The Study of the Antioxidant Activity and Skin Moisturizing Efficacy of Polysaccharides in Mung Bean Shell Extracts from Industrial By-Product

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Abstract. Natural products are gaining popularity in the cosmetics industry, especially those containing plant-based extracts with properties such as anti-inflammatory effects, antioxidant activity, skin hydration, and pollution protection. Many plant extracts show potential for development into dietary supplements or healthcare products. This study investigated polysaccharides extracted from mung bean (*Vigna radiata*) shells using a reflux extraction method at different times. The total sugar content was determined by the phenol-sulfuric acid colorimetric assay, along with antioxidant activity. The highest sugar content (52.28 mg/g) was obtained after 1 hour. Longer extraction times led to sugar loss compared to the xylose standard. The antioxidant capacity of the extract, evaluated using the DPPH free radical scavenging assay, showed an IC_{50} of 0.47 mg/mL, while ascorbic acid had an IC_{50} of 0.03 mg/mL. Moisturizing tests showed that the moisture absorption rate (Ra) and retention rate (Rh) were comparable to standard humectants such as chitosan, sodium hyaluronate, and sodium alginate. These findings indicate that mung bean polysaccharides possess antioxidant and moisturizing properties and have potential for further development into effective cosmetic and healthcare products, adding value to mung bean shells, which are typically discarded as industrial by-products.

1 Introduction

Mung bean (*Vigna radiata* L.) is a leguminous crop primarily cultivated in Southeast and East Asia. [1]. It is widely used in many industries, especially in food production, due to its high nutritional value. The bean contains a good amount of protein, vitamin C, lysine, phosphorus, and vitamin A [2]. People often use it to make vermicelli, sweet dishes, and different kinds of food. Due to their high nutritional value and low cost compared to animal-based proteins, mung beans have become an noticeable plant-based protein source. Despite the growing use of mung beans, their processing result in significant by-products, especially mung bean shell, which are often discarded as waste. However, this shell possess potential for further utilization. They have been used as animal feed [3], compost material, and more recently, as a source of bioactive substances for uses with added value [4].

These bioactive substances include, polysaccharides extracted from mung bean shells have obtained increasing interesting for their useful properties. These complex carbohydrates exhibit strong antioxidant activity, effectively scavenging free radicals and protecting skin cells from oxidative stress, which is a major cause of skin aging and inflammation. Additionally, mung bean shell polysaccharides display anti-inflammatory effects, helping to smooth irritated skin and promote the restoration of the skin barrier. Their strong moisture retention helps hydrate skin and enhance its elasticity and texture. Compared to other widely used polysaccharides such as hyaluronic acid and alginate, those derived from mung bean shells are notable for their natural origin, biodegradability, and availability as an agricultural by-product, combining in ideally with the growing demand from consumers for environmentally friendly and sustainable cosmetic ingredients.

Although the promising biological activities of mung bean shell polysaccharides have been showed in initial research, detailed investigations into their extraction, characterization, and efficacy in topical applications remain limited. This study sets out to explore these issues by carefully examining both the antioxidant properties and the moisturizing ability of polysaccharides extracted from mung bean shells, thereby supporting their potential use in the health and beauty industries.

Several studies have reported that mung bean shell contains antioxidants and other phytochemicals that are beneficial for skin care. Natural extracts with antioxidants

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[5], anti-inflammatory [6], and moisturizing properties have gained popularity in cosmetic and health product development to meet consumer demand for natural and environmentally friendly products [7].

Mung bean-derived ingredients, particularly from its shell, have shown potential to be developed into scrubs, moisturizers, and functional skin-care formulations [8]. Given these prospects, The goal of this study is to explore the antioxidant activity and skin moisturizing efficacy of mung bean shell for its possible use in the cosmetics and health industries.

2 Materials and methods

2.1 Materials

Mung bean shell was a kind gift from Thai Wah Public Company (TWPC)., Thai Wah Tower 1, 21/59, 21/63-64 South Sathorn Road, Tungmahamek, Sathorn, Thailand. The fresh mung bean shells were stored at 4°C to maintain quality before processing. All substances used were acquired from Sigma-Aldrich (St. Louis, MO, USA) and were analytical grade.

2.2 Polysaccharide extraction from mung bean shell

Fresh mung bean shells were promptly collected and stored at 4°C to minimize microbial growth and enzymatic degradation, ensuring the preservation of polysaccharide content and quality prior to extraction. The extraction was modified according to a previously reported procedure [9]. Mung bean shell powder (10.000 g) was combined with 200.0 mL of deionized water. The mixture was extracted by refluxing for 1, 2, and 3 hours, respectively. Following extraction, Whatman No. 1 filter paper was used to filter the mixture under vacuum. The clear supernatant was then separated from the filtrate by centrifuging it for 10 minutes at 6000 rpm, which was collected as the polysaccharide extract from mung bean shell. An ethanol precipitation method was employed by adjusting the extract to 80% (v/v) ethanol using 95% ethanol, and the mixture was then incubated at 4°C for 16 hours.

For the collection of the precipitated polysaccharides, the solution was centrifuged for 12 minutes at 6,000 rpm following incubation. (Figure 1), which were then retained for further use.

2.3 Total sugar analysis

The phenol-sulfuric acid method was employed to quantify total sugar content, with D-xylose serving as the calibration standard. [11]. A test tube was filled with 1.60 mL of the polysaccharide extract. After that, 2.00 mL of 98% sulfuric acid and 0.40 mL of a 5% (w/v) phenol solution were added. After thoroughly mixing the mixture using a vortex mixer, it was allowed to stand for half an hour at room temperature. The absorbance was determined at a wavelength of 490 nm with a Spectronic 21 spectrophotometer.

2.4 Fourier transform infrared (FTIR) analysis

The chemical composition of the polysaccharide extract was analyzed using Fourier Transform Infrared (FTIR) spectroscopy. The sample was mixed with potassium bromide (KBr) and pressed into a pellet. FTIR spectra were recorded in the range of 400–4000 cm^{-1} using a Fourier Transform Infrared Spectroscope (PerkinElmer, Spectrum 100, USA).

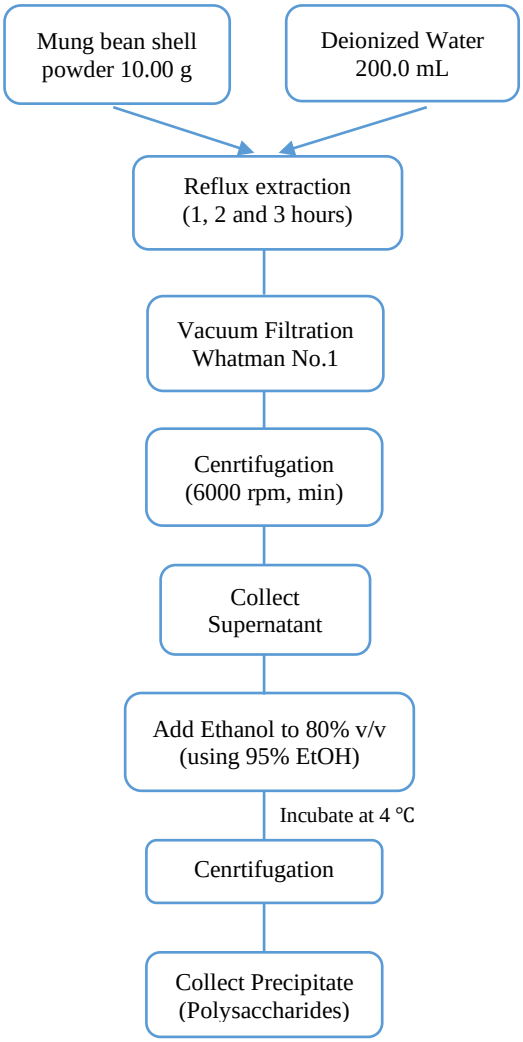

Fig. 1. Extraction procedure of polysaccharides from the shell of *Vigna radiata*.

2.5 Antioxidant assay

The DPPH radical scavenging assay was employed to assess antioxidant activity, with ascorbic acid (vitamin C) serving as the positive control. [9]. A 0.50 mL portion of the polysaccharide extract was added to a test tube, followed by 1.50 mL of deionized water. Subsequently, 2.00 mL of DPPH radical solution was introduced into the mixture. The solution was mixed thoroughly using a vortex mixer and incubated in darkness at ambient temperature for 30 minutes. Absorbance was recorded at

517 nm with a UV-visible spectrophotometer. The following formula was used to determine the capacity to scavenge the DPPH:

$$\text{DPPH scavenging effect (\%)} = [1 - (A_2 - A_1)/A_0] \times 100\% \quad (1)$$

where A_0 is the absorbance of DPPH solution without sample
A_1 is the absorbance of the control sample (without DPPH solution)
A_2 is the absorbance of the sample mixed with DPPH solution

2.6 Evaluation of moisturizing efficacy

Moisture absorption and retention were assessed by placing dried samples in desiccators containing saturated salt solutions of sodium carbonate (Na_2CO_3; 43% RH) and ammonium sulfate ($(NH_4)_2SO_4$; 81% RH). The samples were maintained at room temperature, and weight changes were recorded over time to evaluate their interaction with moisture under varying humidity conditions [12].

2.6.1 Moisture Absorption

Polysaccharide extracts and commonly used cosmetic humectants—chitosan, sodium hyaluronate, and sodium alginate—were each weighed at 100 mg per sample. After that, the samples were dried for 4 hours at 100°C in a hot-air oven. Following drying, the samples were placed in moisture absorption chambers with saturated solutions of sodium carbonate (Na_2CO_3) and ammonium sulfate ($(NH_4)_2SO_4$), which generate relative humidities of 43% and 81%, respectively, at 25°C. Moisture absorption was measured over a period of 0 to 48 hours. The relative absorption (Ra) was calculated as follows:

$$R_a\ (\%) = \frac{A_1 - A_0}{A_0} \times 100\% \quad (2)$$

where A_0 represents the weight of the sample before exposure to the moisture absorption chamber.
A_1 represents the weight of the sample after exposure to the moisture absorption chamber.

2.6.2 Moisture Retention

Polysaccharide extracts and commonly used cosmetic humectants—chitosan, sodium hyaluronate, and sodium alginate—were each weighed at 100 mg per sample. From this, the samples were dried for four hours at 100°C in a hot-air oven. Following drying, each sample obtained 20 mL of distilled water. The hydrated samples were then placed in moisture retention chambers containing silica gel and saturated salt solutions of sodium carbonate (Na_2CO_3) and ammonium sulfate ($(NH_4)_2SO_4$), which produced atmospheric relative humidities of 43% and 81%, respectively, at 25°C. The test duration ranged from 0 to 48 hours. The moisture retention capacity (Rh) was determined using the equation below:

$$R_h\ (\%) = \frac{B_1}{B_0} \times 100\% \quad (3)$$

where B_0 is the weight of the sample prior to placement in the moisture retention chamber.
B_1 is the weight of the sample after being placed in the moisture retention chamber.

3 Results and discussion

3.1 Extract yield from mung bean shells (%)

Table 1. Yield of dried polysaccharide extract based on fresh mung bean shell.

Time (hours)	Yield of polysaccharide extract per gram of fresh mung bean shell (mg/g)
1	55.5
2	70.4
3	83.7

Extraction of polysaccharides from mung bean shell using hot water for 1, 2, and 3 hours revealed that the highest yield of 83.73 mg/g was obtained after 3 hours. This is nearly double the yield reported in a previous study using water extraction on mung bean hulls [11]. The discrepancy could be due to differences in extraction conditions, such as extraction time, temperature, material to solvent ratio, or physical characteristics of the raw material shell. In addition, prolonged heating may have enhanced the breakdown of cell wall components, facilitating the release of bound polysaccharides into the solution. These results suggest that optimizing the extraction parameters can significantly influence the recovery and efficiency of beneficial polysaccharides extraction from agricultural by products.

3.2 Total sugar content

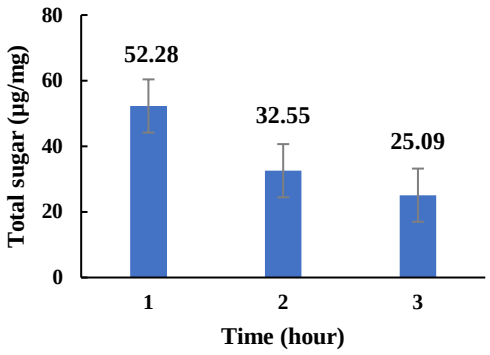

Fig. 2. Comparison of total sugar content extracted under varying reflux durations.

The total sugar content of polysaccharide extracts obtained by hot water extraction at different extraction times (1, 2, and 3 hours) was analyzed, as presented in (Figure 2). The highest total sugar content was observed at 1 hour, yielding 52.28 µg/mg. In contrast, a previous study reported a significantly higher total sugar content of 634.30 µg/mg after 3 hours of extraction [9]. The difference in yield may be due to variations in raw materials, extraction conditions, and difficulty in controlling temperature during extraction. This discrepancy may be caused by thermal degradation and structural changes in polysaccharides during prolonged extraction. Such changes can break down sugar chains into smaller fragments or form derivatives that are not detectable by the phenol–sulfuric acid method. Similar results were reported in a previous study [10], where increased polysaccharide yield but decreased reducing sugar content was observed after extended hot water extraction of *Agaricus bisporus*. These findings suggest that longer extraction times may increase overall polysaccharide yield but reduce measurable sugar content due to degradation. These findings support the hypothesis that prolonged heating may induce thermal degradation of heat-sensitive sugar structures, leading to lower detectable sugar content.

3.3 FT-IR spectroscopy

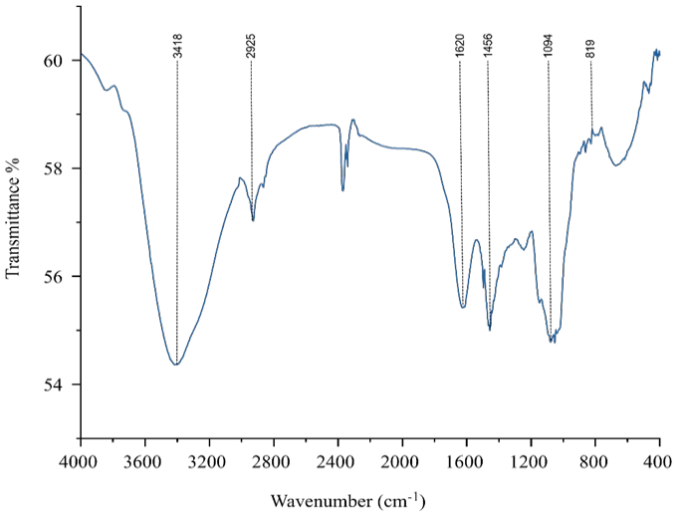

Fig. 3. FT-IR spectra of polysaccharides extracted from mung bean shells.

The FTIR analysis of the polysaccharide structure extracted from mung bean shell was (extracted for 3 hours) recorded in the range of 4000–400 cm^{-1}, as illustrated in (Figure 3). A broad stretching vibration peak was observed at approximately 3,418 cm^{-1}, corresponding to the O–H stretching vibration, suggesting that hydroxyl groups, which frequently appear in polysaccharide structures, are present. These groups are essential for water solubility and hydrogen atom donation, which may be related to the extracted material's antioxidant activity. Moreover, hydroxyl groups can form hydrogen bonds with water molecules, which contributes significantly to the water-holding capacity of polysaccharides [13]. A weaker stretching region appeared around 2,925 cm^{-1}, which is characteristic of C–H bond stretching and bending motions [14]. The FTIR spectrum shows an absorption band near 1,620 cm^{-1}, which is attributed to the asymmetric stretching vibration of carboxylate ions (COO^-), which corresponds with previous findings locating this vibration in the 1,630 to 1,600 cm^{-1} [15]. This suggests the presence of functional groups that may enhance the bioactivity of the extracted polysaccharides, including antioxidant and metal-chelating properties. A peak at 1456 cm^{-1} was observed, which corresponds to the asymmetric bending of CH_3 groups in lignin. Previous studies have reported this vibration in the range of 1456–1465 cm^{-1}, indicating the presence of lignin [16]. This is significant because lignin influences the composition and quality of the polysaccharide, which affects extraction optimization. The peaks around 1094 cm^{-1} are typical of C–O stretching in polysaccharides, which generally absorb at 1050–1150 cm^{-1} [17, 18]. The peak around 819 cm^{-1} is attributed to C–O–C stretching of pyranose rings and COH ring vibrations [14].

3.4 Antioxidant

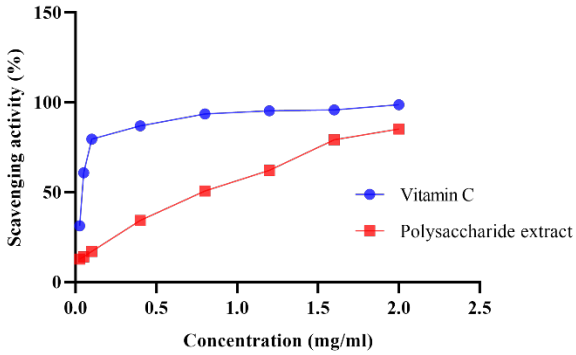

Fig. 4. Antioxidant activity of polysaccharide extract evaluated by DPPH radical scavenging assay.

Antioxidants are compounds that inhibit oxidative damage by neutralizing free radicals. The evaluation of free radical scavenging is a standard way to measure antioxidant activity in natural compounds [19]. The positive control for antioxidant activity assessment was vitamin C. The polysaccharides extracted after 3 hours were selected for further testing. As shown in (Figure 4), the ability of the polysaccharide extract to scavenge free radicals improved with increasing sample concentrations between 0.025 to 2 mg/mL At the highest tested concentration of the polysaccharide extract (2 mg/mL), the scavenging activity reached 85.24% (IC_{50} = 0.47 mg/mL). When compared at the same concentration, this value was lower than that of ascorbic acid, which showed 98.583% (IC_{50} = 0.03 mg/mL). Previous studies reported that polysaccharides extracted from mung bean shell using hot water exhibited antioxidant activity, as indicated by an IC_{50} of 0.73 mg/mL [9]. It is important to note that the reduced antioxidant activity observed in this study may result from variations in extraction conditions. Specifically,
a shorter extraction time might result in the incomplete release of bioactive polysaccharides. Additionally, variations in temperature during hot water extraction can

affect both extraction efficiency and antioxidant stability. Bioactive polysaccharides are carbohydrate polymers that have positive effects on cells, like decreasing blood sugar levels, enhancing lipid levels, acting as antioxidants, reducing inflammation, improving immune response, and exhibit anticancer activity [20, 21]. These compounds are increasingly explored for their potential applications in functional foods, nutraceuticals, pharmaceuticals, and cosmetics.

3.5 Evaluation of moisturizing efficacy

3.5.1 Moisture Absorption

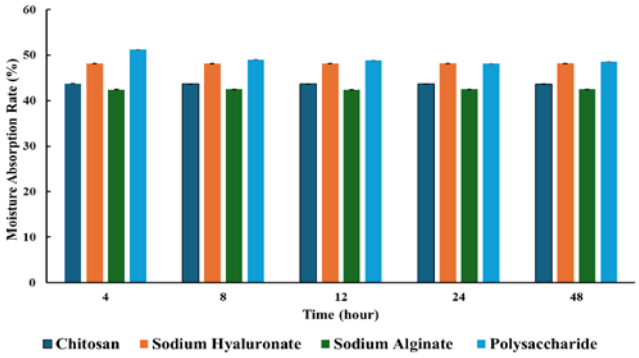

Fig. 5. Moisture absorption of chitosan, sodium hyaluronate, sodium alginate and polysaccharide extract at 43% relative humidity over the indicated time periods.

The moisture absorption capacity (Ra) of polysaccharides extracted from mung bean shell (extracted for 3 hours) was investigated under two different relative humidity (RH) conditions: 43% (Figure 5) and 81% (Figure 6). The results revealed a consistent ability to retain moisture over time, with comparatively better performance than commonly used standard moisturizers. At 43% RH, the polysaccharide sample showed its highest recorded moisture absorption at 51.25% ± 0.02% during the testing period. After 48 hours, the value slightly decreased to 48.57% ± 0.02%, reflecting a reduction of only 5.23%, which was significantly lower ($p < 0.001$) than the reductions observed in standard moisturizers such as chitosan, sodium hyaluronate, and sodium alginate. This relatively small change indicates excellent moisture retention stability, especially when compared with standard moisturizers such as chitosan, sodium hyaluronate, and sodium alginate, which generally exhibited a more substantial decline in moisture absorption over time.

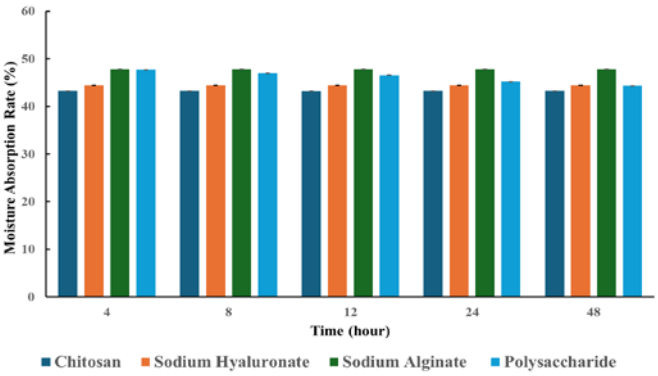

Fig. 6. Moisture absorption of chitosan, sodium hyaluronate, sodium alginate and polysaccharide extract at 81% relative humidity over the indicated time periods.

These results indicate that the mung bean shell polysaccharides possess a continuous moisture absorption capacity along with structural stability under varying levels of relative humidity. Notably, under 81% RH conditions, where typical moisturizers often experience saturation or moisture desorption, the polysaccharide samples were still able to maintain relatively stable Ra values throughout the testing period. This suggests a strong affinity for water and a robust matrix structure capable of sustaining moisture uptake over time.

The mechanism underlying this behavior may be attributed to the polysaccharide structure containing abundant hydroxyl (–OH) and carboxyl (–COOH) groups, which are particularly able to forming long-term hydrogen bonds with molecules of water. Moreover, the physical structure of the polysaccharides is reported to consist of a tightly packed, complex three-dimensional network formed by associated molecular chains capable of efficiently trapping water molecules within. [22, 23]. This network may act as a hydrogel-like matrix capable of swelling and retaining water over extended periods, resulting in a slow and gradual decrease in moisture absorption [13, 24].

3.5.2 Moisture Retention

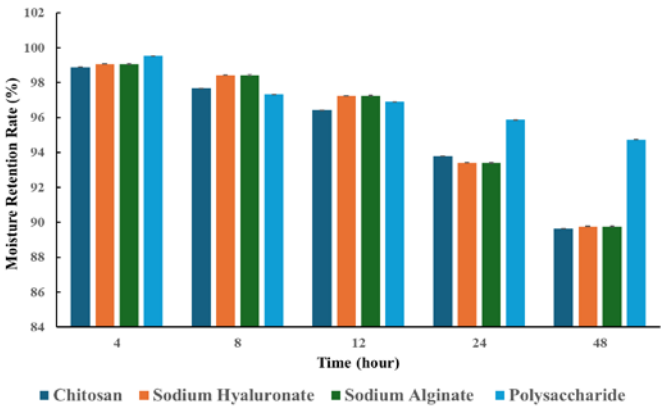

Fig. 7. Moisture retention of chitosan, sodium hyaluronate, sodium alginate and polysaccharide extract at 43% relative humidity over the indicated time periods.

The moisture retention capacity of polysaccharides extracted from mung bean shell (extracted for 3 hours) was evaluated under two relative humidity (RH) conditions: 43% and 81%. Under 43% RH (Figure 7), which represents a low humidity environment, the polysaccharide samples demonstrated a remarkably high initial moisture retention of 99.525 ± 0.035%. After 48 hours, the value slightly decreased to 94.735 ± 0.045%, indicating only a 4.81% reduction *($p < 0.001$)*, which was significantly lower than the declines observed in standard moisturizers such as chitosan, sodium hyaluronate, and sodium alginate.

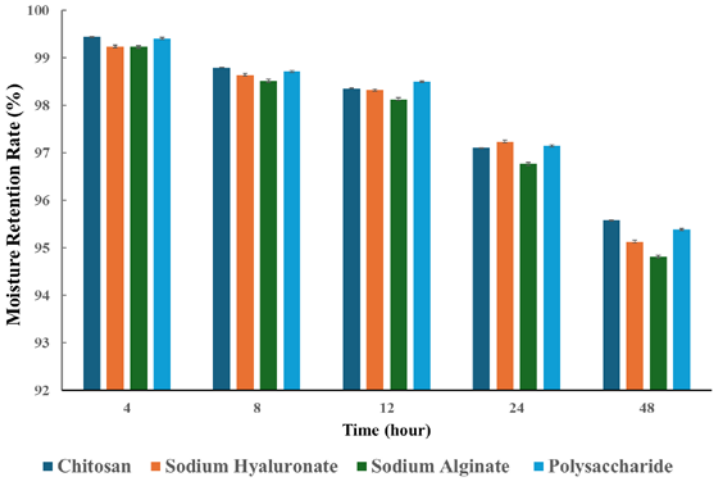

Fig. 8. Moisture retention of chitosan, sodium hyaluronate, sodium alginate and polysaccharide extract at 43% relative humidity over the indicated time periods.

Furthermore, under high humidity conditions 81% RH (Figure 8.), where conventional moisturizers often reach saturation or experience moisture desorption, the mung bean shell polysaccharides still retained excellent moisture retention properties. The highest recorded retention at the beginning of the test was 99.405 ± 0.025 %, which gradually decreased to 95.39 ± 0.03% after 48 hours, reflecting a minimal reduction of only 4.04% ($p < 0.001$), significantly lower than the moisture loss typically observed in standard moisturizers such as chitosan, sodium hyaluronate, and sodium alginate. These results indicate that the polysaccharides can maintain consistent hydration performance and structural integrity even under varying environmental humidity

Together, these findings confirm that mung bean shell polysaccharides possess high and stable moisture retention properties under both low and high RH conditions, making them highly suitable for applications in cosmetic, cosmeceutical, or biopolymer film products that require long term moisture control.

4 Conclusion

This study demonstrated that polysaccharides extracted from mung bean (*Vigna radiata*) shells, an underutilized industrial byproduct, possess notable antioxidant and skin moisturizing properties. The highest yield of polysaccharides was obtained after 3 hours of hot water extraction, while the greatest total sugar content was observed at the 1-hour extraction mark. The extracts showed antioxidant activity, with an IC_{50} value of 0.47 mg/mL, was concentration dependent, though slightly lower than that of ascorbic acid. Moisturization tests revealed that the extracted polysaccharides exhibited high moisture absorption and retention capacities under both low (43% RH) and high (81% RH) humidity conditions. Compared to standard moisturizers such as chitosan, sodium hyaluronate, and sodium alginate, the mung bean shell polysaccharides showed more stable hydration performance over time. The results show that polysaccharides extracted from mung bean shells have antioxidant and moisturizing properties, which means they could be useful as ingredients in cosmetics or biopolymer products. However, more biological tests are needed to confirm how well they work for health and beauty uses. This work also highlights a way to add value to agricultural waste in an eco-friendly way.

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