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Valorization of Pumpkin Peel: A Sustainable Source of Bioactive Compounds for Nutritional Additive Development

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INTRODUCTION & AIM

The rapid expansion of the global agro-industrial sector has led to a massive increase in production volume, which, while essential for food security, simultaneously generates vast quantities of organic waste. In the pharmaceutical and nutraceutical industries, the management of these residues constitutes a critical challenge. Traditionally, by-products such as fruit and vegetable peels are discarded or used for low-value applications, creating a detrimental ecological footprint and resulting in significant economic losses. However, in the context of the circular economy, these matrices are increasingly recognized not as waste, but as untapped reservoirs of bioactive compounds. Scientific literature suggests that the outer layers of vegetables often contain higher concentrations of phytochemicals—such as antioxidants and antimicrobials—than the edible pulp itself.

Among these crops, the pumpkin is widely processed, leaving behind substantial amounts of peel that are rich in essential nutrients. At the same time, there is a growing global demand for natural food additives capable of mitigating chronic diseases, particularly those related to oxidative stress and metabolic disorders like diabetes. Therefore, valorizing pumpkin peel offers a dual solution: it addresses the environmental burden of agro-industrial disposal while providing a sustainable, cost-effective source of functional ingredients for human health.

The primary aim of this research was to scientifically validate a valorization strategy for pumpkin peel, transforming it from a by-product into a high-value food additive. To achieve this, the study pursued three specific goals:

Chemical Characterization: To provide a comprehensive analysis of the peel's nutritional profile by quantifying total sugars, lipids, vitamins, mineral salts, and ash content.

Bioactive Profiling: To determine the concentration of key phytochemicals, specifically focusing on phenolic compounds, carotenoids, and flavonoids.

Biological Assessment: To evaluate the functional properties of the peel through a battery of *in vitro* antioxidant assays (DPPH) and to explore its potential antidiabetic activity.

Ultimately, this study seeks to demonstrate that pumpkin peel is a potent candidate for nutritional enrichment in food formulations, contributing to sustainable industrial practices and improved public health outcomes.

METHOD

2.1. Plant Material and Sample Preparation

Pumpkin (Cucurbita maxima) peels were collected from local agricultural markets in Biskra (Algeria). After manual peeling, the peels were washed with distilled water and air-dried at room temperature (25 °C). The dried material was ground into fine powder and sieved (0.5 mm). The final pumpkin peel powder was stored at −70 °C until analysis. All experiments were performed in triplicate.

2.2.Chemical Characterization

The proximate composition of pumpkin peel powder was determined using standard protocols. Dry matter and total ash contents were assessed via gravimetric methods (drying and incineration at 900°C). Macronutrients were quantified spectrophotometrically:

Proteins: Determined by the **Bradford assay** (595 nm) using a BSA standard curve.
Total Sugars: Quantified using the **phenol-sulfuric acid method** (Dubois et al., 1956) at 490 nm.
Total Lipids: Measured via the **vanillin colorimetric assay** (Cheng et al., 2011).
Phytochemical Profiling & Antioxidant Activity: Phenolic compounds were isolated using an **80% methanol extraction** (double extraction, 1:15 solid-to-solvent ratio). The extracts were analyzed for:
Total Phenolic Content (TPC): Evaluated using the **Folin-Ciocalteu method** at 750 nm (expressed as Gallic Acid Equivalents).
Flavonoids: Determined by the **aluminum chloride complexation method** at 510 nm (expressed as Rutin Equivalents).
Antioxidant Capacity: Assessed via the **DPPH radical scavenging assay**. Absorbance was read at 517 nm after 30 minutes of dark incubation, with results expressed as Trolox Equivalents (TE/g).
antidiabetic activity:
Polysaccharide Extraction and Purification
Pumpkin polysaccharides were extracted by hot-water extraction (40 g, 80 °C, 4 h), followed by defatting with n-hexane and ethanol precipitation. The crude extract was purified using the Sevag method, dialyzed, and freeze-dried. The final yield obtained was **3.24 g (8.1%)**.
Enzyme Inhibition Assays
The inhibitory potential of PP-PE was evaluated against **α-glucosidase** and **α-amylase** using microplate assays. Samples (5–100 mg/mL) were tested, with **acarbose** as the positive control. Absorbance was recorded at **405 nm (α-glucosidase)** and **540 nm (α-amylase)**. Results were expressed as % inhibition and **IC_{50} values**, based on triplicate analyses.

RESULTS & DISCUSSION

Chemical Compound

Table 1: Chemical composition of pumpkin peel

compounds	Moisture	Total sugar	Protein	Lipid	Ash
ppm	10.25	240.23	40.57	5.98	8.47

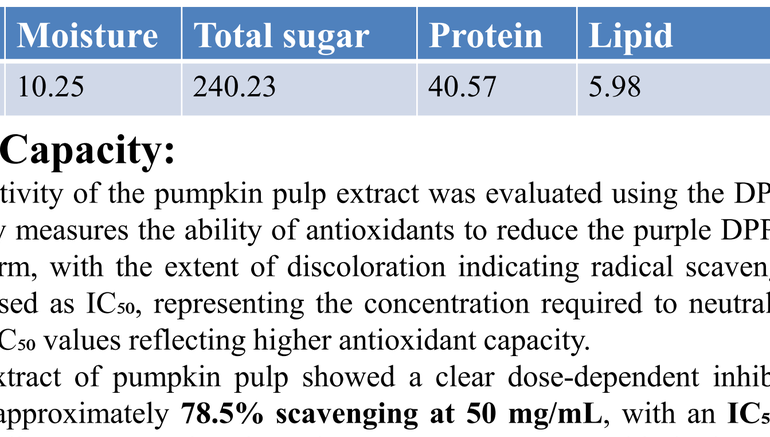
Antioxidant Capacity:

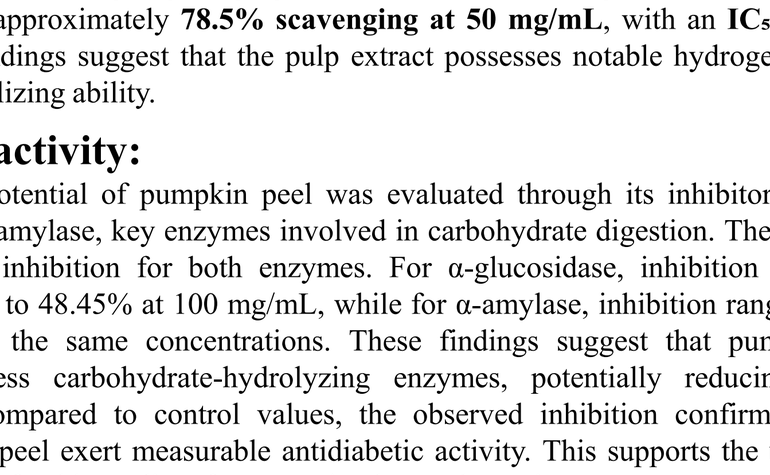
The antioxidant activity of the pumpkin pulp extract was evaluated using the DPPH free radical method. This assay measures the ability of antioxidants to reduce the purple DPPH radical to its yellow reduced form, with the extent of discoloration indicating radical scavenging efficiency. Results are expressed as IC_{50}, representing the concentration required to neutralize 50% of the radicals — lower IC_{50} values reflecting higher antioxidant capacity.

The methanolic extract of pumpkin pulp showed a clear dose-dependent inhibition of DPPH activity, reaching approximately **78.5% scavenging at 50 mg/mL**, with an **IC_{50} value of 16.5 mg/mL**. These findings suggest that the pulp extract possesses notable hydrogen-donating and free-radical-neutralizing ability.

antidiabetic activity:

The antidiabetic potential of pumpkin peel was evaluated through its inhibitory effects on α-glucosidase and α-amylase, key enzymes involved in carbohydrate digestion. The results indicate a dose-dependent inhibition for both enzymes. For α-glucosidase, inhibition increased from 4.24% at 5 mg/mL to 48.45% at 100 mg/mL, while for α-amylase, inhibition ranged from 3.43% to 39.87% across the same concentrations. These findings suggest that pumpkin peel can moderately suppress carbohydrate-hydrolyzing enzymes, potentially reducing postprandial glucose levels. Compared to control values, the observed inhibition confirms the bioactive compounds in the peel exert measurable antidiabetic activity. This supports the use of pumpkin peel as a functional food ingredient for managing hyperglycemia.





CONCLUSION

This study confirms that pumpkin byproducts possess significant bioactive potential. Chemical analysis of pumpkin peel revealed a composition rich in sugars and proteins. The methanolic extract of the pulp displayed notable antioxidant capacity (IC50 = 16.5 mg/mL), while the peel extract demonstrated a dose-dependent ability to inhibit key digestive enzymes (α-glucosidase and α-amylase). Collectively, these results support the valorization of pumpkin peel as a functional food ingredient capable of contributing to the management of hyperglycemia and oxidative stress.

FUTURE WORK / REFERENCES

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