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FABRICATION OF BIODEGRADABLE MATERIALS USING SODIUM ALGINATE AND TAMARIND SEED POWDER

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ABSTRACT
The fashion industry is a major polluter due to synthetic fabrics that persist in landfills for centuries. This study explored sodium alginate, a biodegradable polymer from seaweed, combined with tamarind seed powder (TSP), to create sustainable biofilms for textiles. By incorporating natural flower extracts—Hibiscus for pH sensitivity, Marigold for UV protection, and Rose for antioxidant activity—the films have value added from the eco-friendly colouration and functional properties. These biofilms not only degrade safely without leaving dangers on the use of microplastics but also merge sustainability with aesthetics, offering a step towards responsible innovation.

Key Words: Biodegradable, Sodium Alginate, Tamarind Seed Powder (TSP), Flower extracts, Eco-friendly, Biofilms, Sustainability.

1. INTRODUCTION
1.0 Biopolymers:
1.1.1 Definition:
Baranwal, J., Barse, B., Fais, A., Delogu, G. L., & Kumar, A. (2022). Biopolymers are large macromolecules of natural origin, derived from living organisms or renewable resources. They are biodegradable, biocompatible, and widely used in food packaging, pharmaceuticals, wound healing, tissue scaffolds, and edible films.

1.1.2 Commonly Used Materials, Advantages and Disadvantages
Nair, L. S., & Laurencin, C. T. (2007). Reddy, N., Reddy, R., & Jiang, Q. (2013). Biopolymers include polysaccharides (starch, cellulose, chitosan, alginate), proteins (gelatin, soy protein, casein), and microbial polyesters (PHAs, PLA). They are renewable, biodegradable, and eco-friendly but often have weaker mechanical strength, higher moisture sensitivity, and higher production costs compared to synthetic polymers.

1.2 Relevance of Sodium Alginate
Li, J., He, J., & Huang, Y. (2017). Kumar, A., Sharma, S., & Singh, R (2020). Sodium alginate, a polysaccharide from brown algae, is valued in textiles for its film-forming, gelation, and dye-carrying abilities. It is biodegradable, non-toxic, and supports eco-friendly processes like coatings, printing, and biofilm production, making it an important material for sustainable textiles.

1.3 Relevance of Tamarind Seed Powder (TSP)
Surati, B. I., & Minocheherhomji, F. P. (2018). Thombare, N., Srivastava, S., & Chowdhury, A. R. (2014). Tamarind seed powder (TSP) is widely used in textiles as a natural thickener and sizing agent. Its high molecular weight, adhesive strength, and film-forming ability make it effective in dye printing, fabric finishing, and conditioning, supporting sustainable textile applications.

1.4 Natural Dyes
Saxena, S., & Raja, A. (2014). Natural dyes are eco-friendly pigments from plants, insects, and minerals. They are biodegradable and safe, but face challenges such as limited shades, variation in colors, and lower colourfastness. The research focuses on enhancing their performance through improved extraction and mordanting techniques.

1.5 Flower-Based Dyes

Kombey, P. (2023). Samanta, A. K., & Agarwal, P. (2009). Flower-based dyes provide biodegradable, non-toxic pigments with unique colors for textiles. Despite offering sustainability and aesthetic appeal, they face industrial limitations like restricted color range and shade variability. Advances in extraction and mordanting aim to improve their use in sustainable fashion.

2. REVIEW OF LITERATURE

Li, X., Zhang, Y., & Wang, Z. (2025). Sodium alginate (SA) is a biodegradable seaweed polysaccharide valued for its film-forming ability, non-toxicity, and compatibility with additives. SA biofilms support uses in hydrogen generation, wastewater treatment, and sustainable packaging, processed under mild, eco-friendly conditions. Kumar, H., Singh, A. K., & Kumar, M. (2022). Adding natural extracts and essential oils to SA films improves their antimicrobial and antioxidant activity, expanding their use in food and biomedical packaging. Kumar, H., Singh, A. K., & Kumar, M. (2023). Blending SA with polysaccharides, proteins, or plasticizers enhances water resistance, tensile strength, and durability while maintaining eco-friendliness. Mahmud, S., Pervez, N., Taher, M. A., Mohiuddin, K., & Liu, H. H. (2020). Green-synthesized AgNPs with sodium alginate improved cotton fabric's strength, UV resistance, and antibacterial properties through a simple dip-dry method, producing vibrant, functional textiles. Thakur, S., Sharma, B., Verma, A., Chaudhary, J., Tamulevicius, S., & Thakur, V. K. (2018). Sodium alginate-based hydrogels effectively remove dyes and heavy metals from wastewater. Composites improve adsorption but face challenges like nanoparticle aggregation and recovery issues.
Grineviciute, D., Krauledas, S., & Gutauskas, M. V. (2012). Biodegradable fabrics (lyocell, bamboo, soybean protein, seaweed) showed soft hand feel, influenced by structure and softening treatments, supporting their use in skin-contact textiles. Nguyen, P. T. T., Dang, C. P., Van, L. Q., Trang, D. T. T., & Truc, T. T. (2023). TSP–PVA–anthocyanin films act as smart indicators, changing color with pH to detect seafood spoilage while offering good mechanical and barrier properties. Malviya, R., Tyagi, A., Fuloria, S., Subramaniyan, V., Sathasivam, K., Sundram, S., Fuloria, N. K. (2021). TSP–chitosan composites created flexible, biocompatible films for drug delivery, showing tunable swelling, pH resistance, and controlled release. Zhang, H., Cui, H., Xie, F., Song, Z., & Ai, L. (2024). TSP's branched xyloglucan structure supports water affinity and film formation but requires plasticizers or blends to reduce hydrophilicity and improve strength. Narayanankutty, H., Jayaprakasha, G. K., Pillai, M., Ravishankar, S., & Patil, B. S. (2025). TSP-based edible wraps extended grape shelf life by ≥14 days, confirming practical potential in fresh food preservation. Narayanankutty, H., Jayaprakasha, G. K., Pillai, M., Ravishankar, S., & Patil, B. S. (2025). Silva, C. F., et al. (2019).TSP–glycerol films formed flexible, clear wraps that extended fruit shelf life, demonstrating scalability for real food systems. Ning, R., Cheng, X., Lei, F., Duan, J., Wang, K., & Jiang, J. (2024). Blending TSP with chitosan improved film strength, reduced water vapor transmission, and added antibacterial activity, enabling thinner, more effective films. Zhang, M., & Chen, H. (2023). Alginate–starch films with clay and essential oil showed improved barrier, antibacterial, and thermal properties, degrading completely within ~22 days in soil. Deepa, B., Abraham, E., Pothan, L. A., Cordeiro, N., Faria, M., & Thomas, S. (2016). Nanocellulose-reinforced alginate films displayed enhanced water resistance and mechanical strength due to strong hydrogen bonding, addressing SA's weaknesses.

3. RATIONALE

3.1 Purpose of Study

This study explores fabrication of biodegradable film using sodium alginate and tamarind seed powder, both strong film-formers. It emphasizes sustainability by offering renewable, non-toxic, and biodegradable alternatives to plastics while incorporating flower dyes and petals for eco-friendly aesthetics.

3.2 Aim
The aim is to develop biodegradable films from sodium alginate and tamarind seed powder, enhanced with flower-extracted dyes for sustainable, aesthetic, and functional textile applications.

3.3 Objectives
- To understand awareness about biodegradability among respondents.
- To fabricate biodegradable films using sodium alginate and tamarind seed powder, and incorporating flower-extracted dyes into the biopolymer mixture as a novel approach for imparting natural colouration and added functionalities.
- To perform tests on the biofilms.
- To conduct a survey rating aesthetics, colour and eco-friendliness.

3.4 Scope and Significance
The research addresses plastic pollution and underused natural resources like tamarind by-products and floral waste. By merging biopolymers with natural dyes, it offers sustainable, functional, and visually appealing material alternatives.

4. METHODOLOGY
The methodology for this research covers stages from the pre-survey and fabrication of biodegradable sheets using sodium alginate tamarind seed powder (TSP), to post-survey evaluation.

4.1 Pre-Survey:
A pre-survey with forty-four respondents was administered using a Google Form to assess consumer awareness about biodegradability and biopolymers for textiles.

4.2 Selection of Raw Materials:
Commercial sodium alginate powder and tamarind seed powder (prepared from seeds) were chosen as base materials biopolymers. Locally available flower waste, including marigold, hibiscus, and rose, served as sources of natural dyes rich in carotenoids, anthocyanins, and flavonoids.




Figure 4.2.2.1: Orange marigold https://shorturl.at/5gyiu

Figure 4.2.2.4:Yellow marigold https://shorturl.at/3G2pB

Figure 4.2.2.2: Hibiscus https://tinyurl.com/3n64d8t2

Figure 4.2.2.3: Rose https://tinyurl.com/ys3uvux3

4.3 Preparation of Flower Extracts:

Fresh or dried petals were cleaned, boiled in water for 30–60 minutes, filtered, and concentrated to obtain dye solutions, which were stored for later use.

Plate 4.3.1: Yellow, Orange marigold dye extract.

Plate 4.3.2: Rose dye extract.

Plate 4.3.3: Hibiscus dye extract.

4.4 Biopolymer Film Solutions:

Sodium alginate was dissolved into a gel-like solution, while TSP formed a slurry. Glycerol was added as a plasticiser to improve flexibility and reduce brittleness. Tarique, J., Sapuan, S. M., & Khalina, A. (2021).

Plate 4.4.1: Sodium Alginate Solution

Plate 4.4.2: Sodium Alginate Solution mixing.

Plate 4.4.3: Tamarind Seed Powder Solution.

Plate 4.4.4: Tamarind Seed Powder Solution after mixing.

4.5 Incorporation of Dyes:

Flower extracts were mixed into the polymer blend, with thorough stirring to achieve uniform coloration and compatibility.

4.6 Film Casting:

The polymer-dye solution was cast on steel plates, dried in sunlight, peeled off, and stored as biodegradable films.

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a. Before drying:

Plate 4.6.1: Without dye, Sodium Alginate Bio-film.

Plate 4.6.2: Without dye, Tamarind Seed Powder Bio-film.

Plate 4.6.3: Hibiscus dye extract and yellow, orange marigold flower petals, Tamarind Seed Powder Bio-film.

Plate 4.6.4: Yellow, Orange marigold dye extract and yellow, orange marigold flower petals, Tamarind Seed Powder Bio-film.

Plate 4.6.5: Without dye, Hibiscus and marigold flower petals, Tamarind Seed Powder Bio-film.

Plate 4.6.6: Half without dye and half Rose dye extract, Tamarind Seed Powder Bio-film.

Plate 4.6.7: Without dye, pressed dried flowers and leaves, Tamarind Seed Powder Bio-film.

Plate 4.6.8: Without dye, pressed dried flowers and leaves, Tamarind Seed Powder Bio-film.

Plate 4.6.9: Hibiscus dye extract, Tamarind Seed Powder Bio-film.

Plate 4.6.10: Yellow, Orange marigold with turmeric dye extract, Tamarind Seed Powder Bio-film.

b. After drying:

Plate 4.6.11: Without dye, Sodium Alginate Bio-film

Plate 4.6.12: Without dye, Tamarind Seed Powder Bio-film.

Plate 4.6.13: Without dye, pressed dried flowers and leaves, Tamarind Seed Powder Bio-film.

Plate 4.6.14: Without dye, Hibiscus and marigold flower petals, Tamarind Seed Powder Bio-film.

Plate 4.6.15: Half without dye and half Rose dye extract, Tamarind Seed Powder Bio-film.

Plate 4.6.16: Yellow, Orange marigold dye extract and yellow, orange marigold flower petals, Tamarind Seed Powder Bio-film.

4.7 Ethical & Environmental Considerations:

Sourcing prioritized temple and market flower waste, and water-based extraction methods were used to minimize environmental impact.

4.8. Testing:

4.8.1 Thickness Test:

The thickness of the biofilm was measured using the Shirley Thickness Tester under standard pressure. Multiple readings were taken at different points and averaged to assess material quality, comfort, durability, and suitability for textile use.

4.8.2 Stiffness Test:

Stiffness was evaluated using the Shirley Stiffness Tester by measuring the bending length of standard-sized biofilm strips. The bending length was used to calculate stiffness, providing insights into drape, handle, and end-use suitability.

4.8.3 Grammage (GSM) Test:

Grammage was determined by weighing 5 × 5 cm specimens on a digital balance and multiplying the values by 400 to obtain GSM (g/m²). Three samples were tested, and the average was reported to indicate density, quality, and durability.

4.9 Post-Survey:
A post-survey was conducted to gather feedback on the fabricated biofilms regarding appearance, colour quality, attractiveness, and eco-friendliness, using both scale-based ratings and open-ended responses.

5. RESULTS & DISCUSSIONS

5.1 Pre-survey - understanding awareness about biodegradability among respondents.

Target Respondents and Sample Size: 44 Respondents.
Survey Design: The pre-survey included both qualitative and quantitative questions.
Survey Method: An online Google survey form was created.

5.1.1. Age and Gender of the Respondents.

Out of 44 respondents, 95.5% were female and 4.5% male, showing a predominantly female participation.

5.1.2. Occupation

Most respondents were students (81.8%), followed by professionals (11.4%), while one respondent each was an entrepreneur, a lawyer, or NA. No homemakers participated.

5.1.3. Familiarity with the Concept of Biodegradability.

A total of 45.5% were very familiar, 52.3% somewhat familiar, and only 2.3% not familiar, indicating good awareness of biodegradable products.

5.1.4. Importance of Sustainability.

For purchase decisions, 20.5% rated sustainability as extremely important, 45.5% as important, and 34.1% neutral, reflecting an overall positive attitude toward sustainability.

5.2. Testing results

a. (Sample No. 1 MEMFTSP)
Yellow, Orange marigold dye extract and yellow, orange marigold flower petals, and Tamarind Seed Powder Bio-film.
b. (Sample No. 2 HMFTSP)
Without dye, Hibiscus and marigold flower petals, Tamarind Seed Powder Bio-film.
c. (Sample No. 3 HWHRESP)
Half without dye and half Rose dye extract, Tamarind Seed Powder Bio-film.
d. (Sample No. 4 WDPDFLSP)
Without dye, pressed dried flowers and leaves, Tamarind Seed Powder Bio-film.

5.2.1. Thickness Test

Sample	**R (mm)**										
	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	**Avg.**
S1	0.61	0.71	0.56	0.70	0.68	0.50	0.58	0.69	0.75	0.54	**0.65**
S2	0.65	0.61	0.52	0.39	0.51	0.48	0.49	0.66	0.69	0.34	**0.53**
S3	0.58	0.59	0.47	0.29	0.29	0.33	0.39	0.48	0.56	0.58	**0.45**

S4	0.61	0.71	0.56	0.70	0.68	0.50	0.58	0.69	0.75	0.54	**0.65**

The thickness test results of the biofilm samples showed variation across different specimens. Sample 1 and Sample 4 had the highest and most consistent thickness, both averaging 0.65 mm, indicating relatively uniform film formation. Sample 2 recorded a lower average thickness of 0.53 mm, while Sample 3 showed the thinnest films with an average of 0.45 mm, suggesting less uniformity in fabrication. Overall, the results highlight that while the films demonstrated measurable thickness suitable for testing, slight inconsistencies in preparation affected uniformity across samples.

5.2.2. Stiffness Test

	Sample 1 (in cm)	**Sample 2 (in cm)**	**Sample 3 (in cm)**	**Sample 4 (in cm)**
Overall average Length	**2.2**	**2.2**	**2**	**2.0**
Bending Length (L/2)	**1.1**	**1.1**	**1**	**1**

The stiffness test revealed that Sample 1 and Sample 2 exhibited the highest bending length of 1.1 cm, indicating slightly greater stiffness and better structural integrity. In comparison, Sample 3 and Sample 4 showed a bending length of 1.0 cm, reflecting relatively lower stiffness and greater flexibility. Overall, the results suggest that while all samples demonstrated comparable stiffness, Samples 1 and 2 were marginally stiffer.

5.2.3. GSM Test

	S1	**S2**	**S3**	**S4**
Sr. no.	**Weight (in gms)**	**Weight (in gms)**	**Weight (in gms)**	**Weight (in gms)**
1	1.363	1.011	1.285	1.800
2	1.369	1.019	1.291	1.806
3	1.352	1.012	1.282	1.803
Avg.	**1.361**	**1.014**	**1.286**	**1.803**
x 400 gm/sq m	**544.4 gm/sq m**	**405.6 gm/sq m**	**514.4 gm/sq m**	**721.2 gm/sq m**

The GSM (grams per square meter) test of the biofilm samples showed notable variation in fabric density. Sample 4 had the highest average GSM of 721.2 g/m², indicating the densest and potentially most durable film, while Sample 2 recorded the lowest at 405.6 g/m², reflecting a lighter and less compact structure. Sample 1 and Sample 3 had intermediate GSM values of 544.4 g/m² and 514.4 g/m², respectively, suggesting moderate density and strength. Overall, these results demonstrate that the biofilms varied in thickness, which can influence their suitability.

5.3. Post-survey - rating aesthetics, colour and eco-friendliness.

Target Respondents and Sample Size: 41 Respondents.
Survey Design: The pre-survey included both qualitative and quantitative questions.
Survey Method: An online Google survey form was created.

5.3.1. Rating Aesthetics, Colour and Eco-friendliness for Sample No. 1 MEMFTSP

Among 41 respondents, the films were well-received overall. Visual appeal averaged 4.15, while colour quality scored 4.05, showing that the natural colours were appreciated. Eco-friendliness received the highest rating of 4.54, indicating strong recognition of the films' sustainability and environmental friendliness.

5.3.2. Rating Aesthetics, Colour and Eco-friendliness for Sample No. 2 HMFTSP

A total of 41 respondents evaluated the films. Overall appearance received high ratings, with an average of 4.02, reflecting general visual appeal. Colour quality was slightly lower, averaging 3.88, indicating the natural colours were well-received. Eco-friendliness scored the highest, with an average of 4.41, showing that the films were widely perceived as sustainable and environmentally friendly.

5.3.3. Rating Aesthetics, Colour and Eco-friendliness for Sample No. 3 HWHRESP

A total of 41 respondents evaluated the films. The overall appearance was well-received, averaging 3.93, while colour quality scored slightly lower at 3.88, indicating the natural colours were generally appreciated. Eco-friendliness received the highest rating, averaging 4.27, showing that the films were widely perceived as sustainable and environmentally friendly.

5.3.4. Rating Aesthetics, Colour and Eco-friendliness for Sample No. 4 WDPDFLSP

Among 41 respondents, the films were generally well-received. Overall appearance averaged 3.93, indicating visual appeal, while colour quality scored 3.88, showing the natural colours were appreciated. Eco-friendliness received the highest rating of 4.27, reflecting strong recognition of the films' sustainability and environmental friendliness.

5.4.5. What people liked the most about the bio-films?

The feedback on the biodegradable films was overwhelmingly positive. Respondents highly appreciated their eco-friendliness and biodegradability, noting they were sustainable and harmless to the environment. The design and appearance, including intricate details, natural colours, and creative use of flowers, were also praised. Many valued the innovative concept behind the films, highlighting the successful combination of functionality, aesthetics, and creativity. Overall, the films were recognized for being both environmentally conscious and visually appealing.

5.4.6. What people disliked/felt needed improvement?

Feedback on the biodegradable films also pointed out areas for improvement. Some respondents suggested brighter colours and a wider range of shades to enhance visual appeal. Improvements in flower placement, arrangement, and spacing were recommended for a more balanced design, while a few noted that refining texture and stiffness could enhance usability. A small number mentioned enhancing colour quality for sharper details. Overall, the key areas for development include colour brightness, flower arrangement, and texture refinement.

5.4.7. Additional suggestions/comments:

Responses also showed strong encouragement and appreciation for the films. Participants praised the initiative with comments like "Excellent work" and "Amazing concept," reflecting admiration for the creativity involved. Many celebrated the innovation without offering critiques, highlighting overall support. This positive feedback indicates that the project was well-received and motivates further development of the biodegradable films.

6. CONCLUSION

The study on biodegradable films using sodium alginate and tamarind seed powder demonstrates the potential of natural polymers to support sustainability. Pre-survey results showed respondents were aware of biodegradability and favoured eco-friendly innovations. During fabrication, flower-extracted natural dyes were successfully incorporated, providing colour and functionality without synthetic additives. Physical properties such as GSM, stiffness, and thickness were tested to ensure quality. Post-survey feedback indicated strong acceptance, with high ratings for appearance, colour, and eco-friendliness. Overall, the research highlights the feasibility of developing visually appealing, functional, and sustainable biopolymer-based films.

7. SCOPE AND LIMITATION

7.1. Scope:

The study focuses on the independent fabrication of biodegradable films from sodium alginate and tamarind seed powder, emphasizing the potential of each material as a sustainable alternative. A pre-survey was conducted to assess respondents' awareness of biodegradability and eco-friendly materials. Natural flower-extracted dyes were incorporated to enhance aesthetics, colour, and functionality without the use of synthetic chemicals. The films' physical properties and performance were evaluated using standard tests such as GSM, stiffness, and thickness. A post-survey measured user perceptions of appearance, colour quality, and eco-friendliness, providing insights for practical applications. Overall, the findings contribute to sustainability and material innovation by offering a green alternative.

7.2 Limitations:

The fabricated films face some limitations. Mechanically, they may have limited tensile strength and flexibility compared to synthetic plastics. Their high water-sensitivity makes them prone to swelling or dissolution in humid conditions, and being biodegradable, they are more susceptible to microbial attack during storage, resulting in a short shelf life. The study did not explore blending the two biopolymers, which could have enhanced performance. Additionally, the colour stability of the flower-extracted dyes under light, moisture, or storage conditions was limited in investigation and testing. Finally, aspects such as industrial scalability, cost-effectiveness, and feasibility for large-scale production remain unexplored, indicating areas for further areas for research and development.

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