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Biowaste-Derived UV Protection: Fabrication and Optimization of Mud Crab (*Scylla serrata*) Shell-Based Films

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Abstract: *Ultraviolet (UV) radiation poses serious health risks, necessitating protective solutions. This study used Mud crab (Scylla serrata) shell powder to develop anti-radiation films, addressing environmental waste and public health concerns. A Research and Development (R&D) design was employed, incorporating shell powder at concentrations of 0 %, 25 %, 50 %, 75 %, and 100 %. UV shielding efficiency was assessed at 9 AM, 12 PM, and 3 PM using a UV radiometer. Statistical analysis via one-way ANOVA and Tukey HSD revealed a significant increase in UV shielding with higher shell powder concentrations (F-values > 957.47, p < 0.0001). However, improvements plateaued beyond 75 %. The 100 % concentration provided the highest UV protection but showed no statistically significant advantage over 75 % (p > 0.05). Shielding performance varied throughout the day due to fluctuations in UV intensity. The findings confirm that mud crab shells, rich in calcium carbonate and chitin, enhance UV protection. Repurposing seafood waste into anti-radiation films offers a sustainable, non-toxic alternative to conventional materials. This research contributes to material science and environmental conservation by demonstrating the potential of biowaste-based UV shielding technologies.*

Keywords: *Anti-Radiation Films, Mud Crab Shells, Sustainable Materials, UV Radiation*

1. Introduction

Ultraviolet (UV) radiation is a significant health hazard that can cause skin damage and a higher risk of getting cancer. Overexposure can lead to sunburn, DNA damage, immune suppression, and different skin cancers, including melanoma and non-melanoma types [1]. Protecting against UV radiation is important for health, emphasizing the need for solutions to mitigate its harmful effects. Scylla serrata, also called the Mud Crab, is a type of swimming crab with an oval-shaped shell. This crab lives in estuaries and mangrove swamps and can be found in saltwater and freshwater environments. Additionally, their shells make up a large portion of seafood processing waste [2]. Crab shells mainly comprise calcium carbonate ($CaCO_3$) embedded in a protein matrix [3] Calcium carbonate ($CaCO_3$) is a chemical compound commonly found in rocks such as limestone, chalk, and shells [4]. Calcium carbonate has a high atomic number and density, effectively absorbing and blocking radiation. Converting this waste into materials for blocking ultraviolet radiation will not only address environmental concerns but also enhance public health safety. Research shows that increasing chitosan concentration reduces the water content and improves how well the materials blend in the film, which impacts its texture and overall characteristics [5,6].

The issue with using Mud Crab shells arises from the large amounts of waste the seafood industry generates. These shells are often discarded in large quantities, leading to environmental pollution and waste management issues [7]. While the use of natural materials in various applications is well-documented, research on their potential for radiation shielding remains limited. Addressing this gap will improve understanding of the material's properties and promote sustainable practices. Evidence-based research on this natural material could support the development of sustainable radiation shielding solutions that preserve environmental resources.

This study could contribute to making an eco-friendly and non-toxic alternative to conventional radiation shielding materials by examining the Mud Crab powder found in crab shells as an ingredient in anti-radiation films [8]. Crab shells, rich in calcium carbonate and chitin, have qualities that can help the strength and effectiveness of radiation shielding films [9]. This study contributes to the field of material science by exploring how natural composites can be used to create better protective films. Natural materials such as crab shells can benefit the environment as they help reduce waste and pollution compared to traditional manufacturing methods.

Mud crab shells are mainly made up of calcium carbonate ($CaCO_3$), which accounts for about 20 % to 50 % of their weight. They also contain 20 % to 40 % protein, 15 % to 40 % chitin, and smaller amounts of pigments and fats [10]. Calcium carbonate, with high atomic number and density, is effective at blocking and absorbing radiation, although its use in radiation shielding materials has not been thoroughly explored. However, a study shows that processed oyster shells were used to create eco-friendly radiation shielding materials, effectively blocking about 37.32 % of low-energy X-rays, highlighting the potential of utilizing abundant waste shells that are typically discarded [11]. Crab shells have chitosan, which creates waterproof and long-lasting films. These films can be applied to fabrics to protect against wear and water damage, even after multiple washes [12]. Moreover, chitosan-based coatings can be used for sponges made of polyurethane that absorb water, making them excellent at soaking up oils and solvents from mixtures of oil and water [13]. Crab shells are mostly composed of calcium carbonate, protein, and chitin, with calcium carbonate making up approximately 68 % of their total mass. This compound plays a significant role in various applications, including biosorption processes. Additionally, Fourier-transform infrared spectroscopy (FTIR) and X-ray diffraction (XRD) have been used to analyze the structural properties within crab shells [14].

This research aims to develop an innovative, eco-friendly material for fabricating anti-radiation films using Mud Crab (S. serrata) shell powder. By harnessing the natural properties of crab shells, the study seeks to create a potential and sustainable alternative for radiation protection. The process involves grinding the shells into powder, incorporating the material into film matrices, and evaluating the films' radiation shielding properties.

2. Materials and Methods

2.1. Research Design

The quantitative study utilized a Research and Development design, which involved gathering and analyzing relevant literature, formulating objectives, developing and testing the product, and collecting data for necessary revisions [15]. The research aimed to assess the radiation-blocking capability of the films using a UV radiometer, with measurements taken at five different concentrations: 0 %, 25 %, 50 %, 75 %, and 100 %. The researchers performed experiments to assess the fabricated films (independent variables) and the effects or outcomes of these films (dependent variables) [16].

2.2. Locale of the Study

This study was conducted in four different areas. The Mud Crab (*S. serrata*) shells were collected from Prawn House Restaurant in Cagayan De Oro City. They were fabricated at San Isidro College, Barangay 10, Impalambong, Malaybalay City, Bukidnon. The collected samples were carefully handled and transported to the Wet Laboratory of San Isidro College for further processing and experimentation. Moreover, the Mud Crab (*S. serrata)* samples were sent for species confirmation to Central Mindanao University, located in Musuan, Maramag, Bukidnon.

2.3. Sample Collection

Mud Crab shells were collected from Prawn House Restaurant in Cagayan De Oro, which serves mud crabs. The restaurant was selected according to the number of crab dishes they offer to guarantee a significant amount of Mud Crab shells are required for the research. The restaurant was followed up on a fixed date, with the collection occurring through gathering Mud Crab shells to ensure sufficient quantities. During collection, the shells were packed in appropriately labelled, clean, and sealed containers to minimize any chance of contamination while in transit to the Wet Laboratory at San Isidro College, Malaybalay City. When the shells arrived at the laboratory, they were cleaned to ensure that all the organic matter and other unwanted materials were removed. The cleaning process of these shells was performed by rinsing the shells under tap water to remove dirt and other debris on the shells and then rinsing the shells in a dilute detergent solution to eliminate the oils and proteins. The shells were washed by hand and brushed to remove any organic matter that might have adhered to them. A final rinse was performed to eliminate any remaining detergent. The cleaned crab shells were then dried in the sun. The dried shells were kept in a desiccator until further processing. A study method involved crushing dried Mud Crab shells. The shells were ground into a fine powder with a blender, and the powder was sieved to obtain uniform particle sizes [17]. The films were measured in December, with tests conducted at three different times: 9:00 am, 12:00 pm, and 3:00 pm. The three replicates of each film formulation were prepared to ensure consistency and reliability in the results.

2.4. Data Gathering Procedure

The study began with the collection of Mud Crab (*S. serrata*) shells from Prawn House Restaurant in Cagayan de Oro City. The shells were washed, brushed, and sun-dried for five hours before being ground into a fine powder and sieved for uniformity. Anti-radiation films were fabricated by incorporating crab shell powder at varying concentrations (0 %, 25 %, 50 %, 75 %, and 100 %) with carrageenan and glycerine. The mixtures were poured into molds and dried to form uniform films. UV radiation shielding tests exposed the films to natural sunlight at 9 AM, 12 PM, and 3 PM. To ensure accuracy, a UV radiometer measured the radiation passing through each film, with three trials per concentration. Data were recorded and analyzed using Microsoft Excel. One-way ANOVA and Tukey HSD tests determined statistical differences in UV shielding. Ethical considerations were observed by utilizing seafood waste sustainably and ensuring data integrity.

2.5. Preparation of Crab Shell Powder

With a few modifications, the method for preparing the powder began with collecting Mud Crab (*S. serrata)* shells. The shells were washed thoroughly to remove dirt and impurities, then dried in the sun for 5 hours to eliminate moisture. After drying, the shells were crushed using a mortar and blended into a fine powder in a blender. The powder was sieved through a 100-mesh strainer to ensure a smooth and consistent texture. This fine powder was then used in film formation, preserving its natural raw material properties [17].

2.6. Film Formation

Carrageenan powder (3.5 g), glycerine (3.5 g), and water (90.0 mL) were used as the primary components in all film formulations. The Mud Crab (*S. serrata*) shell powder was incorporated at varying concentrations depending on the formulation. Specifically, the 100 % formulation included 5.0 g of Mud Crab shell powder, the 75 % formulation contained 3.8 g, the 50 % formulation used 2.5 g, and the 25 % formulation had 1.3 g. The control formulation did not include any Mud Crab shell powder. Carrageenan powder is a flexible polymer matrix due to its excellent film-forming properties and biodegradability [18]. Glycerine, or glycerol, is widely used as a plasticizer due to its ability to enhance flexibility and reduce brittleness in various materials [19]. Once the ingredients were accurately measured, they were combined to form a homogeneous slurry. This mixture was then poured into a tray or mold where it was evenly spread to achieve the desired thickness. The resulting blend was allowed to cool for 10 minutes before proceeding with subsequent processing steps.

2.7. UV Radiation Shielding Test

The UV radiation testing method was as follows: First, films made from Mud Crab (*S. serrata*) shells, with varying concentrations of shell powder (0 %, 25 %, 50 %, 75 %, and 100 %), were prepared. These films were made to a standard size to ensure the results could be easily compared across different samples. Before testing, the samples were conditioned to ensure they reached a consistent environmental state, stabilizing their mechanical properties. The UV radiation shielding test was carried out using a UV radiometer, which measured only UV radiation intensity. Each film sample was exposed to UV radiation from natural sunlight, and the UV radiometer recorded the amount of UV radiation that penetrated the film. The testing was repeated for all concentrations, and the readings from the radiometer provided a quantitative measure of how the film blocked UV radiation. The films were measured in December, with tests conducted at three different times: 9:00 am, 12:00 pm, and 3:00 pm. After the testing, the data were collected and analyzed, focusing on how much UV radiation was blocked by each film concentration. This allowed the researchers to determine which concentration best protected against UV rays [20].

2.8. Statistical Treatment

The sample data in this study were analyzed using descriptive statistics, including means, standard deviations, and percentages. The intensity of radiation passing through the fabricated anti-radiation films was measured using a UV radiometer at varying concentrations (0 %, 25 %, 50 %, 75 %, and 100 %). The study employed the one-way ANOVA test to determine the effect of the fabricated Mud Crab (*S. serrata*) shell films on radiation shielding. This was used to compare the mean performance of the anti-radiation films in terms of radiation shielding at different concentrations. A p-value of <0.05 was considered the statistical analysis criterion.

2.9. Ethical Consideration

The study followed ethical guidelines in collecting and using Mud Crab shells. Mud crabs (*S. serrata*) were sourced from the restaurant, and no harm was caused to live crabs during the research. Focus was placed on the responsible use of natural resources, minimizing waste, and ensuring proper disposal of materials to protect the environment. Respect for the work of other researchers was maintained by properly citing all sources of information and methods used. Data were handled and analyzed with integrity, ensuring accurate and fair results.

3. RESULTS & DISCUSSION

3.1. Effect of Fabricated Mud Crab (*S. serrata*) Shell Films at Varying Concentrations on UV Radiation Shielding

Table1. *UV Radiation Shielding of Mud Crab Shell Films at Different Concentrations and Timepoints*

The data presented in the table provides an overview of the mean UV radiation shielding observed for each concentration at different times of the day, along with corresponding F-values and P-values from statistical analysis. The ANOVA results reveal that there is a statistically significant difference in UV radiation shielding across different concentrations of Mud Crab shell films (F-values: 1072.54 at 9 AM, 999.94 at 12 PM, and 957.47 at 3 PM; P-values < 0.0001). The Tukey HSD test confirms significant pairwise differences between most concentration groups, especially between 0 % (control) and the other concentration.

Concentration	9 AM Mean	12 PM Mean	3 PM Mean	F-Value	P-Value
0 % (Sample 1)	64.67	53. 33	67.00	1072.54	<0.001
25 % (Sample 2)	17.67	15.00	29.67	999.94	<0.001
50 % (Sample 3)	12.00	11.33	19.00	957.47	<0.001
75 % (Sample 4)	8.67	10.00	8.33	9.57.47	<0.001
100 % (Sample 5)	5.67	2.67	3.67	957.47	<0.001

At 9 AM, the efficiency improved significantly as the concentration increased, with higher shielding observed at 50 %, 75 %, and 100 % concentrations. However, differences between 75 % and 100 % concentrations were nonsignificant, indicating a plateau in shielding efficiency at higher levels. At 12, similar trends were observed, with significant differences in lower concentrations (0 % and 25 %) compared to higher ones. However, the effect appeared slightly less pronounced compared to the morning results. The lower overall shielding observed during this time may not solely be due to UV intensity but could also be influenced by seasonal weather conditions in December, affecting UV exposure levels.

At 3 PM, the films demonstrated a significant improvement in shielding as the concentration increased, following the same trends as earlier times. These results suggest that the fabricated Mud Crab shell films have the potential to shield UV radiation, with higher concentrations providing better performance. The consistent performance beyond a 75 % concentration highlights a potential optimal range for material use, minimizing waste while maximizing UV protection. The differences in the results observed at different times of the day could be attributed to changes in UV radiation intensity, with films showing greater relative effectiveness during times of lower UV exposure (e.g., 9 AM and

12 PM). A study demonstrates that natural materials, such as crab shells, exhibit significant potential for UV radiation absorption, moreover, the study reveals that chitosan films derived from crab shells show enhanced barrier properties against UV radiation as shell content increases, reinforcing the notion that higher concentrations lead to improved protective capabilities. Furthermore, a study concludes that crab shells can serve as alternatives to traditional shielding materials, demonstrating their potential in radiation protection applications [21][22][23].

3.2. Significant Difference in the Anti-Radiation Shielding Properties of Fabricated Mud Crab (*Scylla serrata*) Shell Films at Varying Concentrations

Table2. *UV Shielding Performance at Different Concentrations*

The table summarizes the descriptive statistics, including mean UV shielding values, total UV shielding, variance, standard deviation, and standard error for each concentration. The study investigated the UV radiation shielding performance of Mud Crab shell films at varying concentrations (0 %, 25 %, 50 %, 75 %, and 100 %) across three time points (9 AM, 12 PM, and 3 PM). The statistical analysis shows that the F-values are higher than the critical values, and the p-values are below 0.05. This means that there are significant differences in the UV shielding ability of the Mud Crab shell films at different concentrations. Therefore, the null hypothesis is rejected, and it is concluded that the concentration of Mud Crab shell powder affects the UV radiation shielding performance of the films.

Concentration (%)	9 AM (Mean)	12 PM (Mean)	3 PM (Mean)	Total (Sum)	Variance	Std. Dev.	Std. Err.
0 %	64.67	53.33	67.00	194	4.33	2.08	1.20
25 %	17.67	15.00	29.67	53	1.33	1.15	0.67
50 %	12.00	11.33	19.00	36	1.00	1.00	0.58
75 %	8.67	10.00	8.33	26	0.33	0.58	0.33
100 %	5.67	2.67	3.67	17	1.33	1.15	0.67

The Tukey HSD test results show that the concentration of Mud Crab shell powder potentially influences UV shielding but with diminishing returns at higher concentrations. At 9 AM, significant differences were observed between the control (0 %) and higher concentrations (25 %, 50 %, 75 %, and 100 %). For instance, the difference between M1 (0 %) and M2 (25 %) is significant, meaning that even a small amount of shell powder could improve UV shielding. As the concentration increases, there are significant differences between M1 and M3, M4, and M5, suggesting a potential improvement in shielding performance. However, the comparisons between M3 (50 %) and M4 (75 %) and between M4 (75 %) and M5 (100 %) were not significant. This could mean that beyond 50 %, the improvement in UV protection becomes less noticeable. The statistical analysis reveals that the relationship between concentration and UV shielding is not linear; after a certain point, the increase in concentration does not lead to a significant increase in UV blocking.

At noon (12 PM), the pattern of results is similar, with significant differences observed between M1 and all higher concentrations, supporting the idea that Mud Crab shell powder contributes to better UV shielding. The comparison between M2 (25 %) and M4 (75 %), and between M3 (50 %) and M5 (100 %), also showed significant differences. This suggests that concentrations beyond 50 % could offer substantial improvements in UV shielding. However, the comparison between M3 (50 %) and M4 (75 %) was not significant, similar to the 9 AM results, further supporting the idea that after a certain concentration, additional increases in shell powder concentration have a minimal impact on shielding ability. At 3 PM, the results follow a similar trend, with significant differences between the 0 % control sample and higher concentrations. However, the difference between M4 (75 %) and M5 (100 %) was significant at the 0.05 level, though less pronounced than the differences observed at lower concentrations. The lack of significance in some comparisons, particularly between higher concentrations (e.g., 75 % vs. 100 %), likely reflects a point of diminishing returns. As the concentration increases, the material may approach a point where further additions of Mud Crab shell powder provide minimal added benefits. This explains why the results become less significant at higher concentrations, as the additional powder does not contribute meaningfully to improving UV protection. A study emphasized the UV absorption potential of chitosan, a biopolymer derived from crustacean shells, for use in applications such as sunscreens and packaging films [24]. This aligns with the observed improvement in UV shielding as Mud Crab shell powder concentrations increase. Additionally, a study validates that chitosan has UV-blocking abilities because it absorbs light at the wavelength of 215 nm which makes the material suitable for sunscreen products and protective garments [25]. Chitosan-based films provide better UV protection which strengthens its potential for protective devices [26]. Furthermore, a study highlighted the physicochemical properties of chitosan extracted from mud crab shells, which may contribute to its ability to shield UV radiation [27].

4. CONCLUSION

The study revealed that Mud Crab (*S. serrata*) shell films blocked UV radiation, with the reduction increasing as the concentration of shell powder in the films rose. This is possibly due to Mud Crab shells being rich in calcium carbonate and chitin, compounds known for absorbing and scattering UV rays. At higher concentrations (75 % and 100 %), the compounds in the film are packed more tightly, improving their ability to block UV rays. In contrast, lower concentrations (0 %, 25 %, and 50 %) have fewer particles that block UV, leading to less protection. The results emphasize that the concentration of shell powder plays a key role in creating a thicker, more protective barrier, making these films sustainable for uses that require strong UV protection, such as packaging or sun-resistant materials.

The study confirmed a significant difference in UV radiation shielding among the films with varying Mud Crab shell powder concentrations. Higher concentrations (75 % and 100 %) consistently outperformed lower ones (0 %, 25 %, and 50 %) due to the higher calcium carbonate and chitin content, which are key components in blocking and scattering UV rays. The statistical analysis validated that these differences were not due to chance but were directly related to the concentration of shell powder. This outcome emphasizes that the higher the concentration, the denser the film matrix, leading to fewer gaps for UV rays to penetrate. These results prove that the concentration of Mud Crab shell powder is a critical factor in enhancing the films' anti-radiation properties, offering a solution for optimizing these materials for practical use in UV protection.

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