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EXPLORING CORN STARCH-BASED BIODEGRADABLE PLASTICS FOR FOOD PACKAGING APPLICATIONS

Nur Syahida Abdul Rahim[1*], Liyana Karmila Noazman [2], Mohd Muzammir Firdaus Abu Bakar [3]

[1] Pusat Asasi STEM, Universiti Malaysia Terengganu, Kuala Terengganu, Malaysia
Email: syahida.rahim@umt.edu.my
[2] Pusat Asasi STEM, Universiti Malaysia Terengganu, Kuala Terengganu, Malaysia
Email: liyanakarmila13@gmail.com
[3] Pusat Asasi STEM, Universiti Malaysia Terengganu, Kuala Terengganu, Malaysia
Email: muzammir.firdaus@gmail.com
[*] Corresponding Author

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Abstract:

Recently, there has been growing interest in the use of biodegradable plastics made from corn starch to enhance environmental sustainability. This study explores the potential of biodegradable plastics to foster eco-friendly practices and serve as alternatives to traditional plastics as food packaging. The study focuses on developing a packaging solution by leveraging the unique properties of hydrogels combined with corn starch in different ratios to create durable biodegradable plastics. Additionally, the study evaluates the impact resistance and rebound characteristics of hydrogel-based packaging materials using the coefficient of restitution (COR), which measures the elasticity of collisions. By assessing the mechanical properties and potential uses of hydrogels with varying corn starch content, this research aims to identify formulations that balance functionality, environmental impact, and sustainability. The study's findings show hydrogel with the largest percentage of cornstarch (20%) exhibits the best outcome as a reliable and efficient biodegradable plastic to traditional plastic. Future research is recommended to explore the properties of biodegradable plastic in analysis including examining mechanical strength, barrier properties, and degradation rate.

Keywords:

Biodegradable Plastics, Hydrogel, Eco-Friendly, Coefficient Of Restitution, Food Technology Industry

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Introduction

Plastics are crucial in modern society, playing key roles in construction, packaging, agriculture, the automotive industry, and more. Due to all these activities, more plastic is now being produced, which is bad for the environment (Pinto, F., Costa, P., et al. 1999). Although plastic was formerly believed to be innocuous and inert, years of environmental plastic waste have resulted in several linked problems.

The pollution caused by plastic trash is now widely recognized to be a serious environmental problem, especially in aquatic regions where plastics are hazardous to wildlife, decompose slowly, and can be difficult to remove (Rochman CM, Browne MA, et al., 2013). Furthermore, combustion can emit a wide range of pollutants, including dust, dioxins, light hydrocarbons, nitrous and sulfur oxides, and other poisons, that are particularly damaging to the environment depending on their composition.

Although plastic packaging plays a significant role in keeping food safe, its non-biodegradable nature, recycling difficulties, and the release of hazardous chemicals into food and soil raise considerable concerns for both the environment and human health (Sid, S., Mor, R. S., 2021). The best approach to deal with the problem of the accumulation of plastic solid waste would be to use biodegradable plastics. Biodegradable plastics are materials that can decompose by microorganisms into carbon dioxide (CO_2), methane (CH_4), and microbial biomass.

Microorganisms assimilate carbon and obtain energy from the carbon substrate found in plastic polymers. Both anaerobic and aerobic circumstances can support this activity, although the aerobic method gains energy more efficiently. In normal laboratory studies, the amount of CO2 released as a function of time can be used to assess the rate of biodegradation (Castro- Aguirre, E., Auras, et al. 2017)

Due to the harm that plastic causes to the environment, researchers are looking into employing more sustainable and environmentally friendly materials for food packaging. "Design of chemical products and processes to reduce or eliminate the use and generation of hazardous substances" is the definition of "green chemistry." According to Anastas P. and Eghbali N. (2010), green chemistry is defined by meticulous planning of chemical synthesis and molecular design to minimize negative effects.

Hydrogels were the first biomaterials developed especially for human use. One alternative for green chemistry plastic packaging that is now being researched is hydrogel (Kopeček, J. 2007). Hydrogels are squishy materials made of long chains of distinct molecules joined together to produce a structure resembling a net. Large volumes of water can be absorbed by them without causing them to dissolve or crumble. Water gel beads, which significantly expand in size when submerged in water, are arguably the most common name for hydrogels.

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Materials and Methods

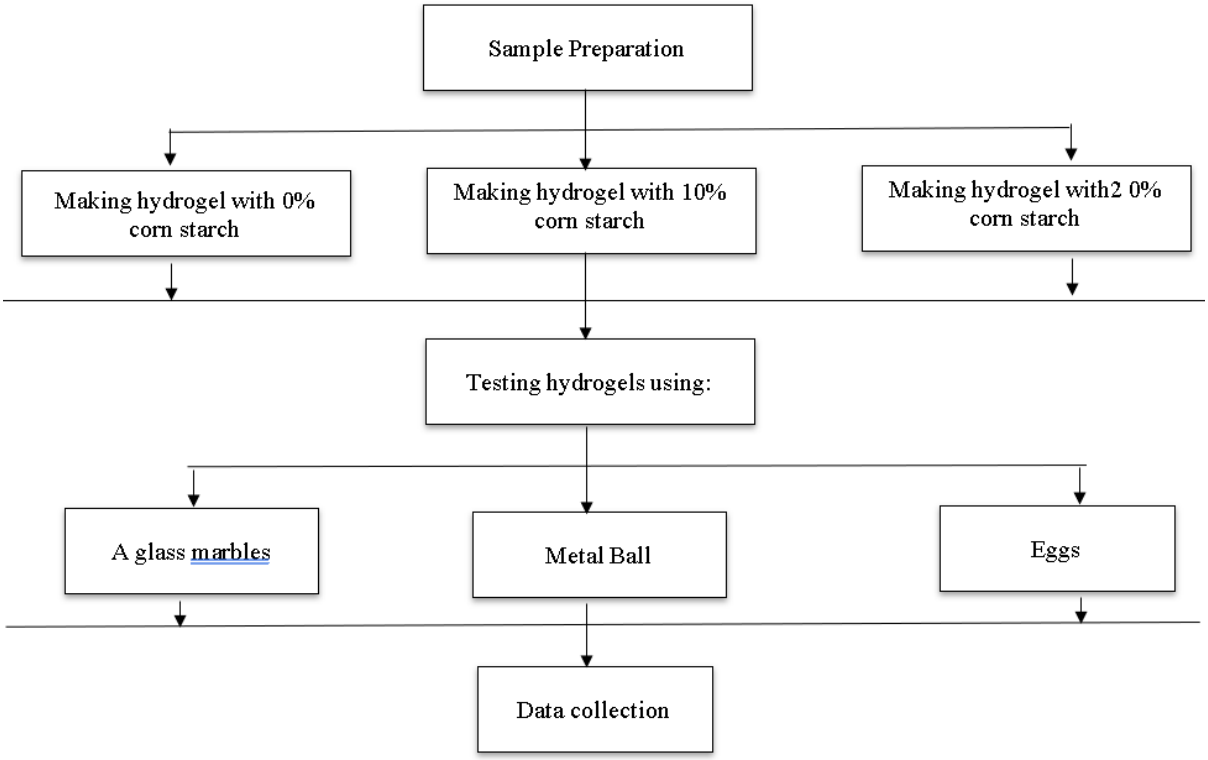

Figure 1: Overview of Methods and Experimental Design

Preparation Of Biodegradable Plastic

Tape and markers were used to label the three beakers and the three heat-resistant containers. The beakers and the containers were labeled "0% starch", "10% starch", and "20% starch". As shown in Figure 2 for material preparation, 150 ml of distilled water was measured. Then, the amount of cornstarch was weighed using the amount needed. A small amount of distilled water was poured into the bowl with cornstarch. A fork was used to mix it with water to ensure it dissolved. The remaining water was put in a beaker. The beaker was placed onto a hot plate. Once the water boiled, the 15 g of gelatin powder and the dissolved cornstarch were added into the water. A glass rod was used to mix until everything dissolved. The hot mixture was poured carefully into the appropriately labeled heat-resistant containers. The containers were put into the refrigerator to let the hydrogels solidify. Once the hydrogel was solid, the hydrogels were taken out from the refrigerator. A sharp knife was used to cut the edge of the glass containers to separate the gels. Each hydrogel was wrapped in a piece of cling wrap and labeled with the appropriate starch percentage. Steps 2-6 were repeated two more times using different percentages of cornstarch.

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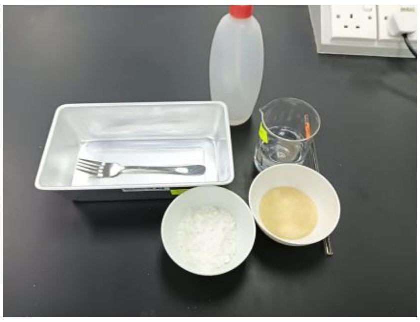

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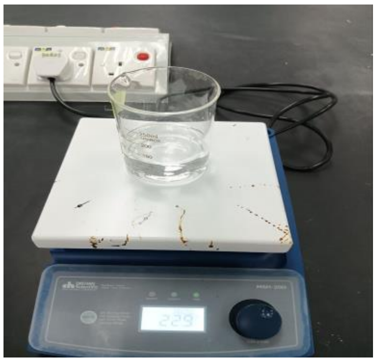

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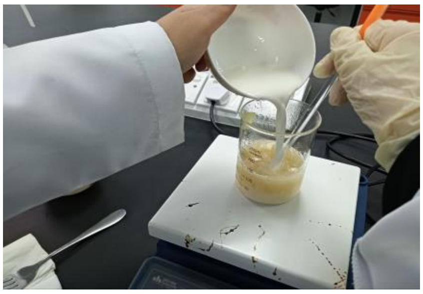

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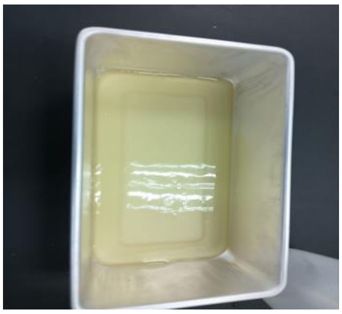

(d)

Figure 2: (A) Materials Preparation, (B) Distilled Water Was Boiled onto a Hot Plate At 100 C, (C)15g Gelatin Powder And 30g Cornstarch Were Poured into The Boiled Water and (D) The Mixture Was Cooled in a Chiller.

Evaluating Hydrogel Performance With Marble And Metal Ball Testing

From each three samples of hydrogel 0%,10% and 20% cornstarch pieces were cut to 5cm × 6 cm pieces with a sharp knife. The thickness of the hydrogels was measured with a Vernier calliper. As shown in Figure 3, one of the gel pieces was laid flat on a table, and a ruler was placed upright with the zero mark at the bottom. A camera was set up facing the ruler, and the glass marble was held at the 25 cm mark of the ruler. The glass marble was dropped directly onto the sample, the camera was stopped, and the video was reviewed. The drop Height (H) was 25 cm. From the view in the recorded video, the highest point measured from the bottom of the marble was found on its first bounce after it touched the hydrogel for the first time. The ruler was read at the point, and the bounce height (h) was recorded in centimeters in the data table. Steps 5 and 6 were repeated with the two remaining gels with the same cornstarch percentage. Steps 1-7 were repeated with different percentages of cornstarch. Next, the metal ball was used to find the depth and diameter of the curve of the hydrogel by following steps 1-7. The table of observations was recorded.

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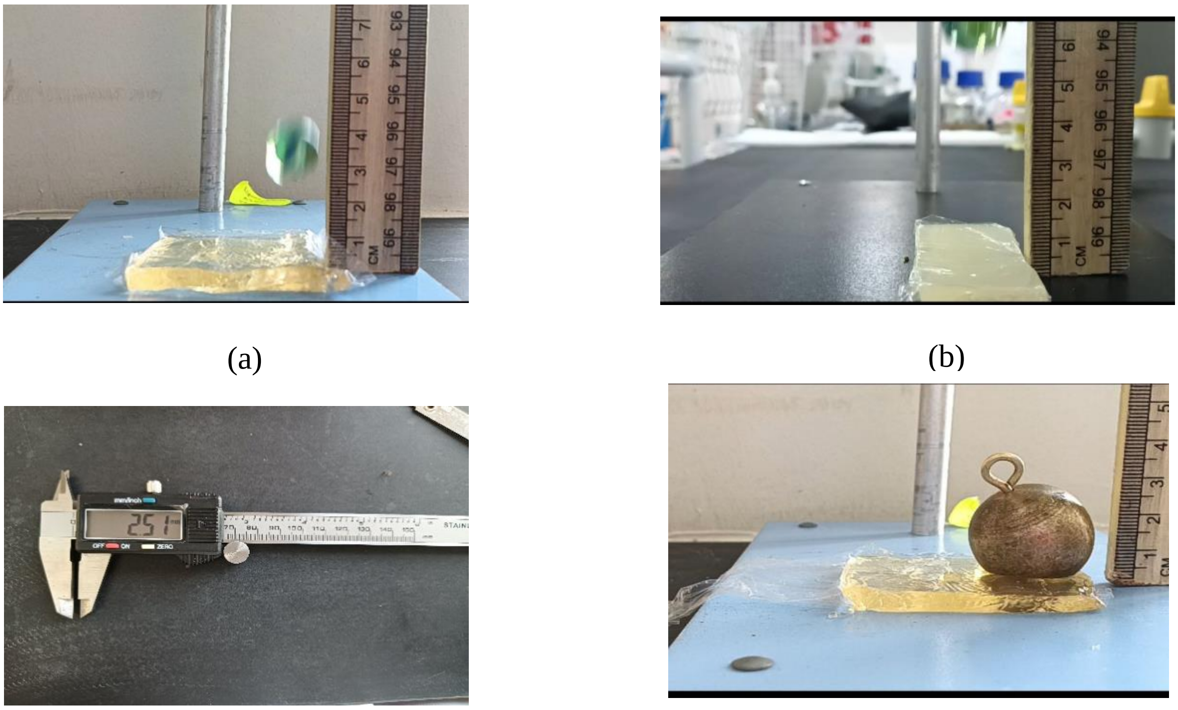

(a) (b)

(c) (d)

Figure 3: (A) A Glass Marble Was Dropped Onto The Hydrogel, (B) The Hydrogel and A Meter Stick Were Set Up For The Coefficient Of Restitution (COR) Test, (C) A Metal Ball Was Dropped Onto The Hydrogel, And (D) A Vernier Caliper Was Used to Measure The Depth and Diameter Of The Hydrogel.

Evaluating Food Packaging Performance Using Eggs

From each of the three hydrogels with different percentages of corn starch, a 17 cm× 6 cm piece was cut with a sharp knife. An egg was wrapped in one of the hydrogel strips, and one piece of tape was used to hold the strip together as in Figure 4. While wrapping the egg, the texture of the hydrogel was observed, and the observations were recorded in the data table. The ruler was held upright on a table using one hand. The wrapped egg was held next to the ruler so that its bottom lined up to the 38 cm (15 inch) mark. The egg was held so the taped, double-layered hydrogel part was at the top. The egg was dropped onto the hard surface. Then, the egg was carefully unwrapped, and it was checked whether it cracked upon impact. The results were recorded. Steps 2 and 3 were repeated with the same cornstarch percentage but different eggs for the new trials. Steps 1-4 were repeated using different percentages.

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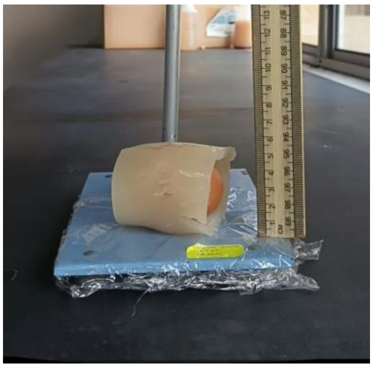

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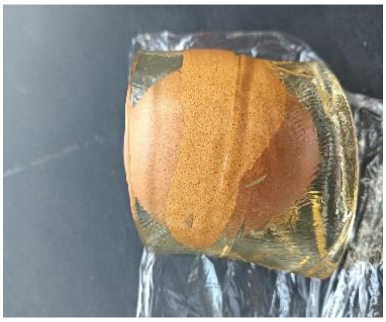

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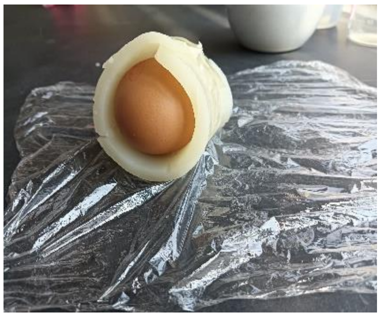

(d)

Figure 4: (A) Egg Was Dropped From Height 38 Cm While Wrapped With Hydrogel, (B) Meter Stick Was Set Up For The Dropped Test, (C) and (D) Eggs Condition After Dropped Test

Coefficient of Restitution (COR) evaluation

For an evaluation test of biodegradable plastic, the coefficient of restitution (COR) equation was used to calculate thickness of the hydrogel. Coefficient of Restitution (COR) is the ratio of final velocity to the initial velocity between two objects after their collision. It provides information about the colliding materials' nature. COR determines a material's capacity to resist collisional impact. This is crucial for packing material that must safeguard items from harm during handling and transportation. The test operates is described in the study paper: When a marble is put onto a surface from a certain height (H), the height (h) to which it bounces is subsequently calculated as shown in equation 1.

$$\sqrt{\frac{h}{H}} \quad (1)$$

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Results and Discussion

Characteristics of biodegradable plastic play an important role in this study such as color, transparency and surface texture. The color of the hydrogel changes significantly with the addition of cornstarch. Hydrogels without cornstarch are transparent, allowing light to pass through easily. As the concentration of cornstarch increases, the color shifts towards opaque white. This color change can have practical implications in applications where the appearance of the hydrogel is important. As the cornstarch concentration rises, transparency falls. Although cornstarch-free hydrogels are very transparent, adding cornstarch makes it harder for light to flow through the hydrogel. This reduction in transparency may influence devices or contact lenses—applications where optical clarity is necessary. Adding cornstarch to the hydrogel also modifies its texture. The consistency of the hydrogel changes when cornstarch is added, even though hydrogels without cornstarch have a smooth, gel-like feel. Compared to hydrogels without cornstarch, the texture thickens or becomes more viscous at lower concentrations of cornstarch (10%). Higher concentrations (20%) may cause the texture to become paste-like or more solid as in Table 1.

Table 1: Characteristic of Hydrogel

Characteristic of Hydrogel	Percentage of corn starch (%)		
	0	10	20
Colour	Transparent	High	Smooth, gel-like
Transparency	Translucent to opaque	Moderate	Slightly thicker or more viscous compared to 0%
Texture of hydrogel surface	Opaque white	Low	More gel-like, solid and paste-like

Table 2: Coefficient of Restitution (COR) Test

Trial	Depth	Diameter	Drop height in H 25cm	Bounce height in h	Coefficient of restitution (COR)
Hydrogel with 0% corn starch					
1	3.37	6.59	25	3.4	0.369
2	3.32	6.91	25	3.4	0.369
3	4.29	6.80	25	3.5	0.374
average	3.66	4.42	25	3.43	0.371

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Hydrogel with 10% corn starch					
1	2.51	5.18	25	3.5	0.374
2	0.52	4.15	25	4.5	0.424
3	3.72	6.45	25	3.0	0.346
average	2.25	5.26	25	3.67	0.381
Hydrogel with 20% corn starch					
1	1.19	4.56	25	4.1	0.404
2	2.00	4.19	25	4.1	0.404
3	1.46	4.52	25	4.2	0.410
average	1.55	4.42	25	4.13	0.406

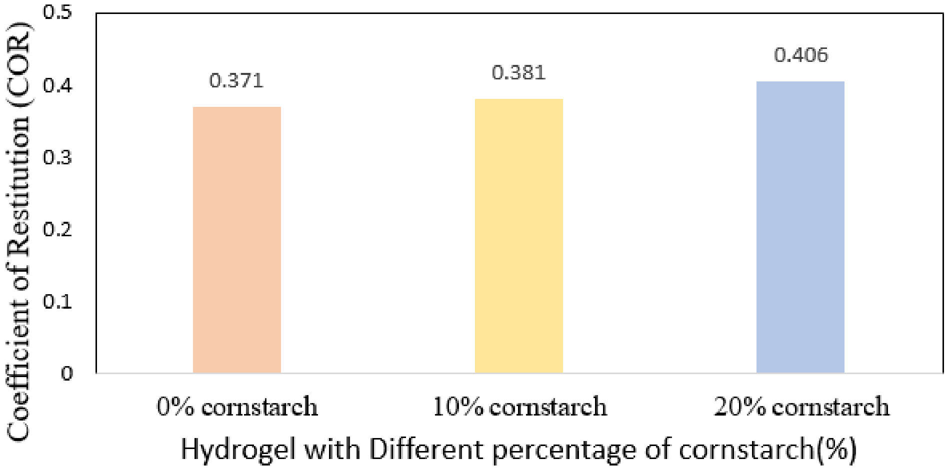

Figure 5: Graph of Average COR of Hydrogel With Different Percentage of Cornstarch

Based on the data presented in Figure 5, the hydrogel with the highest percentage of cornstarch (20%) demonstrates the best result in terms of the Coefficient of Restitution (COR). This observation aligns with the discussion, where it was anticipated that the presence of cornstarch would enhance the hydrogel's elasticity and resilience. Conversely, the hydrogel with 0% cornstarch is depicted as not showing a good result in COR. This outcome is consistent with the expectation that the absence of structural reinforcement would lead to higher energy loss during collisions, resulting in a lower COR value. Therefore, the increasing the percentage of cornstarch in the hydrogel formulation improves its mechanical properties, as evidenced by higher COR values indicating better elasticity and resilience.

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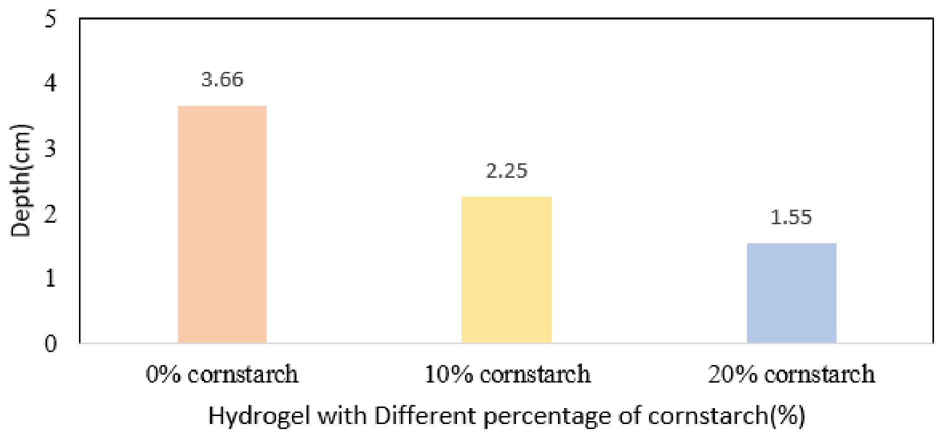

Figure 6: Graph of Average Depth of Hydrogel Test With Metal Ball

Figure 6 illustrates that hydrogel with higher cornstarch content, which tend to be stiffer and more resistant to deformation, allow for shallower penetration by a metal ball, with a maximum depth of 3.66 cm. In contrast, hydrogels with no cornstarch (0 %) typically have a softer, more gel-like texture, facilitating deeper penetration. The addition of cornstarch alters the hydrogel's microstructure, creating denser and more solid structures at higher concentrations, which reduces penetration depth. Moreover, hydrogels with higher cornstarch concentrations exhibit greater compression resistance, enabling them to withstand more force before breaking or allowing penetration, while those without cornstarch tend to rupture more easily. Additionally, the distribution of cornstarch within the hydrogel matrix can affect penetration depth; uneven distribution may lead to variations in resistance. In summary, the amount and distribution of cornstarch affect the hydrogel's texture and compression resistance, which in turn influences the penetration depth of the metal ball.

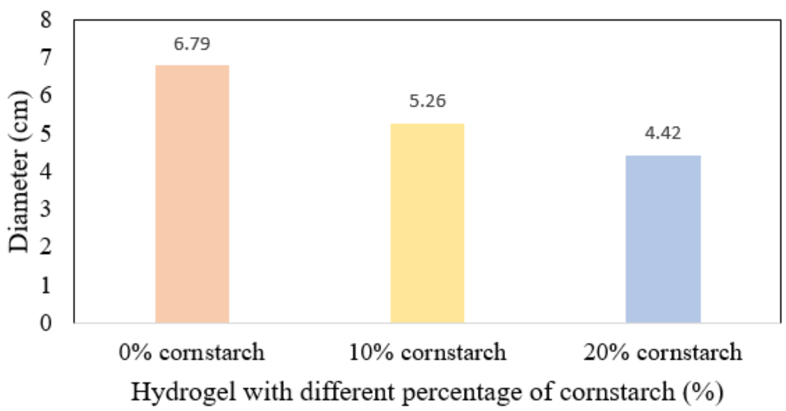

Figure 7: Graph of Average Diameter of Hydrogel When Tested With Metal Ball.

The hydrogel with 0% cornstarch is expected to exhibit a greater value (6.79 cm) compared to hydrogels with 10% and 20% cornstarch, which show values of 5.26 cm and 4.42 cm, respectively, as depicted in Figure 7. This expectation is supported by the observation that hydrogels with higher cornstarch concentrations tend to be less elastic and compress less upon impact, resulting in smaller diameter measurements. Conversely, hydrogels without cornstarch

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are likely to be more elastic, allowing them to deform more when struck and thereby resulting in a larger diameter measurement.

Table 3: Food Packaging Test.

Trials	Did the gel break during the eggs wrapping	Did the eggs break during the impact
Hydrogel with 0% corn starch		
1	Break	Doesn't crack
2	Break	A little crack
3	Break	Doesn't crack
Hydrogel with 10% corn starch		
1	Break	Doesn't crack
2	It doesn't break	A little crack
3	It doesn't break	crack
Hydrogel with 20% corn starch		
1	It doesn't break	Doesn't crack
2	It doesn't break	Doesn't crack
3	It doesn't break	Crack

Based on Table 3, the formulation with 20% cornstarch demonstrated the best performance in preventing egg breakage among the hydrogel films tested with different cornstarch concentrations (0%, 10%, and 20%) as wraps for egg preservation. This is likely due to the mechanical properties of the 20% cornstarch hydrogel, which provided an optimal balance between strength and flexibility. Hydrogel films with either too little or unbalanced cornstarch ratio might have been less flexible or weaker, leading to increased brittleness. Thus, the 20% cornstarch formulation was likely the most effective in providing the necessary structural support to prevent eggs from breaking during handling and storage. Therefore, it is the most suitable option for food packaging.

Conclusion

In conclusion, this study confirms that increasing the percentage of cornstarch in the hydrogel formulation enhances its mechanical properties, as demonstrated by higher COR values that indicate improved elasticity and resilience. Additionally, the study emphasizes that both the amount and distribution of cornstarch influence the hydrogel's texture and compression resistance. Looking ahead, the 20% cornstarch formulation appears to be the most effective at

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providing the structural support needed to prevent egg breakage during handling and storage, making it the most suitable option for food packaging.

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References

Agarwal, S., Singhal, S., Godiya, C. B., & Kumar, S. (2023). Prospects and applications of starch based biopolymers. *International Journal of Environmental Analytical Chemistry*, *103*(18), 6907-6926.

Ahmed, E. M. (2015). Hydrogel: Preparation, characterization, and applications: Areview. *Journal of advanced research*, *6*(2), 105-121.

Ahsan, W. A., Hussain, A., Lin, C., & Nguyen, M. K. (2023). Biodegradation of Different Types of Bioplastics through Composting—A Recent Trend in Green Recycling. *Catalysts*, *13*(2), 294.

Anastas P, Eghbali N. Green chemistry: principles and practice. Chemical Society Reviews. 2010.

Asgher, M., Arshad, S., Qamar, S. A., & Khalid, N. (2020). Improved biosurfactant production from Aspergillus niger through chemical mutagenesis: characterization and RSM optimization. *SN Applied Sciences*, *2*, 1-11.

Batista, R. A., Espitia, P. J. P., Quintans, J. D. S. S., Freitas, M. M., Cerqueira, M. Â., Teixeira, J. A., & Cardoso, J. C. (2019). Hydrogel as an alternative structure for food packaging systems. *Carbohydrate polymers*, *205*, 106-116.

Bayer, I. S. (2021). Biopolymers in Multilayer Films for Long-Lasting Protective Food Packaging: A Review. *Sustainable Food Packaging Technology*, 395-426.

Castro-Aguirre, E., Auras, R., Selke, S., Rubino, M., & Marsh, T. (2017). Insights on the aerobic biodegradation of polymers by analysis of evolved carbon dioxide in simulated composting conditions. *Polymer Degradation and Stability*, *137*, 251-271.

Chodijah, S., Husaini, A., & Zaman, M. (2019, February). Extraction of pectin from banana peels (musa paradiasica fomatypica) for biodegradable plastic films. In *Journal of Physics: Conference Series* (Vol. 1167, No. 1, p. 012061). IOP Publishing

Fouhy, K. (1993). Plastics recycling's diminishing returns. *Chemical Engineering*, *100*(12), 30.

Han, J. W., Ruiz-Garcia, L., Qian, J. P., & Yang, X. T. (2018). Food packaging: A comprehensive review and future trends. *Comprehensive Reviews in Food Science and Food Safety, 17*(4), 860–877.

Helanto, K. E., Matikainen, L., Talja, R., & Rojas, O. J. (2019). Bio-based polymers for sustainable packaging and biobarriers: A critical review. *BioResources*, *14*(2), 4902-4951.

Karamanlioglu, M., Preziosi, R., & Robson, G. D. (2017). Abiotic and biotic environmental degradation of the bioplastic polymer poly (lactic acid): A review. *Polymer Degradation and stability*, *137*, 122-130.

Kopeček, J. (2007). Hydrogel biomaterials: a smart future?. *Biomaterials*, *28*(34), 5185-5192.

Otoni, C. G., Espitia, P. J., Avena-Bustillos, R. J., & McHugh, T. H. (2016). Trends in antimicrobial food packaging systems: Emitting sachets and absorbent pads. *Food Research International*, *83*, 60-73.

Volume 7 Issue 28 (December 2024) PP. 472-483
DOI: 10.35631/IJEMP.728033
Sid, S., Mor, R. S., Kishore, A., & Sharanagat, V. S. (2021). Bio-sourced polymers as alternatives to conventional food packaging materials: A review. *Trends in Food Science & Technology*, *115*, 87-89.

Singh, N., Hui, D., Singh, R., Ahuja, I. P. S., Feo, L., & Fraternali, F. (2017). Recycling of plastic solid waste: A state of art review and future applications. *Composites Part B: Engineering*, *115*,409-4.