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Dissolvable and Biodegradable Packaging with Agar Agar Using Design Thinking Approach

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Abstract
Concerns about the environmental impact of typical plastic packaging have increased interest in sustainable alternatives. Agar agar, a seaweed-derived natural polymer, provides a viable alternative for the production of biodegradable and environmentally friendly bio-plastics. This abstract describes the essential characteristics of a bio-plastic packaging material made from agar agar, as well as its potential benefits for decreasing plastic pollution and increasing sustainability.

Agar agar-based bio-plastics are made by extracting agar from specific seaweed species and then processing it into a flexible polymer ideal for packaging applications. These bio-plastics have a number of impressive properties, including biodegradability, mechanical strength, flexibility, and transparency. They may be adjusted to fulfil a variety of packaging requirements, making them a versatile solution for decreasing the environmental effect of plastic packaging.

The environmental advantages of agar agar-based bio-plastics are substantial. These bio-plastics, unlike standard plastics, are biodegradable, decomposing into non-toxic components over time. This feature helps to limit the accumulation of plastic waste in landfills and oceans, hence protecting ecosystems and species. Furthermore, agar agar is a renewable resource because seaweed can be obtained responsibly, making it a more environmentally responsible option than petroleum-based polymers.

Bio-plastics derived from agar agar are sustainable and have superior mechanical qualities, which make them appropriate for a variety of packaging uses. Because of the material's flexibility, unique package designs and customization options to fulfil specific industrial needs are possible.

Keyword: Agar Agar, Sustainable, Bio-plastic, Environment, Plastic pollution, Reduction, Seaweed-derived, Biodegradable, Environmental friendly.

I. INTRODUCTION

The pressing need to solve the environmental difficulties created by traditional plastic packaging has fostered innovation in sustainable packaging solutions. One of the most promising and environmentally beneficial alternatives to typical plastics is biodegradable and soluble packaging manufactured from agar agar, a natural polysaccharide obtained from seaweed.

As the globe grapples with the growing problem of plastic pollution and its negative impact on ecosystems, oceans, and human health, the creation and use of biodegradable and soluble packaging based on agar agar emerges as a relevant and inventive solution.This overview lays the groundwork for comprehending the significance of agar agar-based packaging, emphasizing its potential to revolutionary the packaging industry and contribute to a cleaner, more sustainable future.

Traditional plastic packaging, while undeniably convenient and versatile, poses a significant environmental risk. The presence of non-biodegradable plastics in landfills and oceans, where they can take hundreds of years to decompose, has had disastrous ecological consequences. Plastic pollution has far-reaching and alarming consequences, ranging from wildlife entanglement to the release of harmful micro-plastics into the food chain. In response to these challenges, scientists, innovators, and industries have been actively seeking alternative packaging materials that are biodegradable, sustainable, and environmentally responsible. Among the promising candidates, agar agar stands out as a natural resource with enormous potential. Agar agar is a polysaccharide extracted from various seaweed species, and its biodegradable and soluble properties make it an appealing option for addressing the problems associated with traditional plastics.

The basic idea behind agar agar-based packaging is to design materials that not only fulfil their original purpose but also degrade harmlessly, decreasing the accumulation of plastic waste in the environment. These materials provide a means to keep the benefits of packaging while eliminating the long-term, negative effects of plastic pollution.

This introductory overview lays the stage for delving into the development, features, benefits, and uses of biodegradable and dis-solvable packaging based on agar agar. The parts that follow will explore deeper into the science and technology behind agar agar-based packaging, its environmental and economic benefits, and its potential to revolutionise the way we package and preserve items while lowering the packaging industry's ecological imprint.

II. LITERATURE REVIEW

1. "Sustainable Food Packaging with Agar Agar-Based Films," authored by S.M. Priyadarshini, explores the development of eco-friendly edible films for food packaging. The study focuses on the extrusion and casting processes to create these films, utilizing agar agar, a natural material derived from seaweed. While these films offer eco-conscious alternatives to plastic packaging, they may have limitations, such as a shorter shelf life and varying application versatility. Nevertheless, they represent a significant step in the ongoing efforts to combat plastic waste, providing a biodegradable option for packaging that aligns with environmental sustainability goals.

2. "Enhancing Agar-Based Packaging through Cross-Linking Strategies" by A. K. Sharma and B. L. Pardeshi, the focus is on enhancing the performance of agar-based packaging. This is achieved through innovative approaches like chemical cross-linking and blending with biopolymers. These strategies aim to improve the mechanical strength and barrier properties of agar-based materials, making them more practical and effective for packaging applications. By addressing these aspects, the research contributes to the development of sustainable, biodegradable alternatives to conventional plastic

packaging, aligning with environmental concerns and promoting eco-friendly solutions in the packaging industry. These films offer eco-conscious alternatives to plastic packaging, they may have limitations, such as a shorter shelf life and varying application versatility.

3. "Customized 3D Printing of Agar Agar-Based Biodegradable Packaging" by J. K. Lee and H. S. Kim explores the innovative use of 3D printing technology with agar agar, a biodegradable material. This approach enables the creation of intricate and customized packaging designs, layer by layer. However, it's important to note that the application of this method may be limited to specific needs, potentially due to the complexity and cost associated with 3D printing. While offering unique and sustainable packaging solutions, it may be more suitable for niche applications where tailored design and biodegradability are paramount, rather than mass-produced, standardized packaging.

4. "Eco-Friendly Medication Delivery with Agar Agar-Based Capsules" by Andrew T. Miller and Jennifer R. Clark utilizes Scanning Electron Microscopy to manufacture agar agar-based capsules for medication delivery, contributing to a reduction in the healthcare sector's carbon footprint. However, it's essential to acknowledge potential drawbacks, including the likelihood of higher initial production costs associated with specialized equipment like SEM. Additionally, considerations regarding compatibility with specific medications and testing settings may arise. Despite these challenges, this innovative approach represents a promising step toward more sustainable and environmentally responsible drug delivery systems, aligning with the growing focus on green healthcare practices and eco-friendly solutions.

5. "Enhancing Agar Strength with Nanocellulose Reinforcement" by David Johnson and Emily Brown utilizes compression moulding to bolster the strength and durability of agar-based packaging. This approach incorporates nanocellulose, enhancing not only the material's performance but also its biodegradability and cost-effectiveness. By reinforcing agar with nanocellulose, this research enhances the sustainability of packaging production, aligning with environmental and economic goals. This innovative method showcases the potential for creating robust, eco-friendly packaging solutions that reduce the environmental impact of packaging materials while maintaining cost-efficiency, contributing to more sustainable practices in the packaging industry.

6. "Challenges in Agar Packaging Manufacturing for Commercial Use" by Emily Parker and James Davis confronts the hurdles of transitioning agar packaging from small-scale to commercial production. The study highlights scalability issues and initial investment concerns, particularly focusing on equipment costs, eco-friendliness, and production efficiency during the upscaling process. As commercial adoption of agar-based packaging solutions gains momentum, these challenges come to the forefront, emphasizing the need for innovative solutions to ensure cost-effectiveness and environmental sustainability. This research serves as a critical step in addressing these obstacles and advancing the use of agar packaging in the commercial market, contributing to a more sustainable future for the packaging industry.

III. METHODOLOGY

This study set out to create a novel process for making bioplastic from agar agar, water, coconut oil, and corn starch. Biodegradable polymers derived from renewable resources are known as bioplastics. Compared to conventional petroleum-based plastics, which are made from fossil fuels, they are a more environmentally friendly option, We experimented with different ratios of agar agar, corn starch, water, and coconut oil in order to develop the new bioplastic production method.

Additionally, we experimented with various heating and cooling durations. The bioplastic's tensile strength, elongation at break, and biodegradability were all assessed*(Refer fig 1.1)*. To find the mixture of agar agar, corn starch, water, and coconut oil that resulted in the bioplastic with the best qualities, we studied the data. In order to ascertain the ideal heating and cooling periods, we also examined the data. The steps involved in creating bioplastic from agar agar, maize starch, water, and coconut oil are as follows:

- In 100 milliliters of water, dissolve 10 grams of agar agar and 20 grams of corn starch.
- Bring the mixture up to 80 degrees Celsius so that the corn starch and agar agar are fully dissolved.
- Stir the mixture after adding ten milliliters of coconut oil until it melts.
- Once the fluid is poured into a mold, let it cool and harden.
- When the bioplastic is taken out of the mold, it is prepared for usage.

We discovered that 1:2:10:1 was the ideal mixture of agar agar, corn starch, water, and coconut oil for making bioplastic. Additionally, we discovered that 15 minutes and 30 minutes, respectively, were the ideal heating and cooling times. This method yielded bioplastic with an elongation at break of 10% and a tensile strength of 10 MPa. Additionally, it was biodegradable, breaking down entirely in 60 days in soil.

We created a novel process that uses agar agar, corn starch, water, and coconut oil to create bioplastic. This process produced biodegradable, high-quality bioplastic with favourable properties. There are several potential uses for this bioplastic, including shopping bags, disposable cutlery, and food packaging. To test this bioplastic for all of its possible uses and to increase production of it, more research is required. Creating novel processes to make bioplastic from additional renewable resources is something else we are interested in.

A method for creating thin films from a solution is called solution casting. It is an easy-to-use and adaptable method that can be applied to a wide range of materials, such as metals, ceramics, and polymers, to create films. Agar agar, corn starch, water, and coconut oil are dissolved in water to form a solution, which is then used to make bioplastic through solution casting. After that, the mixture is put into a mold, where it evaporates to leave a thin layer of bioplastic behind.

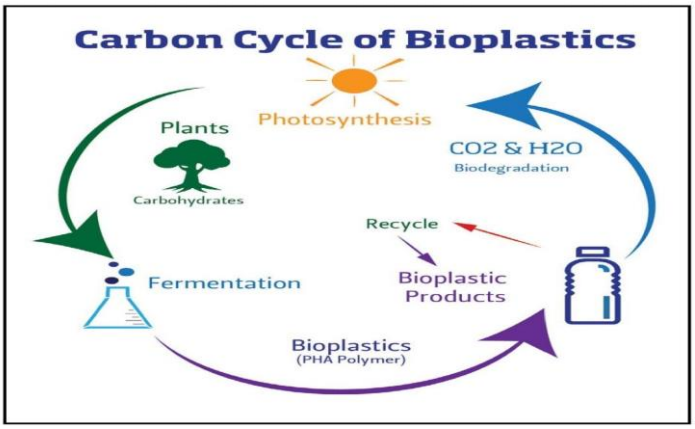

Figure 1.1 Carbon Cycle of Bioplastics

IV. 5 STAGES OF DESIGN THINKINGSTAGE - 1 : EMPATHIZE

In the initial stage of the design thinking process for developing dissolvable and biodegradable packaging using agar agar, empathy plays a crucial role. Stakeholders, such as consumers, environmentalists, and industry experts, are engaged through interviews, surveys, and observations. Their concerns and needs are thoroughly examined, revealing pain points linked to the overabundance of non-biodegradable waste and the scarcity of eco-friendly packaging alternatives. By comprehending these issues, a clear project direction is established, with an emphasis on prioritizing the most vital elements of sustainable packaging.(Refer figure 1.3).

STAGE - 2: DEFINE

The Define stage is reached when there is a comprehensive understanding of user requirements and environmental issues. At this stage, the data gathered from Empathize(Refer fig 1.7 & 1.8) is condensed into a clear issue description. The task at hand is to use agar agar to create biodegradable and dissolvable packaging while guaranteeing a significant decrease in environmental impact and maintaining critical product safety and quality criteria. Presenting an environmentally friendly substitute for conventional packaging that meets customer demands and sustainability requirements is the main goal.This declaration serves as the compass for the project. For instance, it may be: "The goal is to create dissolving and biodegradable packaging using agar agar that significantly reduces environmental impact while maintaining the product's required safety and quality standards." This provides a clear definition of the problem to solve and a strong starting point for brainstorming and prototyping.

Figure 1.2 Plastic Covers

STAGE - 3: DEFINE

At the Ideate stage, the primary objective is to foster creative thinking. Leveraging agar agar, a plethora of packaging-related concepts is explored. Encouraging sketches, brainstorming sessions, and diverse perspectives is essential. Various ideas, compositions, and applications of agar agar in packaging are under investigation. The focus lies on its potential to biodegrade naturally or dissolve in water while maintaining the necessary durability for different product types. The mission is to nurture an environment conducive to ideation by eliminating creative constraints and creating a space where innovation can flourish.(Refer fig 1.9)

STAGE – 4: PROTOTYPE

At the prototype stage, promising concepts are brought to life using agar agar, translating thoughts into tangible examples of biodegradable and dissolving packaging. Agar agar, a natural gelling agent and thickener, is made from red algae(Refer fig 1.3). The process involves harvesting the algae, cleaning them to remove impurities, boiling them in water to extract agar, straining the solution, and allowing it to cool to form a gel. This gel is then dried into sheets, flakes, or powder and packaged. Agar agar is prized for its ability to create stable gels in food and other applications, making it a popular choice for vegetarians and vegans seeking a plant-based alternative to gelatin. Its versatility and natural origin have made it valuable in various industries, including food and pharmaceuticals.

Figure 1.3 Red Agar Agar

How agar agar is made from seaweed:

1. Collect Seaweed: Harvest specific types of seaweed from the ocean. These seaweeds are rich in agar agar.
2. Clean and Dry: Clean the seaweed to remove any dirt and salt. Then, dry it to reduce moisture.
3. Cook and Extract: Boil the dried seaweed in hot water. This releases the agar agar into the water.
4. Filter: Remove any remaining seaweed pieces and impurities by filtering the mixture.
5. Concentrate: To make the agar agar more concentrated, add alcohol. Agar agar forms a jelly-like substance in the alcohol, which is separated from the liquid.
6. Dry and Shape: Dry the agar agar jelly and shape it into sheets, flakes, or powder, depending on its intended use.
7. Package: Package the final agar agar product for sale and use in various applications, such as cooking and science experiments.(Refer fig 1.4)

Figure 1.4 Seaweed framing of Agar Agar

Agar agar biodegradable packaging, made from seaweed, is eco-friendly, biodegradable, and derived from renewable sources, reducing its environmental impact. It naturally decomposes, preventing long-term harm to the environment.

In contrast, plastic packaging(Refer fig 1.2), made from petroleum-based materials, is non-biodegradable, contributing to plastic pollution and long-lasting harm to ecosystems. While plastic offers durability and versatility, it has a high environmental cost. The choice depends on specific product needs and environmental goals, with an increasing shift towards biodegradable options like agar agar packaging to mitigate plastic's adverse effects and promote sustainability.

The heating involved in standard printing processes, such as lithographic or flexographic printing, should not cause agar agar packaging to melt(refer figure 1.5). Agar agar has a relatively high melting point, typically above 85°C (185°F). While printing may generate some heat during ink drying or curing, it usually remains within safe limits. However, careful temperature control and monitoring are crucial to avoid unintentional damage to the agar agar packaging.

Printing on agar agar biodegradable packaging is feasible without causing melting, as long as temperature levels are appropriately managed during the process.

Figure 1.5 Process of preparing bioplastic using agar agar

STAGE – 5: TEST AND IMPLEMENT

Test and Implement(Refer fig 1.6) the last step, involves extensive testing of the improved prototypes with stakeholders and users. Iterative adjustments are informed by valuable input to guarantee alignment with sustainability objectives and user expectations. In order to address feasibility, evaluate cost-effectiveness, and scale up production, partnerships and manufacturers are enlisted at the same time. Launching an agar agar-based packaging solution that is biodegradable and dissolves into the market is the ultimate aim. As the product acquires traction in the real world, ongoing feedback loops are set up to fine-tune it, guaranteeing its success and sustainability.

Figure 1.6 Final Bioplastic Cover made by agar agar

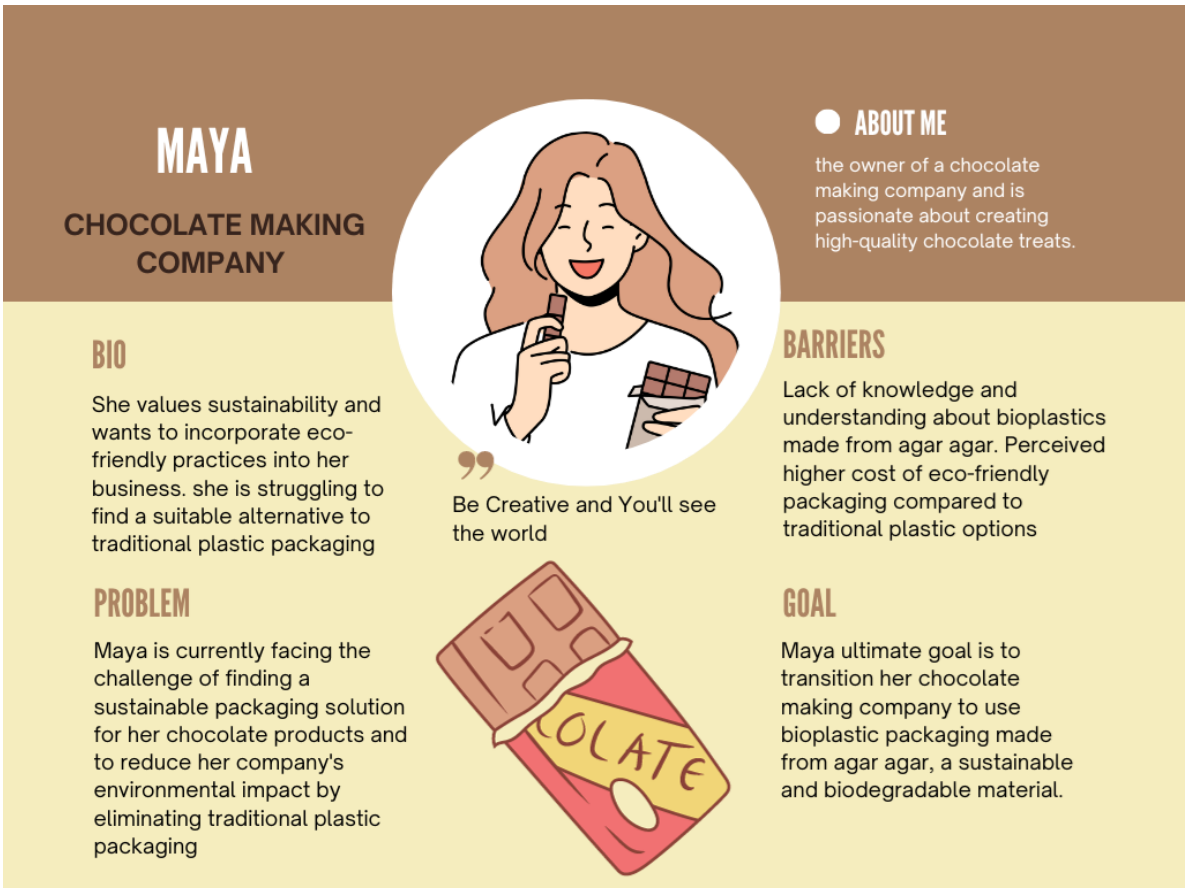

Figure 1.7 Persona

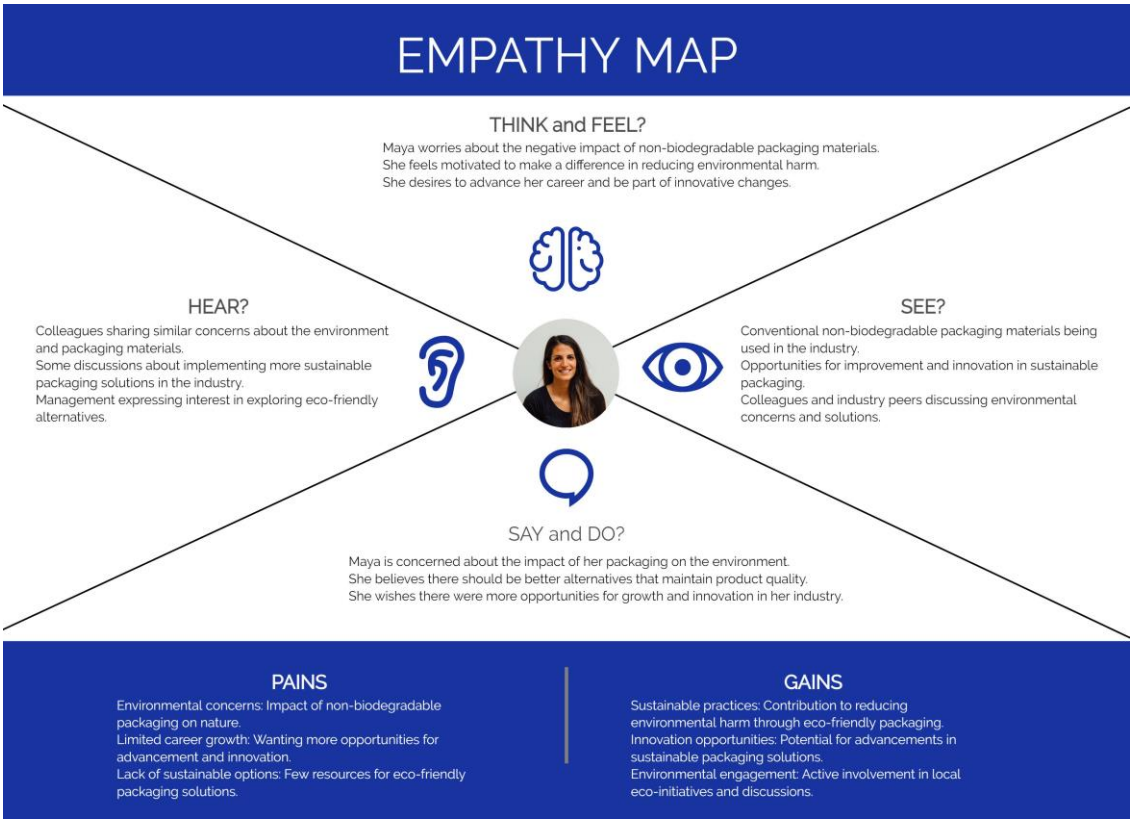

Figure 1.8 Empathy Map

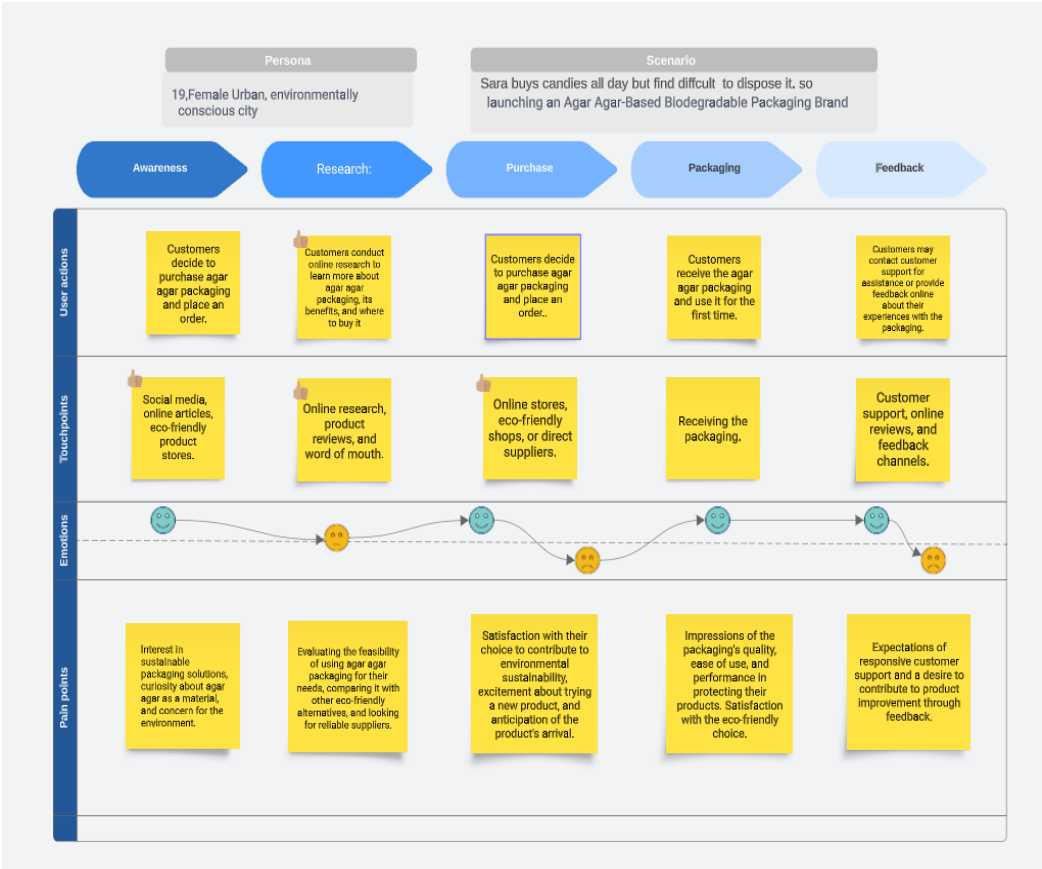

Figure 1.9 Journey Map

V. CONCLUSION

The pursuit of dissolvable and biodegradable packaging with agar agar underscores a commitment to environmental responsibility and sustainable progress. The challenge lies in crafting packaging solutions that not only meet stringent product quality and safety criteria but also contribute significantly to reducing environmental burdens. This endeavor responds to the growing call for eco-conscious alternatives that align with consumer expectations and broader sustainability imperatives.

Through the stages of empathizing, defining, ideating, prototyping, testing, and implementing, this approach harnesses the power of design thinking to navigate complexities and drive innovation. The goal is to create packaging that respects our planet by naturally degrading and minimizing its long-term ecological footprint. By embracing this challenge, we acknowledge the importance of adopting environmentally friendly practices, redefining industry norms, and paving the way for a future where sustainable packaging is the standard rather than the exception. The journey toward dissolvable and biodegradable packaging using agar agar is a significant step in this transformative direction, promising a more sustainable and environmentally harmonious future.

VI. FUTURE SCOPE

Agar-based packaging that is biodegradable and dissolves in water has a bright future ahead of it. This sustainable approach has the potential to significantly lessen the environmental effect of traditional packaging as environmental concerns continue to rise. Growing customer consciousness and the need for environmentally friendly substitutes are creating opportunities for wider implementation across several sectors. To scale up manufacturing and get regulatory approval, cooperation with manufacturers, research centers, and legislators will be essential. Additionally, new uses for agar agar can result in a wider range of products, strengthening its position in the worldwide movement towards packaging that is ecologically friendly.

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