STUDY OF SUSTAINABLE ALTERNATIVES TO DISPOSABLE DIAPERS: PROCESS AND PRODUCT DEVELOPMENT

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Abstract: The consumption of disposable diapers is associated with environmental side effects, financial impacts on family income and risk of diaper rash and allergies. It is possible to find alternatives to common disposable diapers in the market, nevertheless they are not widely adopted. This work provides an improved solution to reduce the environmental impact without compromising the convenience of the disposable ones. The product concept incorporates a reusable and biodegradable liner and a bioactive solution for the preliminary cleaning that minimizes odor and speed up the cleaning process.

Keywords: biodegradable diapers; ecological diapers; sustainability

ESTUDO DE ALTERNATIVAS SUSTENTÁVEIS À FRALDA DESCARTÁVEL: PROCESSO E DESENVOLVIMENTO DE PRODUTO.

Resumo: O consumo de fraldas descartáveis está associado a efeitos colaterais ambientais, impactos financeiros na renda familiar e risco de assaduras e alergias. É possível encontrar no mercado alternativas às fraldas descartáveis comuns, porém não são amplamente adotadas. Este trabalho oferece uma solução aprimorada para reduzir o impacto ambiental sem comprometer a conveniência dos descartáveis. O conceito do produto incorpora um forro reutilizável e biodegradável e uma solução bioativa para a limpeza preliminar que minimiza o odor e acelera o processo de limpeza.

Palavras-chave: fraldas biodegradáveis; fraldas ecológicas; sustentabilidade

1. INTRODUCTION

The need to contain the feces and urine of babies and young children using various materials has always existed. Nowadays, the consumption of disposable diapers has become significant. They are easy to use and accessible. Nevertheless, they are not recyclable and become a problem for garbage management. It is estimated that a child consumes an average of 6.000 diapers in the first 3 years of life. Additionally, the number of children being born is substantial. According to the Brazilian government portal, in the year 2022, there was registered births of 2.471.519 children, respectively. Only in Brazil, in 2014, 7,9 billion diapers were sold, earning the country the 3rd position in the global ranking [1-3].

The convenience that disposable diapers provide for parents and caregivers is an influential factor in their choice, despite being considered a consumable item that impacts the family budget due to their cost. Another aspect to be observed regarding the use of disposable diapers is the risk of diaper rash and allergies, situations widely reported by parents and caregivers. This led to the development of new materials for diapers and rash creams. However, studies have shown the presence of toxic substances in disposable diapers, such as a French study that identified more than 60 toxic substances, indicating the risk of health damage through skin contact [4].

Finally, another relevant aspect to consider is the environmental aspect: a) high demand for raw materials for their production and consequently high consumption of inputs, including water and energy, as well as the production of waste (solid, liquid, and gaseous); b) fuel consumption and consequent atmospheric emissions, including greenhouse gases, for the logistics involved throughout the lifecycle of disposable diapers; and c) disposal of diapers in the environment, even in cases where they are intended for licensed landfills, as they accumulate over centuries.

In this context of economic, health, and environmental impacts related to the consumption of disposable diapers, initiatives have been undertaken to develop alternative diapers that aim to eliminate or minimize the impact of disposal and increase convenience compared to conventional cloth diapers. Thus, this research sought to develop a new product that could contain the feces and urine of young children, increasing sustainability without compromising the convenience already possible with disposable diapers.

2. METHODOLOGY

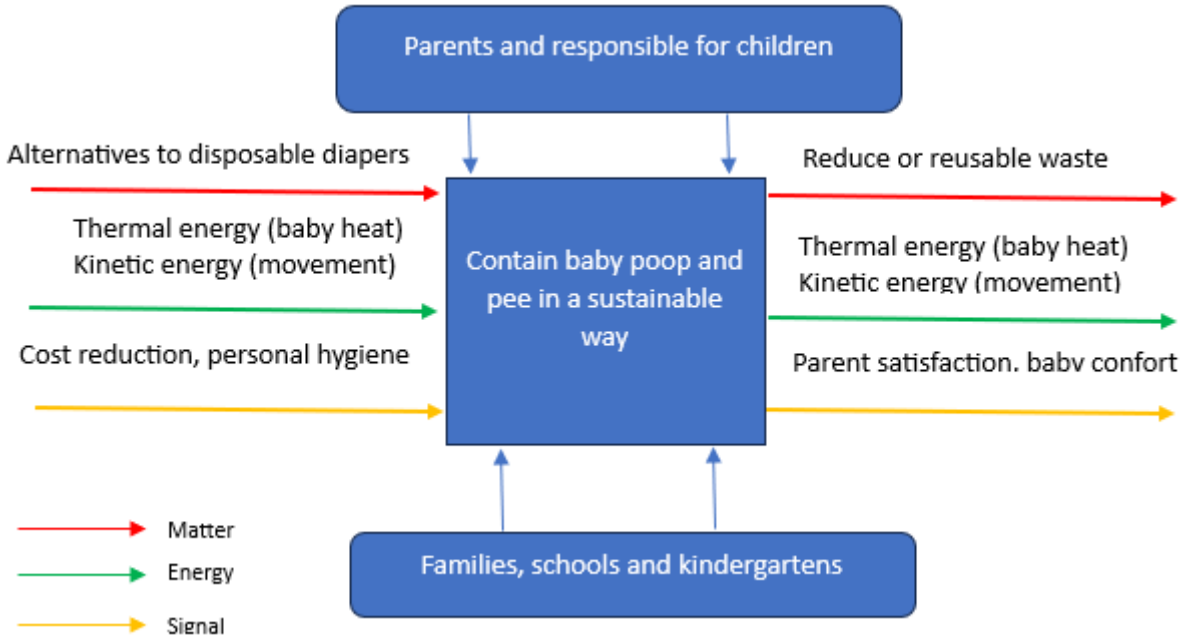
The methodology adopted for the development of this research was the Product Development Process (PDP). This methodology focuses on innovation for problem solving. Through 17 defined steps, it offers the possibility of generating patents based on the idealized solution. An electronic Google Forms questionnaire was applied in whatsapp groups of mothers residing in Salvador-Bahia, which obtained voluntary, anonymous and random adherence of 80 respondents to identify the needs of customers. Furthermore, QFD (Quality Function Deployment), Morphological Matrix, Global Function, Functional Synthesis, among other tools, were used. This protocol can be refer to Back et. al. (2008) [5], Baxter (1998) [6] and Rozenfeld (2006) [7].

3. RESULTS AND DISCUSSION

3.1. Problem system

The interfaces of the problem system were defined, aiming to reduce the impacts of using conventional disposable diapers and promote a sustainable alternative that can contribute to the reduction of environmental impacts, while maintaining convenience for parents and caregivers. Figure 1 illustrates the interfaces of the problem-system.

Figure 1: Problem-system interfaces.



3.2. Life cycle

Based on the problem situation, eight phases of the product life cycle were identified as a solution to mitigate the issue of disposable diaper disposal. These phases were assigned to their respective potential customers, categorized as internal, intermediary, and external, as shown in Table 1.

Table 1: Life Cycle and identification of main costumers.

Type	Phase	Costumer
Internal	Demand/Opportunity	Members of the development team (Research, Development and Innovation); Consumer.
	Development	Members of the development team; Experts; Consumer.
	Manufacturing	Company that manufactures the solution and its internal customers; Raw material suppliers
Intermediary	Purchase	Consumer
	Sale	Retailers in physical stores; Retailers in online stores; Own online sales channel
External	Use	Consumer
	Maintenance	Maintenance entreprise
	Reuse/Recycle/Dispose	Detachment groups (purchase or donation of the product after the child stops using diapers); Recycling cooperatives for packaging

3.3- Similar Competitors and Patents

Initially, competitors and similar products that already have demand and recognition in the infant diaper market were researched, categorizing them into conventional disposable, reusable, and biodegradable diapers. Additionally, patent searches were conducted.

Conventional disposable diapers are made of plastic elements and cannot be reused. In the case of reusable diapers, predominantly made of fabric, there are no dominant brands in the market. These diapers typically have internal absorbents, the quantity of which can vary according to the baby's needs. The third case refers to a disposable model of diapers made from biodegradable materials, combining the convenience of disposable diapers with a higher cost.

To complete the research, patent documents related to "Disposable and Reusable Diapers" were searched on the Google patent database. It was observed that the main patent holders are The Procter & Gamble Company and Kimberly-Clark Corporation, owners of the Pampers and Huggies brands, respectively. Patent documents for different types of diapers existing and registered worldwide were obtained, and the three most relevant ones were selected as the focus: P1 - Disposable diaper; P2 - Reusable outer cover for absorbent articles with areas of varying properties; P3 - Biodegradable diaper.

3.4- Identification of Customer Needs

The identification of customer needs was carried out through the application of an electronic questionnaire in March 2023, among groups of mothers in the city of Salvador-Bahia, resulting in 80 responses. The percentage distribution of volunteers by gender showed a majority participation of women with 88,75% of the participants. It was possible to identify that 75% of the individuals were in the age range of 35 to 44 years. Regarding the average family income, 77,5% of the volunteer group consisted of individuals from social classes A (22,5%) and B (55%). As for the number of children, it was noted that 97,4% had up to 2 children under their care. The sample, therefore, consists of individuals with high family income and a small number of children. It was identified that there are records of newborns up to over 4 years old (53,9%) under the care of the interviewees.

The results indicate the current dominance of disposable diapers, as 98,8% of the respondents reported being familiar with this type of product. Cotton diapers ranked second with 66,3% of the mentions, and biodegradable disposable diapers ranked third with 28,7% of the responses.

Based on the conducted research, the reported customer needs were interpreted and translated into requirements that the product will need to meet. Table 2 provides a summary of the listed topics, allocated to each product development phase.

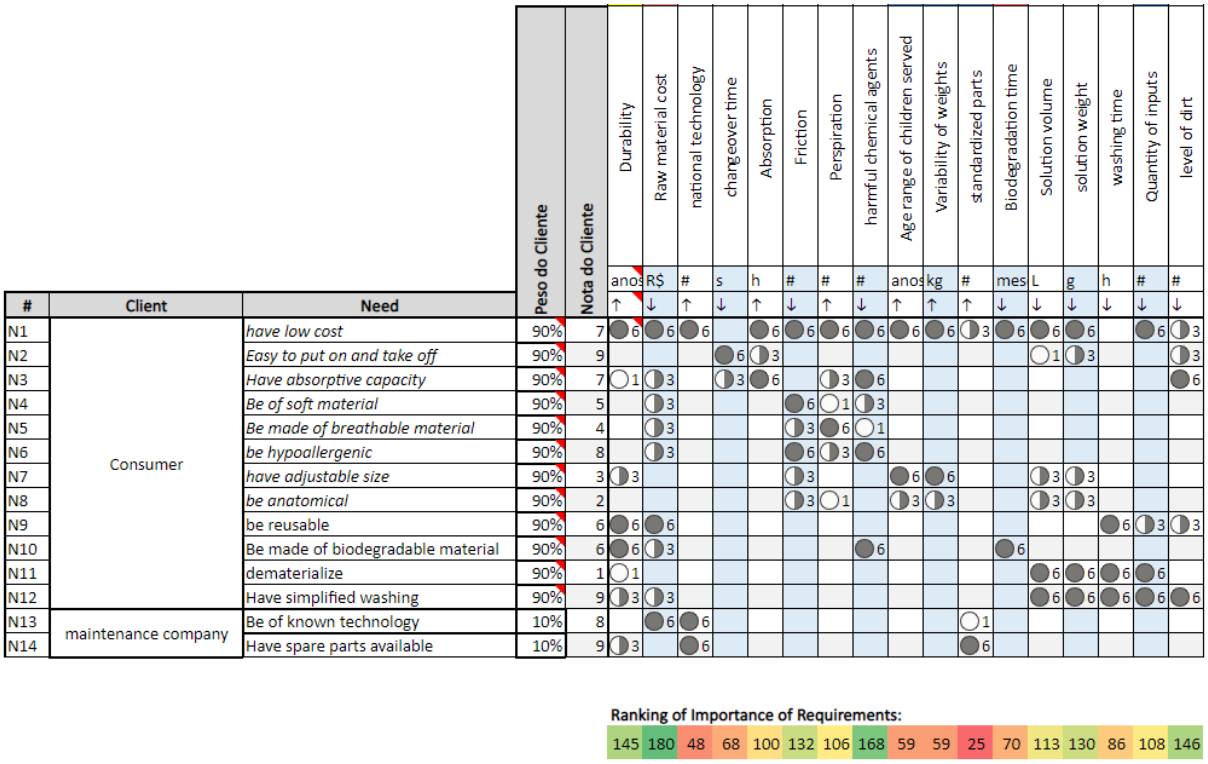
Table 2: Translation and consolidation of customer needs

Customer/ Actor	Product life cycle	Need expressed by the customer	Need translated
Business person	*Production/ Sales*	*Need to be profitable*	*Have low cost (includes production, materials, logistics, etc.)*
		Requires little training to manufacture/ assemble	*Have low cost (includes production, materials, logistics, etc.)*
Consumer	Use	*Have to be tough*	*Be robust*
		Low Cost - lifecycle	*Have low cost*
		Practicality	Easy to put on and take off
		Avoid diaper rash	Have absorptive capacity
			Be of soft material
			Be made of breathable material
		Do not leak	Have absorptive capacity
		Not cause allergy	Be hypoallergenic
		Comfort	Have adjustable size
			Be anatomical
			Be of soft material
Specialized company	Maintenance	ease maintenance	Be of known technology
			Have spare parts available
Consumer	After use destination	Reduce environmental impact	Be reusable
			Be made of biodegradable material
			Dematerialize
		Ease of disposal	Be made of biodegradable material
			Have simplified washing

3.5 - Quality Function Deployment (QFD)

The Quality Function Deployment (QFD) methodology was applied to the problem situation of this study. Fourteen needs were identified for two specific types of customers. In the case of the Consumer, it was classified with a weight of 90% for twelve needs defined as follows: low cost, ease of wearing and removal, absorption capacity, soft material, breathable material, hypoallergenic, adjustable size, anatomical fit, reusable, biodegradable material, dematerialization, and simplified washing. For the Maintenance Company, classified with a weight of 10%, two needs were defined: known technology and availability of spare parts. The fourteen identified customer needs were translated into seventeen technical requirements: Raw Material Cost, Harmful Chemical Agents, Level of Soiling, Durability, Friction, Solution Weight, Solution Volume, Input Quantity, Transpiration, Absorption, Washing Time, Biodegradation Time, Replacement Time, Age Range of Children Served, Weight Variability, National Technology and Standardized Parts. The results of QFD can be observed in figure 2, which is complemented by table 3 that focus on the prioritized requirements of the product proposal.

Figure 2: Quality Function Deployment matrix.



#	Client	Need	Peso do Cliente	Nota do Cliente	Durability	Raw material cost	national technology	changeover time	Absorption	Friction	Perspiration	harmful chemical agents	Age range of children served	Variability of weights	standardized parts	Biodegradation time	Solution volume	solution weight	washing time	Quantity of inputs	level of dirt
					anos	R$	#	s	h	#	#	#	anos	kg	#	mes	L	g	h	#	#
					↑	↓	↑	↓	↑	↓	↑	↓	↑	↑	↑	↓	↓	↓	↓	↓	↓
N1	Consumer	*have low cost*	90%	7	6	6	6		6	6	6	6	6	6	3	6	6	6		6	3
N2		*Easy to put on and take off*	90%	9				6	3								1	3			3
N3		*Have absorptive capacity*	90%	7	1	3		3	6		3	6									6
N4		*Be of soft material*	90%	5		3				6	1	3									
N5		*Be made of breathable material*	90%	4		3				3	6	1									
N6		*be hypoallergenic*	90%	8		3				6	3	6									
N7		*have adjustable size*	90%	3	3					3			6	6			3	3			
N8		*be anatomical*	90%	2						3	1		3	3			3	3			
N9		be reusable	90%	6	6	6													6	3	3
N10		Be made of biodegradable material	90%	6	6	3						6				6					
N11		dematerialize	90%	1	1												6	6	6	6	
N12		Have simplified washing	90%	9	3	3											6	6	6	6	6
N13	maintenance company	Be of known technology	10%	8		6	6								1						
N14		Have spare parts available	10%	9	3		6								6						

Ranking of Importance of Requirements:

145	180	48	68	100	132	106	168	59	59	25	70	113	130	86	108	146

Table 3: Ranking of Requirements.

Ranking of Requirement Importance		
N	**Requirements**	**Score**
1st	Raw material cost	180
2nd	Harmful chemical agents	168
3rd	Nevel of dirt	146
4th	Durability	145
5th	Friction	132

3.6 – Morphological matrix

Based on the previous steps, it was possible to define the global function of the product, diagramming the materials, energy and signals in an input and output logic with the existing interfaces with the user, environments and actors involved. Subsequently, the Functional Synthesis was defined, which is a layout of the flow of use of the product, contemplating the steps related to the problem situation to be solved. For each step, the requirements to be met were identified and, thus, the Morphological Matrix was elaborated (part of it is exemplified in Figure 3) which outlines the possible solutions for meeting the requirements, including the solutions available on the market.

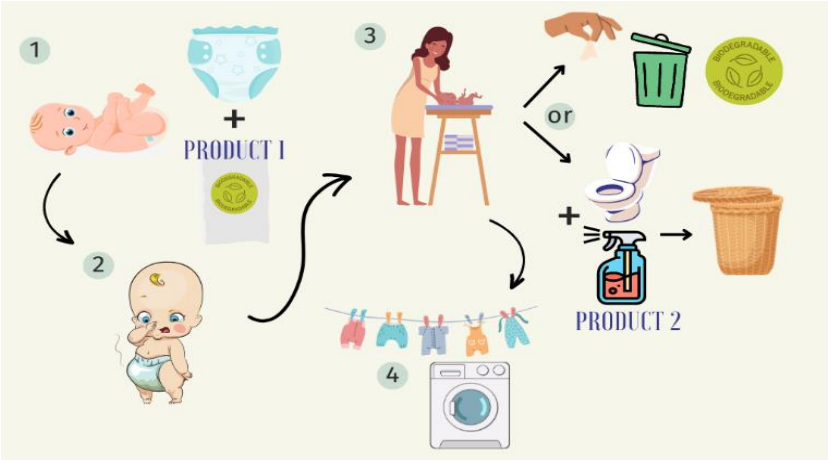
Figure 3: Illustrative part of morphological matrix.

FUNCTIONAL SYNTHESIS 6 - USE A DIAPER									
F	F N1	F	FN2	S1	S2	S3	S4	S5	S6
F4	Dispose of Diapers	F4.4	Store dirty diapers						
		F4.5	Wash absorbent and diaper refills						
		F4.6	Discard the diaper						

3.7 - Concept Selection and Detailing

After generating the 10 concepts, a qualitative evaluation was conducted using the Pugh Matrix, which allows for ranking the concepts based on customer needs and their respective weights. Based on this analysis, the most promising concepts were ranked to satisfy customer needs. Among the top-ranked concepts, two new products were identified that embody innovation with the aim of bringing more convenience to the use of eco-friendly diapers and also promoting their use to reduce environmental impact. These products are: Reusable biodegradable liner and bioactive solution for diaper cleaning. Figure 4 illustrate the step by step of using the products generated by these solutions proposed.

Figure 4: Illustrative application of the proposal products.



The Reusable and Biodegradable Liner can add convenience and reducing environmental impact to the functional process of containing children's feces in a sustainable and innovative way. The combination of two functions currently present separately in two distinct products (Reusable liner and Disposable biodegradable liner) will generate a significant competitive advantage for this new device. The Bioactive Liquid Solution can add convenience to the use of ecological diapers as its application

through a spray bottle allows for storing the diaper for later washing with the biodegradation of residues and reduction of odor.

4. CONCLUSION

The research concluded that there are already sustainable solutions in the market, which can still be improved. Therefore, the proposed solution for the problem at hand aims to increase the environmental benefits of the existing solution by providing a biodegradable, yet reusable liner that can be washed a few times in cases of urine or less soiled feces, minimizing costs for families and reducing environmental impact. Additionally, a bioactive solution was proposed for the preliminary cleaning of diapers and refills, speeding up the cleaning process and minimizing odor. This will allow for a longer interval between diaper changes and washing, as well as the possibility of washing them together with other family items, thus increasing convenience.

Acknowledgments

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