid could leak when a certain pressure is applied, or when the pad move, which happens when the pad is wore by a user.

To summarize, the liquid must be quickly absorbed, then drag away from the surface, distribute through the pad, and locked. To reach this, a pad is constituted of several layers, and most of the pads found in the commerce have at least 4. Those are:

- Top layer or acquisition layer: the goal here is to receive the liquid and to let it pass through. The fibres are often hydrophobic to not absorb any liquid which could give a wet sensation, but at the same time, the liquid must go through. This is generally made of plastic fibre, either non-woven or perforated sheet. If it is a non woven, the grammage is low to enable the liquid to go through even with hydrophobic fibres.
- Transfer layer: it is rapidly transferring the liquid from the top layer to the absorbent core. It is also spreading the liquid longitudinally, to use the total capacity of the absorbent core. It is made of plastic fibres. This layer must attract the liquid through the top layer to the absorbent core. It is most of the time in non-woven plastic fibres.
- Absorbent layer: This is often a mix of cellulose and SAP (super absorbent polymer). The cellulose will quickly absorb the liquid, and then the SAP will take it from the cellulose and lock it in a “gel” like substance. The SAP takes longer to absorb the liquid than the cellulose, this is why it is always a mix when SAP is used. Some pads are also using only cellulose, from wood, but also bamboo, or banana plant for example. The SAP are fossil-based polymer, which does not degrade easily.
- Waterproof layer: plastic film ensuring no leakage.

Observation of pads bought in the market

In addition to Sparsa prototypes, several pads that have been bought in the commerce in Germany, will be tested. Pads from 3 brands have been tested, in each, 2 to 3 models of pads have been bought, with different level of absorption. The first brand, Jessa, is a relatively cheap brand, Always is a very famous brand of pad throughout the world, and finally Natracare, is an eco-brand, which sells certified compostable pad.

Natracare ultra extra pads:

This pad is very interesting, in the sense that only cellulosic fibres are used in the pad, except for the waterproof layer at the bottom of course. It is also certified compostable.

we can see those layers (from top to bottom):

- Non woven cotton
- Thin absorbent paper, which seems to be glued to the top layer following a pattern, see pictures.
- Fluff fibre mattress.
- A more compress mattress of fluff fibre a bit yellowish, and with the same patter than the very thin paper. The process to make this seems to be the same than the second layer. It is fluff fibre pressed in between very thin paper. Maybe it is not paper, but just this layer is shaped when pressed with heat?

Regarding the glue: the first layer and second layer are glued, the bioplastic is glued on its all surface, so it is glue with the last layer, a bit of fluff, and on the top layer

The top layer is hydrophilic, when it is removed and water is poured on it, it quickly distributes. However when it is on the pad, the water does not wet the top layer, but the second one. With a hydrophilic top layer, one solution could be to have a second layer which is narrowly connected to the first layer, and which is more absorbent than the first layer. Here it seems to be the case with this glue/compression pattern. The liquid is indeed quickly distributed via this pattern.

Natracare maxi pads:

Very easy pad with 3 layers:

- Top layer cotton (thicker than the ultra exta pads, and the "holes" are smaller).
- Thick mattress of fluff
- Bioplastic
- Regarding the glue, the bioplastic is glued to the mattress, as well as the top layer. The top layer and the mattress are well linked, difficult to say if this is due to a glue, or just by pressing both materials together.

Jessa ultra pad dry comfort night.

Ultra-thin pad, filled with SAP:

- Perforated plastic film
- Thin layer of plastic fibre non woven sticked under it
- Envelop of cellulose fibre, with SAP inside.
- Plastic back layer.

The envelop of cellulose is glued to the bioplastic, and it seems that top layer and transfer layer are just embossed together, no glue.

The fact that the top layer is not flat but with a 3D pattern, it helps to quickly absorbed the water.

Also, to save cost, they use the plastic pouch directly as "silicone paper". Indeed, there is no silicone paper on the back, the pad is directly sticking to the plastic pouch.

Jessa ultra pad active shape

Ultra-thin pad, filled with SAP:

- Non woven plastic fibre top layer, very thin.
- Non woven cellulosic fibre
- Mattress of cellulosic fibre with SAP.
- Plastic back layer.

Top layer and transfer layer are glued together. Transfer layer and mattress are not linked together.

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Always maxi night

Thick and long pad, constituted of 3 layers:

- Top layer in perforated plastic
- Thick mattress of cellulose
- Plastic back layer

The top layer is embossed with the mattress and maybe glued to it.

Always maxi

Thick pad made of 3 layers:

- Thin top layer made of non-woven plastic fibres
- Thick mattress of cellulosic fibre
- Plastic back layer

It is the same than the always maxi night, except for the size and the top layer. The top layer is also embossed with the mattress and maybe glued to it.

Introduction to the experiment, its goals and limitation

The current Sparsa Pad is very basic, it has only 3 layers. Indeed, the tests showed that under this form, the pad was absorbent enough, and to keep the production relatively simple, and the production cost low, it has been decided to go with this basic form. Now, it is likely that in the future, more version of the Sparsa Pad will be launched, with different absorbency. To be ready to do so, this research has been conducted, and 3 main goals defined:

- Developing a Sparsa pad which has similar or better properties in terms of absorption and retention than pad found in the commerce. This prototype would be a long-term goal.
- Developing an easy improvement to the current version of the Sparsa Pad, to enhance its properties without changing the process.
- Finding solution to use the top layer made of hydrophobic cotton we received.

In addition, this research is here to share knowledge on the science behind the pad absorbency and retention.

First of all, some bibliographic work has been done, pads from the commerce have been analysed, and discussion with expert carried on. From that, several ideas to be tested have been developed. Those ideas have first been, tested visually, and then prototypes based on those ideas have been made, and tested following the protocols developed. Due to the low amount of resource and time, only 2 prototypes for each idea have been made. Some ideas did not work in the visual test, so no prototypes have been made based on it. However, they will still be explained, as it can give further ideas how to continue this research in the future.

All the ideas and prototypes focused on:

- The top layer:
    - 2 different top layers will be tested, in viscose and cotton.
- The addition of a transfer layer
    - Which will be in banana paper or viscose
- The addition of another absorbent layer
    - In banana paper, with different geometry, grammage, etc.
- The addition of SAP
    - 4 different natural SAP will be added and tested, in different ways (mix with the whole mattress, mix with half of the mattress, etc..)
- Modifying the connection between the layers
    - Use of glue
- The agency of the different layers
    - Trying different position especially with the insertion of the banana paper

Everything tested here, always have been thought in a way that it is possible to replicate in Nepal in terms of production, accessibility of raw materials, and production cost.

Materials and methods

Prototypes

The prototype design is based on the dimension of the Sparsa pad but it has been slightly adapted for the experiment. The prototype is indeed rectangle to facilitate the production, its dimension are 24,5 cm in length, and 8,5 cm in width, the dimension of the absorbent core, which is also rectangle is 22,5 cm in length, and 6,5 cm in width. The Sparsa pad has 7g of fibre per pad, however the prototype has only 5g. The fibre mattress of the prototype being press manually, 7g was too much, so it has been decided to go with 5g.

The raw materials used are:

- Viscose non-woven sheet, bought in Germany. The grammage is 30g/m^2.
- Hydrophobic cotton non-woven, received from Sparsa. It is a raw cotton, bought in India. The grammage is 30g/m^2.
- Banana paper, received from Sparsa. This paper has been made in the fibre factory, and has been pulverized in Germany for the experiment, with a small grinder.
- Bioplastics, several have been utilized for quantity reason, with different grammage.
- Glue, 2 different have been used, bought in commerce.
- Super absorbent polymer, 4 different have been tested:
    - Guar-gum, extracted from guar beans, food thickener, bought in Germany
    - Chitosan, polymer extracted from crustacean shell, bought in Germany
    - Sodium Alginate, polymer extracted from algae, food thickener, bought in Germany
    - CMC, cellulose derivative, food thickener among other use, bought in Germany

In addition to the prototypes made with the materials above, conventional pads bought in commerce will be tested as well. They have been selected to represent the different pads available, with different absorption capacity, with or without wings, with or without SAP, industrially compostable or not. Those are:

- Always:
  - Always maxi, size 1 out of 3, normal, without wings
  - Always maxi night, size 3 out of 3, profresh night, without wings
- Jessa (brand of dm):
  - Jessa ultra-binden active shape, absorption 4 out of 6, normal, with wings
  - Jessa utra-binden dry comfort night, absorption 6 out of 6, extra-lang
- Natracare (industrially compostable)
  - Natracare maxi pads, absorption 3 out of 5, super, without wings
  - Natracare ultra extra pads, absorption 5 out of 5, long, with wings.

Methods

The main test which has been conducted, is a mixture of retention tests, as well as total absorbency. It has been designed in a way that with one prototype, several characteristics can be tested. The resource being limited, it has been decided to do so to gain time. In addition, the test has been designed considering the material available.

A tremendous number of tests exist regarding absorbency of a sanitary pad in the literature. None of them is perfect, and none of them reflect the reality, as it is impossible to simulate what happen when a user uses a pad. Therefore, those tests are made to be able to compare a pad to one another rather than to predict their behaviour in a normal use.

The experiment designed allows to get the retention rate at 5mL of liquid poured, 10 mL, 20 mL, and the total absorbency of the pad.

Material:

- Absorbent paper. It can be tissue, wipes, blotting paper, filter paper, etc. Here baby wipes made of 100% cellulose from wood have been used. They measure 21x25 cm, and weight in average 3,2 g.
- Sanitary pad to be tested.
- Scale with a precision of 0,1 g.
- Syringe or graduated burette
- A stopwatch
- Weight of one kilo, with a surface big enough to cover the area where the pad is wet. Here a one kilos weight has been used with a surface of 11,5cm*7,6 cm.
- Coloured salty water. This is the solution used for the test. The concentration of salt is 10g/L. For the colorant, food colorant works well. The coloured chosen has no importance

Protocol

During this protocol, the retention of the pad, with 5 mL, 10 mL and 20 mL of solution will be measured.

1. Weight the dry pad and note it down.
2. Weight the dry blotting paper used for the test and note it down.
3. Prepare 5 mL of the solution. Either by using the scale, and then placing the solution in the syringe, or, by using the graduated burette.
4. Place the menstrual pad on a flat surface.
5. Prepare the stopwatch.
6. Start the stopwatch when the first drop of solution touches the pad. The solution must be poured always at the same place, in the middle of the pad. In this case, the solution has been poured with a syringe, at a speed of 5mL in 15 second.
7. Once the liquid has been poured, one minute is waited.
8. Then the first blotting paper is place in the middle of the pad, where the liquid has been poured, then the 1 kg weight is applied on the blotting paper.
9. The weight is let on the pad for 1 minute.
10. After one minute, the weight is removed, the first blotting paper is weighted, as well as the pad.
11. Now that the retention for 5 mL has been done, it will be done for 10mL, and then 20mL. For that, the quantity of liquid to be added needs to be calculated. Indeed, some liquid has been withdrawn from the pad to the blotting paper.
    The following calculation is done: $m_{wa} = m_{wt} - (m_{wp} - m_{dp})$
    With m_{wa}= mass of water added. This is the mass of water which needs to be added to the pad, to reach m_{wt};
    With m_{wt}= mass of water total. For the 10mL retention, m_{wt}= 10g as we want to reach 10mL in the pad. (the approximation that the solution has a density of 1 is followed here).
    For the 20mL retention, m_{wt}= 20g as we want to reach 10mL in the pad.
    With m_{wp} = mass of the wet pad.
    With m_{dp} = mass of the dry pad.
12. Repeat step 2 to 11 with m_{wa}instead of 5 mL, with $m_{wt} = 10$ and then $m_{wt} = 20$.
13. For the retention with 20mL, 2 consecutive blotting paper will be used. This means that the liquid is poured, then 1 minute waiting time, then one blotting paper with the weight, 1 minute waiting time, weighting the pad and the blotting paper, then a new blotting paper is applied on the pad with the weight for one minute, then the weight of the blotting paper and the pad is taken.
14. Once the retention tests have been conducted for 5, 10 and 20mL, the total absorption start. The pad is immerged in 400 mL of the solution, and soaked for 2 minutes
15. After those 2 minutes, the pad is hanged by one edge, for 3 minutes
16. After those 3 minutes, the pad is weighted.

Calculation

The calculation of the total absorbency is simply:

$$Absorbency\ (g) = m_{saturated} - m_{dry}$$

With:

m_{dry} = initial dry weight of the pad (g)

$m_{saturated}$ = final saturated weight of the pad (g)

If needed, the ratio of mass of liquid absorbed per mass of dry pad can also be calculated, as follow:

$$Ratio\ = \frac{Absorbency}{m_{dry}}$$

The calculation of the retention rate is as follows:

$$Retention\ (\%) = \frac{(m_{wp} - m_{dp})}{m_{water}} * 100$$

With m_{water}= mass of liquid added (g)

Results and Analysis

Prototype

You can see below the list of prototypes that I tested:

Prototype 12	Viscose, fibres 5 g
Prototype 13	Viscose, fibres 5 g
Prototype 14	Viscose, fibres 5 g, thick paper (20cm*2,5cm, 0,6g)
Prototype 15	Viscose, fibres 5 g, thick paper (20cm*2,5cm, 0,6g)
Prototype 16	Viscose, fibre 5 g mix with 3g cmc
Prototype 17	Viscose, fibre 5 g mix with 3g cmc
Prototype 18	Viscose, fibre 5 g mix with 3g guar gum
Prototype 19	Viscose, fibre 5 g mix with 3g guar gum
Prototype 20	jessa
Prototype 21	jessa
Prototype 22	always
Prototype 23	always

Prototype 24	always night
Prototype 25	always night
Prototype 26	Natracare ultra extra pad
Prototype 27	Natracare ultra extra pad
Prototype 28	Natracare maxi pads
Prototype 29	Natracare maxi pads
Prototype 30	Jessa ultra night
Prototype 31	Coton (22g/m^2), viscose, fibre 5g
Prototype 32	Coton (22g/m^2), viscose, fibre 5g
Prototype 33	Coton (22g/m^2), viscose, fibre 5g,thick paper (20cm*2,5cm, 0,6g)
Prototype 34	Coton (22g/m^2), viscose, fibre 5g,thick paper (20cm*2,5cm, 0,6g)
Prototype 35	Coton (22g/m^2), viscose, fibre 5 g mix with 3g guar gum
Prototype 36	Coton (22g/m^2), viscose, fibre 5 g mix with 3g guar gum
Prototype 37	Viscose, 2g fibre, thin paper (6,5cm*22cm, 0,5g), 3g fibre mix with 1g guar gum
Prototype 38	Viscose, 2g fibre, thin paper (6,5cm*22cm, 0,5g), 3g fibre mix with 1g guar gum
Prototype 39	Viscose, 2g fibre, thin paper (6,5cm*22cm, 0,5g), 3g fibre
Prototype 40	Viscose, 2g fibre , thick paper (20cm*2,5cm, 0,7g), 3g fibre
Prototype 41	Viscose, fibre 5 g
Prototype 42	Viscose, fibre 5 g
Prototype 43	Viscose, fibre 5 g, glued together
Prototype 44	Viscose, fibre 5 g, glued together
Prototype 45	Viscose, fibre 5 g, thick paper (20cm*2,5cm, 0,9g)
Prototype 46	Viscose, fibre 5 g, thick paper (20cm*2,5cm, 0,9g)
Prototype 47	Viscose, fibre 5 g, thick paper (20cm*2,5cm, 0,9g), glued in between viscose and fibres, and in between paper and fibre
Prototype 48	Viscose, fibre 5 g, thick paper (20cm*2,5cm, 0,9g), glued in between viscose and fibres, and in between paper and fibre
Prototype 49	Viscose, fibre 5 g, thin paper (6cm*20cm, 0,7g)
Prototype 50	Viscose, fibre 5 g, thin paper (6cm*20cm, 0,7g)
Prototype 51	Viscose, fibre 5 g, thin paper (6cm*20cm, 0,7g), glued in between viscose and fibres, and in between paper and fibre
Prototype 52	Viscose, fibre 5 g, thin paper (6cm*20cm, 0,7g), glued in between viscose and fibres, and in between paper and fibre
Prototype 53	Viscose, thin paper (6cm*20cm, 0,4g, positionned under viscose), fibre 5 g, glued in between viscose and fibres, and in between paper and fibre
Prototype 54	Viscose, thin paper (6cm*20cm, 0,4g, positionned under viscose), fibre 5 g, glued in between viscose and fibres, and in between paper and fibre
Prototype 55	Viscose, thin paper perforated (6cm*20cm, 0,4g, positionned under viscose), fibre 5 g, glued in between viscose and fibres, and in between paper and fibre
Prototype 56	Viscose, thin paper perforated (6cm*20cm, 0,4g, positionned under viscose), fibre 5 g, glued in between viscose and fibres, and in between paper and fibre
Prototype 57	Viscose, 5g fibres with 1 gr of guar gum mixed, glued in between viscose and fibre
Prototype 58	Viscose, 5g fibres with 1 gr of guar gum mixed, glued in between viscose and fibre

The prototype starts at the number 12, as for the 11 first prototypes, the wrong experiment was conducted. I could however already saw that the chitosan and the sodium alginate were less efficient that the CMC and Guar gum in terms of absorption. So, to reduce the number of prototypes afterwards, I only used CMC and Guar gum.

The materials used are always in the same order, from top to bottom. However, as every pad has a bioplastic layer at the bottom, this one is not mentioned.

Results

Retention results, sorted from the best retention for 5mL

		Rentention 5 mL		Retention 10 mL		Rentention 20 mL	
		Retention (%)	Incertitude	Retention (%)	Incertitude	Retention (%)	Incertitude
Prototype 35 and 36	Coton (22g/m^2), viscose, fibre 5 g mix with 3g guar gum	98,0	6,0	97,5	3,0	97,3	1,5
Prototype 28 and 29	Natracare maxi pads	98,0	6,0	98,0	3,0	96,8	1,5
Prototype 26 and 27	Natracare ultra extra pad	98,0	6,0	96,5	3,0	94,0	1,5
Prototype 30	Jessa ultra night	98,0	6,0	99,0	3,0	92,5	1,5
Prototype 33 and 34	Coton (22g/m^2), viscose, fibre 5g,thick paper (20cm*2,5cm, 0,6g)	97,0	5,9	99,0	3,0	97,0	1,5
Prototype 31 and 32	Coton (22g/m^2), viscose, fibre 5g	95,0	5,9	100,0	3,0	97,5	1,5
Prototype 55 and 56	Viscose, thin paper perforated (6cm*20cm, 0,4g, positionned under viscose), fibre 5 g, glued in between viscose and fibres, and in bet	85,0	5,7	88,0	2,9	88,0	1,4
Prototype 57 and 58	Viscose, 5g fibres with 1 gr of guar gum mixed, glued in between viscose and fibre	84,0	5,7	90,0	2,9	88,8	1,4
Prototype 53 and 54	Viscose, thin paper (6cm*20cm, 0,4g, positionned under viscose), fibre 5 g, glued in between viscose and fibres, and in between pape	81,0	5,6	84,5	2,8	85,3	1,4
Prototype 39	Viscose, 2g fibre, thin paper (6,5cm*22cm, 0,5g), 3g fibre	80,0	5,6	85,0	2,9	84,5	1,4
Prototype 40	Viscose, 2g fibre , thick paper (20cm*2,5cm, 0,7g), 3g fibre	74,0	5,5	81,0	2,8	81,5	1,4
Prototype 37 and 38	Viscose, 2g fibre, thin paper (6,5cm*22cm, 0,5g), 3g fibre mix with 1g guar gum	70,0	5,4	78,0	2,8	80,5	1,4
Prototype 41 and 42	Viscose, fibre 5 g	69,0	5,4	77,0	2,8	80,0	1,4
Prototype 51 and 52	Viscose, fibre 5 g, thin paper (6cm*20cm, 0,7g), glued in between viscose and fibres, and in between paper and fibre	66,0	5,3	82,0	2,8	87,8	1,4
Prototype 49 and 50	Viscose, fibre 5 g, thin paper (6cm*20cm, 0,7g)	65,0	5,3	72,5	2,7	82,5	1,4
Prototype 47 and 48	Viscose, fibre 5 g, thick paper (20cm*2,5cm, 0,9g), glued in between viscose and fibres, and in between paper and fibre	65,0	5,3	84,5	2,8	84,5	1,4
Prototype 45 and 46	Viscose, fibre 5 g, thick paper (20cm*2,5cm, 0,9g)	64,0	5,3	71,0	2,7	79,0	1,4
Prototype 43 and 44	Viscose, fibre 5 g, glued together	63,0	5,3	74,0	2,7	77,5	1,4
Prototype 24 and 25	Always night (no SAP)			100,0	3,0	100,0	1,5
Prototype 16 and 17	Viscose, fibre 5 g mix with 3g cmc			89,0	2,9	86,0	1,4
Prototype 20 and 21	Jessa (with SAP)			99,0	3,0	84,5	1,4
Prototype 18 and 19	Viscose, fibre 5 g mix with 3g guar gum			87,0	2,9	84,0	1,4
Prototype 14 and 15	Viscose, fibres 5 g, thick paper (20cm*2,5cm, 0,6g)			79,0	2,8	73,3	1,4
Prototype 12 and 13	Viscose, fibres 5 g			74,5	2,7	69,8	1,3
Prototype 22 and 23	Always (no SAP)			36,0	2,4	30,5	1,2

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Prototype 51 and 52	Viscose, fibre 5 g, thin paper (6cm*20cm, 0,7g), glued in between viscose and fibres, and in between paper and fibre	66,0	5,3	82,0	2,8	87,8	1,4
Prototype 40	Viscose, 2g fibre , thick paper (20cm*2,5cm, 0,7g), 3g fibre	74,0	5,5	81,0	2,8	81,5	1,4
Prototype 14 and 15	Viscose, fibres 5 g, thick paper (20cm*2,5cm, 0,6g)			79,0	2,8	73,3	1,4
Prototype 37 and 38	Viscose, 2g fibre, thin paper (6,5cm*22cm, 0,5g), 3g fibre mix with 1g guar gum	70,0	5,4	78,0	2,8	80,5	1,4
Prototype 41 and 42	Viscose, fibre 5 g	69,0	5,4	77,0	2,8	80,0	1,4
Prototype 12 and 13	Viscose, fibres 5 g			74,5	2,7	69,8	1,3
Prototype 43 and 44	Viscose, fibre 5 g, glued together	63,0	5,3	74,0	2,7	77,5	1,4
Prototype 49 and 50	Viscose, fibre 5 g, thin paper (6cm*20cm, 0,7g)	65,0	5,3	72,5	2,7	82,5	1,4
Prototype 45 and 46	Viscose, fibre 5 g, thick paper (20cm*2,5cm, 0,9g)	64,0	5,3	71,0	2,7	79,0	1,4
Prototype 22 and 23	Always (no SAP)			36,0	2,4	30,5	1,2

Retention results, sorted from the best retention for 20mL

		Rentention 5 mL		Retention 10 mL		Rentention 20 mL	
		Retention (%)	Incertitude	Retention (%)	Incertitude	Retention (%)	Incertitude
Prototype 24 and 25	Always night (no SAP)			100,0	3,0	100,0	1,5
Prototype 31 and 32	Coton (22g/m^2), viscose, fibre 5g	95,0	5,9	100,0	3,0	97,5	1,5
Prototype 35 and 36	Coton (22g/m^2), viscose, fibre 5 g mix with 3g guar gum	98,0	6,0	97,5	3,0	97,3	1,5
Prototype 33 and 34	Coton (22g/m^2), viscose, fibre 5g,thick paper (20cm*2,5cm, 0,6g)	97,0	5,9	99,0	3,0	97,0	1,5
Prototype 28 and 29	Natracare maxi pads	98,0	6,0	98,0	3,0	96,8	1,5
Prototype 26 and 27	Natracare ultra extra pad	98,0	6,0	96,5	3,0	94,0	1,5
Prototype 30	Jessa ultra night	98,0	6,0	99,0	3,0	92,5	1,5
Prototype 57 and 58	Viscose, 5g fibres with 1 gr of guar gum mixed, glued in between viscose and fibre	84,0	5,7	90,0	2,9	88,8	1,4
Prototype 55 and 56	Viscose, thin paper perforated (6cm*20cm, 0,4g, positionned under viscose), fibre 5 g, glued in between viscose and fibres, and in bet	85,0	5,7	88,0	2,9	88,0	1,4
Prototype 51 and 52	Viscose, fibre 5 g, thin paper (6cm*20cm, 0,7g), glued in between viscose and fibres, and in between paper and fibre	66,0	5,3	82,0	2,8	87,8	1,4
Prototype 16 and 17	Viscose, fibre 5 g mix with 3g cmc			89,0	2,9	86,0	1,4
Prototype 53 and 54	Viscose, thin paper (6cm*20cm, 0,4g, positionned under viscose), fibre 5 g, glued in between viscose and fibres, and in between paper	81,0	5,6	84,5	2,8	85,3	1,4
Prototype 20 and 21	Jessa (with SAP)			99,0	3,0	84,5	1,4
Prototype 39	Viscose, 2g fibre, thin paper (6,5cm*22cm, 0,5g), 3g fibre	80,0	5,6	85,0	2,9	84,5	1,4
Prototype 47 and 48	Viscose, fibre 5 g, thick paper (20cm*2,5cm, 0,9g), glued in between viscose and fibres, and in between paper and fibre	65,0	5,3	84,5	2,8	84,5	1,4
Prototype 18 and 19	Viscose, fibre 5 g mix with 3g guar gum			87,0	2,9	84,0	1,4
Prototype 49 and 50	Viscose, fibre 5 g, thin paper (6cm*20cm, 0,7g)	65,0	5,3	72,5	2,7	82,5	1,4
Prototype 40	Viscose, 2g fibre , thick paper (20cm*2,5cm, 0,7g), 3g fibre	74,0	5,5	81,0	2,8	81,5	1,4
Prototype 37 and 38	Viscose, 2g fibre, thin paper (6,5cm*22cm, 0,5g), 3g fibre mix with 1g guar gum	70,0	5,4	78,0	2,8	80,5	1,4
Prototype 41 and 42	Viscose, fibre 5 g	69,0	5,4	77,0	2,8	80,0	1,4
Prototype 45 and 46	Viscose, fibre 5 g, thick paper (20cm*2,5cm, 0,9g)	64,0	5,3	71,0	2,7	79,0	1,4
Prototype 43 and 44	Viscose, fibre 5 g, glued together	63,0	5,3	74,0	2,7	77,5	1,4
Prototype 14 and 15	Viscose, fibres 5 g, thick paper (20cm*2,5cm, 0,6g)			79,0	2,8	73,3	1,4
Prototype 12 and 13	Viscose, fibres 5 g			74,5	2,7	69,8	1,3
Prototype 22 and 23	Always (no SAP)			36,0	2,4	30,5	1,2

Total Absorption

		Absorption total (g)	Ratio (g) absorbed / (g) pad
Prototype 12 and 13	Viscose, fibres 5 g	89,8	12,7
Prototype 14 and 15	Viscose, fibres 5 g, thick paper (20cm*2,5cm, 0,6g)	87,7	11,5
Prototype 16 and 17	Viscose, fibre 5 g mix with 3g cmc	150,7	14,5
Prototype 18 and 19	Viscose, fibre 5 g mix with 3g guar gum	151,2	15,7
Prototype 31 and 32	Coton (22g/m^2), viscose, fibre 5g	85,3	11,4
Prototype 37 and 38	Viscose, 2g fibre, thin paper (6,5cm*22cm, 0,5g), 3g fibre mix with 1g guar gu	110,3	13,3
Prototype 39	Viscose, 2g fibre, thin paper (6,5cm*22cm, 0,5g), 3g fibre	92,7	12,0
Prototype 20 and 21	Jessa (with SAP)	41,1	8,7
Prototype 22 and 23	Always (no SAP)	63,7	8,8
Prototype 24 and 25	Always night (no SAP)	117,4	8,9
Prototype 26 and 27	Natracare ultra extra pad	85,4	7,6
Prototype 28 and 29	Natracare maxi pads	102,0	9,5
Prototype 30	Jessa ultra night	60,4	8,4

Not every prototype has been tested for 5ml retention, as well as for the total absorbency. In the results often the prototypes are gathered by two, as for most of them I made two times the same prototype and took the average as final value. Of course, only two prototypes are not enough to have proper and precise results, however due to lack of time (every pad have been manually made), more prototypes could not have been done.

Analysis:

5mL

We can see that all the prototypes with a layer of cotton on top, have very good results (all more than 95% retention), which directly competes with the commercial pads. Given the uncertainty relatively high for 5 mL test, I would say that they are all equivalent, and it is mostly the cotton which has an important effect, rather that what is under.

After that we can see that another group come together. The prototype with viscose on top, a thin paper glued to the viscose, then fibre. In addition, there is also the prototype with 1g of guar gum mix to the fibre in this group. It is interesting, as this means that the paper allows to quicky absorbed the liquid and spread it in the surface, below the viscose. Once the liquid is in the paper it does not reverse back so much to the viscose. For the guar gum prototype, we can see that 1 g helped to increase the retention.

Then we have all the prototypes with thick or thin paper inside the fibres or at the bottom. However, the results of the prototype with paper in the middle of the fibres were still better than the prototypes with paper at their bottom. Indeed, 5mL liquid was enough to reach the paper placed in the middle of the pad, but not to reach the paper at the bottom. So we can see that the paper helped a bit.

10 mL

As for 5 mL, the same group of pads is leading, with the commercial pad, and the pad with cotton.

Afterwards, we can notice that there is more competition, with more prototypes very close one from another. We can however notice that again, we have the pads with guar gum, and CMC and the pad with the perforated thin paper below the viscose, which have a retention between 87% and 90%.

We have then most of the pad with paper, then the normal pad.

20 mL

For the 20 mL, we found again, roughly the same results than with 10 mL, with only few differences.

So overall, we could say that the best prototypes which have been made are definitely the ones with the cotton on top. It increased the results in every category, and beat even the pad bought in the commerce.

Then we have the pad with the perforated thin banana paper below the viscose and the pad with guar gum and CMC. The pad with the perforated paper, probably had good results, as the paper allow to keep the liquid, as its density is higher than the viscose, but at the same time, thanks to the perforation, allow the liquid to spread inside the banana fibre.

After that, the prototypes do not have great results, and the variation are important between 5, 10 and 20 mL, and difficult to interpret.

Analysis of the glue:

The glue seems to slow down the absorption, as when dry, it acts as a barrier to water. The water instead of making circular stain on the top layer, was making unpredictable shape, probably going where the least glue was. At the same time, we could see that the stains were due to the slow absorbency of the pad, meaning that the pad couldn't absorb the liquid fast enough, so the liquid was moving on the surface until being absorbed. And the liquid was not wetting the top layer, as it does without glue, expanding fast in a circular shape. Due to this behaviour, the quantity of glue added between the top layer and the fibres seems to have an impact on the results. More glue means slower absorption, meaning bigger stain, meaning fewer good results. In addition, once the glue is wet, and we touched the pad, we could feel some glue on our fingers. Which means that the glue is getting diluted in water and then can come out.

Now when we regard the results, the glued does not seems to increase the retention for 5 ml, and in the case of the prototype with only fibres, it even decreases the retention. The hypothesis is that with 5 mL, due to the glue, the liquid stays on surface and does not get absorbed well. At the same time, we see that the prototype with paper and glue, increase their retention for 10 and 20 mL compared to the same prototype without glue. The prototypes with thick paper gain + 13,5 % (from 71 to 84,5 %) when glued, and the prototypes with thin paper gain + 9,5% (from 72,5 to 82%) for 10mL. the increase for 20mL is less. It seems that the glue by connecting the paper and fibre, increase the exchange of liquid between both materials.

The prototypes with thin paper glued to the top layer and the mattresses have good results for 5, 10 and 20ml, with a slight better performance for the perforated paper. As well as the prototype glued and with 1gr of guar gum. Interestingly, this prototype has better results for 10 and 20mL than the prototypes with 3g of guar gum or CMC.

We can also observe that the results of the prototypes with paper (no matter which one) on the bottom, so in between the bioplastic and the mattress, are not so good (less than 70% for 5mL, less than 80% for 10mL). Probably because the liquid does not reach the paper so fast, often it does only after the pressing of 10mL. The fact that the retention is better for 20mL fits this hypothesis. However, we can observe that when the paper is placed in between 2 mattresses (2g fibres on top, and 3g below), the retention is better for every category.

Observation on pad with paper inside fibres:

For the prototypes with paper inside the fibres, during the experiment, I could notice that the liquid had difficulty to reach the back of the pad. Probably because the liquid got stopped by the paper, and spread longitudinally, but not vertically anymore. This means that the liquid rather stayed in the upper half of the pad, rather than in the lower half

Observation on pad with cotton:

We can see that the cotton worked very very well, the retention is close to 100 %, even with 20 mL! it is very impressive. It seems to work the best with the paper. Even though we can not see it on the results, the absorption of the liquid with the guar gum was really slow, and almost to slow for the test. If the waiting time would have been 40 sec instead of 1 min, the guar gum prototype would have very bad results. In addition, even when the pad was already wet, the liquid took time to go through. Contrarily with the ones without guar gum, once the pad is wet, the liquid goes very quickly through. In addition, we can see that the pad with paper, at the end, really spread well the liquid (the paper is almost fully wet at the end, and the wet "stain", is as big as the weight surface. For the guar gum, it is different, the stain is smaller, and the back stain is very small. So it is clear that the liquid is not spread well with guar gum. It even blocks the spreading of the solution, when it is already wet as it forms a gel barrier. In addition, when we touch the guar gum pad, and applied pressure, on our finger, there is the gel sensation, it goes through the 2 top layer. In addition, the cotton seems to slightly reduce the total absorption, but, as it was already pretty good for our pad, this is not a problem.

Additional observation on the natracare pad:

The natracare pad, are very similar than our pad, however their results are much better. It seems that the wood pulp has a much higher absorption speed than our fibre. Indeed, the banana fibre does not absorb right away the liquid, so the puddle at the surface got bigger, then finally when it is absorbed, the wet area is much bigger, which means that a lot of the liquid will remain at the surface. On the contrary the wood pulp, absorb really quickly, and so the wet area at the surface remains quite small. the liquid goes directly deep inside and then expand. so when pressure will be applied, as not many fibres are wet on the surface, not much water can go up. on the contrary for our fibres, where the liquid does not go deep, but expand on surface.

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Conclusion

This report aims to serve as a foundation for further experimentation directly in Nepal using our machine. While the experiments conducted here have several flaws and limitations, they offer useful insights into potential directions for improving the retention performance of the Sparsa pad.

Our findings indicate that using a hydrophobic top layer significantly enhances absorbency. However, sourcing a compostable hydrophobic material free of synthetic chemicals is challenging and can be costly. Moreover, it is essential to validate lab results through real-world user feedback, as users' experiences are ultimately more important than laboratory data. While lab tests help us understand the pad's technical performance, they cannot replace direct input from the people who use it.

The use of CMC (carboxymethyl cellulose) or guar gum as biodegradable superabsorbent polymers (SAPs) could be promising additions to our design. However, when a large amount of SAP is used, it can migrate to the surface and form a gel-like layer. Although the SAPs used in this study are safe (e.g., guar gum is widely used in food products such as vegan cream), further research is needed to ensure they are safe for contact with mucous membranes.

An alternative worth exploring is the use of a perforated banana paper layer. This could act as a homemade, cost-effective solution with potentially better retention performance than observed in this study.

Importantly, the overall absorbency of our current pad is already sufficient and does not require further increase.

Next Steps in Product Development:

- Continue testing with biodegradable SAPs such as CMC and guar gum
- Experiment with a perforated banana paper top layer
- Collect more user feedback to better understand their needs
- Investigate ways to modify the fibers themselves to improve absorption speed and liquid distribution

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Bibliography

Design of an absorbent and comfortable sanitary napkin for applications in developing countries

„ A unitized sanitary napkin achieves absorbance through a low-density cover layer, a higher density transfer layer, a very high density reservoir layer, and then finally an imperable barrier layer"

Absorption definition: "Absorption is characterized in both the speed of uptake and the amount of liquid that the material can hold, and is dependent on both material properties and organizational structure"

Agave sisalana: towards distributed manufacturing of absorbent media for menstrual pads in semi-arid regions

Method to test the absorption, and absorption under pressure

https://www.technicaltextile.net/articles/an-overview-on-sanitary-napkins-7850

(i) Fluid acquisition layer: A lot of R&D has been done to keep the top surface dry so that it does not cling to the body and fits comfortably. This layer is a perforated film which allows liquid to pass through it quickly into the absorbent structure and stays dry, since the fluid is entrapped in the structure. It thus reduces the chance of leakage.

(ii) Distribution component: This component spreads out the fluid, especially in the longitudinal direction, for better utilisation of the product. By spreading fluid, it increases the probability of more retention of fluid.

(iii) Absorbent structure: One of the main characteristics of sanitary pads is to absorb body fluid and retain it for a long period of time and avoid back flow under pressure.

(iv) Liquid impervious membrane: This is the last layer. It acts as a barrier to prevent fluid from leaking

As fluid comes vertically in contact with the first layer, it moves across the fluid acquisition layer to the absorbent layer without spreading in the facing layer. Once fluid reaches the absorbent layer, it spreads and can be held without reversing flow direction.

The first problem in sanitary pads is the interface between acquisition layer and absorbent layer. The acquisition layer is mainly made up of hydrophobic fibre and the absorbent layer is composed of hydrophilic fibre so the fluid must get readily transferred from acquisition layer to absorbing medium. Transfer of fluid from one layer to other will fail if there is not enough intimate contact between the two layers. Any gap will alter the pattern of flow and liquid may spill and lead to failure of the product.

Almost all sanitary pads use fluffed cellulosic pulp as the core component of the absorbent material. This fluff is prepared by defibrillation of unopened compressed cellulosic boards. There is always a chance of some amount of unopened board which gives heterogeneity to the absorbent material. Therefore, uneven flow and retention of fluid will be different from the rest of the area.

Performance of sanitary pads can be evaluated on fluid retention capacity or the amount of fluid sustained after applying pressure. One factor which affects fluid retention is density. Modern commercial sanitary pads are made from super absorbent fibre used in compressed and uncompressed form. Density significantly influences the absorption and stability of the product. A highly compressed fibre will expand on absorption whereas in case of lightly compressed fibre, it will collapse as a result of absorption. So compression of absorbent material is necessary to maintain its structural integrity.

+ description of tests (retention and absorbency)

https://www.sciencedirect.com/science/article/abs/pii/S2590238524003473

they use alginate glycerol materials as blood thickener (no access of the paper)

https://www.sciencedirect.com/science/article/abs/pii/S0921344919303179

impact of sanitary pad compare to cup

Toward sustainable menstrual health management: focus on super absorbent polymers

Interesting paper detailing what is SAP and possible bio alternatives (cellulose, starch, chitin)

Chitosan Superabsorbent Biopolymers in Sanitary and Hygiene Applications

Detailed explanation on chitosan as biosap.

The study and optimization of the hygroscopic properties of selected natural products with an aim of designing a sanitary pad suitable for low- and middle-income population

Detail of experiment with NaOH (they put 1, 2 and 3 %)

Development of Ecological Absorbent Core Sanitary Pads in Combination of Kenaf and Chitosan Fibers

Interesting as they use chitosan directly with kenaf fibre, and their results are rather good.

Liquid absorbent bamboo fiber foams: Towards 100% ligno-cellulosic menstrual absorbent pads

Paper from Flo's university, who made research on how to enhance the absorption quality of cellulosic fibre directly. They made a foam with bamboo, and the results are pretty good.

A way to test absorption and retention is included.

Advancements in Sanitary Napkins: A Comprehensive Analysis of Thermal Comfort, Moisture Management and Sustainable Innovations

Moisture Management Properties

Moisture management refers to the ability of a material to absorb, distribute, and retain moisture. In the context of sanitary napkins, this includes the pad's capacity to absorb menstrual fluid, prevent leakage, and maintain a dry surface. Key factors influencing moisture management in sanitary napkins include:

1. Absorbency: The primary function of a sanitary napkin is to absorb menstrual fluid. The absorbent core, typically made of SAPs, plays a crucial role in this process. SAPs can absorb and lock away large amounts of fluid, preventing leakage and maintaining a dry surface. Research has shown that the use of advanced SAPs with higher absorbency capacity and faster absorption rates improves the overall performance of sanitary napkins (Nakamura & Kondo, 2018).
2. Fluid Distribution: Even fluid distribution within the pad is essential to maximize absorbency and prevent leakage. Recent advancements in the design of sanitary napkins include the incorporation of channels, grooves, and embossing patterns in the absorbent core. These features help distribute fluid evenly, reducing the risk of localized saturation and leakage (Meyer & Werning, 2017). Additionally, the use of zoned absorbency, where different areas of the pad have varying absorbency levels, enhances overall fluid management.
3. Surface Dryness: Maintaining a dry surface is crucial for comfort and preventing skin irritation. The top sheet plays a vital role in this aspect by wicking moisture away from the skin and into the absorbent core. Innovations in top sheet materials, such as the use of hydrophilic fibers and perforated films, enhance the speed and efficiency of moisture transfer, keeping the surface dry (Kang et al., 2019).

SANITARY NAPKIN INCLUDING BODY-FACING PROTRUSIONS FOR PREVENTING SIDE LEAKAGE AND OBLIQUELY ARRANGED EMBOSSED CHANNELS - Patent application (patentsencyclopedia.com)

IN this patent from Johnson and Johnson, they are using embossing to avoid leakage on the wings.

Investigation of fluid distribution and rewet performance with the use of different inner layer design and top sheets in sanitary napkins

Method to measure rewet.

Natural and Sustainable Raw Materials for Sanitary Napkin

List options for compostable napkins

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Notes done during the experiments:

An idea which came in mind: Plastic is used as top layer, as it is hydrophobic. The goal being that there is no wet feeling. Indeed the liquid goes quickly through and is absorb by the absorbent core. Thus the top layer stays dry. Now what is used, for example for the always night pad, is to make holes in a hydrophobic plastic film. As the cellulosic fibres are just below, the liquid will go through the holes and get absorbed. And the top layer remains dry. Now, what if we could use the hydrophobic cotton we have, make holes in it, to let the liquid goes through? it seems that it might work, need more test and see if this cotton can't irritate the skin. So I try several things, to make holes in it, or to extend it to make it thinner. Both technics works, the liquid goes through. I can however see several challenges: with the holes, if the cotton is not properly sticking the fibres, the liquid does not go through, or it requires some pressure. It is a bit the same with the extended cotton, but it seems like fewer pressure also work. On the bright side, once the liquid starts to go through it is quickly absorbed, and the cotton remains dry.

Now I tried with 2 layers: one of cotton at top layer, and one of viscose as transfer layer. The liquid is absorbed even faster. In addition as the liquid spread very fast on the viscose layer, it measn that there is a very thin layer of liquid under a bigger surface of the cotton, which helps the new liquid arriving to go through the cotton.

Now we can try with a very thin banana paper. Indeed, right now in Nepal they do not have viscose, but maybe a very thin banana paper would work. Plus it will make sure that the mattress does not go through the cotton.

I tried to glue the cotton with a layer of banana paper or a layer of viscose. What we can see is that the glue definitely help. However, if no pressure is applied, the liquid does not go through at all. I put drops on the cotton and even after 5 min, nothing happened. If I apply some pressure and the cotton is glued, it will quickly get absorbed. If no glue, the pressure must be higher.

Now I also tried to extend the cotton (fro 18,5 cm width till 25cm width, with the same length), and to glue it to the viscose. I first pour small drops, and it did not go through. Then I tried a bigger one, and eventually it met a bigger hole and went through by itself. In addition, with a tiny little pressure, the liquid went through.

I also tried to put liquid and stronger glue on some points, between the cotton and viscose. The idea is hat the liquid is using the area where it is glued, to go through the first layer. This works very well, where it is glue, the liquid goes easily through.

I also try to link the paper and cotton, or the viscose and cotton, with a hot iron (with and without steam), it is not working, also with a needle, trying to interconnect the fibres, also not working.

I cut the cotton to have some small holes, and I then glue it with viscose, here also it needs a bit of pressure to make the liquid goes through. If there are some holes, it is a tiny bit widened, but no glue, it is not going through easily.

After the second series of prototype test, with the raw cotton and viscose:

Prototype to do (ideas)

The SAP are good, but they are blocking the absorption, so it is slower and slower. This is why it shouldn't be directly on top. The paper works pretty well to distribute the liquid quickly through the pad. The fluff fibres are actually working well to quickly absorb the liquid, even though they are less good than wood fluff. So based on that:

- A thin paper in between 2 mattresses, one on top with only fibres, and one on the bottom with sap. I could do one with holes, and one without holes to see the difference. So 2g fibre of top mattress, the paper on the whole surface, and then 3g of fibre with 1 g of SAP. In addition, we would need a third one without paper to see the difference. Paper used: 6,5*22 for 0,5g => 35g/m^2

Analysis results with thin paper in middle:

The results seems a bit better than the previous series of prototype. However, it might be that doing the 5mL teat before hand change the results of the 10mL. Indeed, the fibres are pressed, and then the fluid absorption is not the same, which lead to differences in terms of results. In addition, the differences in between the 4 prototypes I made is quite weak, which make it difficult to analyse. What we can say, is that the paper in the middle seems not necessarly a good idea, as at the end of the trials, the back of the pads were not so much wet, even with 20mL, and the pressing. This definitely is not good, as it means the liquid stays on surface and does not go through. This was also seeable on the front of the pad, the whole surface where the weight was applied was wet.

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