

Preparation of Energy Booster Balls from *Hylocereus undatus* (White-Fleshed Dragon Fruit): A Nutraceutical and Functional Food Approach

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ABSTRACT

The present study focuses on the formulation and evaluation of nutrient-dense energy balls prepared from *Hylocereus Undatus* (white-fleshed dragon fruit), a tropical fruit valued for its high antioxidant content, dietary fiber, and micronutrient profile. Fresh dragon fruit pulp was combined with complementary natural ingredients such as oats, nuts, seeds, and natural sweeteners to enhance texture, flavor, and nutritional value without the use of synthetic additives. The preparation process involved pulp extraction, blending with dry ingredients, shaping, and low-temperature setting to preserve bioactive compounds. Physicochemical parameters, including moisture content, pH, and total soluble solids, were assessed alongside sensory evaluation for appearance, taste, texture, and overall acceptability. The developed product demonstrated high consumer appeal, retained significant antioxidant activity, and provided a balanced macronutrient composition suitable for functional food applications. [1][2][3][4]. This work highlights the potential of *H. Undatus* as a versatile ingredient in value-added health snacks, aligning with current trends in natural, plant-based, and minimally processed foods.

Keywords: *Hylocereus Undatus*, energy balls, antioxidant, functional food, bioactive compound, dietary fiber.

INTRODUCTION

Functional snack innovations increasingly utilize fruit-based bioactive and dietary fibers to provide convenient nutrition with minimal processing. *Hylocereus Undatus* (white-fleshed dragon fruit, Cactaceae) offers vitamin C, polyphenols, betalain pigments, fermentable fibers, and minerals that can be included in no-bake “energy balls,” typically made with nuts/seeds, dried fruits, and cereals to achieve preferred texture, shelf stability, and nutrient density. Although much of the AI-driven literature mentioned below mainly focuses on pharmaceutical discovery rather than foods, their methodological principles (design–make–test–analyze cycles; multiparameter optimization; stability/safety prediction) can guide rational formulation, process enhancement, and

quality-by-design in functional snacks. [1][2][3][4][5]. This includes multi-objective optimization of texture, moisture, sensory appeal, antioxidant retention, and microbiological safety. Network-based and data-driven methods used in natural product discovery also suggest ways to preserve and standardize plant-derived bioactives in complex matrices. *Hylocereus Undatus*, or white-fleshed dragon fruit, is a climbing cactus valued for both its ornamental appeal and nutritional benefits.



Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

2. Morphology and Botanical Description

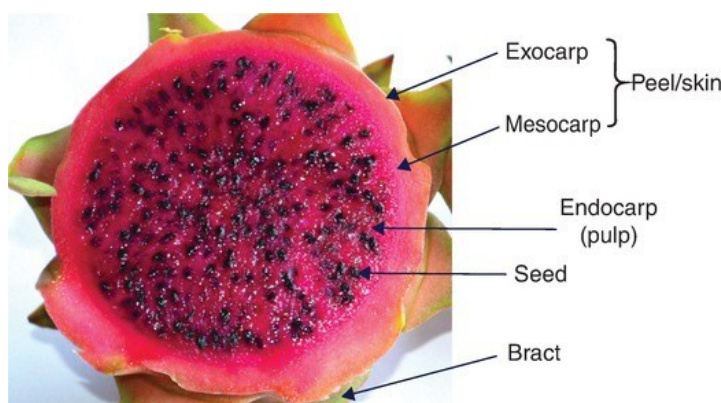
- *Hylocereus Undatus* is a fast-growing, perennial, epiphytic cactus with sprawling, three-sided green stems reaching up to 10 meters.
- The plant lacks leaves but features fleshy, wavy-edged stems with small spines or areoles along the ribs. Aerial roots allow the plant to climb or cling to supports.
- Flowers are nocturnal, large (25-35 cm long), fragrant, and bell-shaped, typically white, with numerous stamens and a prominent star-shaped stigma.
- Fruits are oblong to oval, weighing 350–650 grams, with bright red or pink skin covered in green scales and sweet, white, edible flesh peppered with many tiny black seeds.

Varieties

- *Hylocereus Undatus*: Pink/red skin with white flesh (most common globally).
- *Hylocereus polyrhizus*: Pink/red skin with red flesh.
- *Hylocereus megalanthus*: Yellow skin with white flesh (often classified as *Selenicereus megalanthus*[1][2][3][4][5]).

Cultivation

- Originally native to Central and South America, now cultivated commercially in Asia (especially Vietnam), Australia, and other tropical/subtropical regions.
- Grows best in warm climates with well-drained soil, and is typically propagated by stem cuttings or seeds. The flowering and fruiting cycle requires support structures for optimal growth and fruit set.

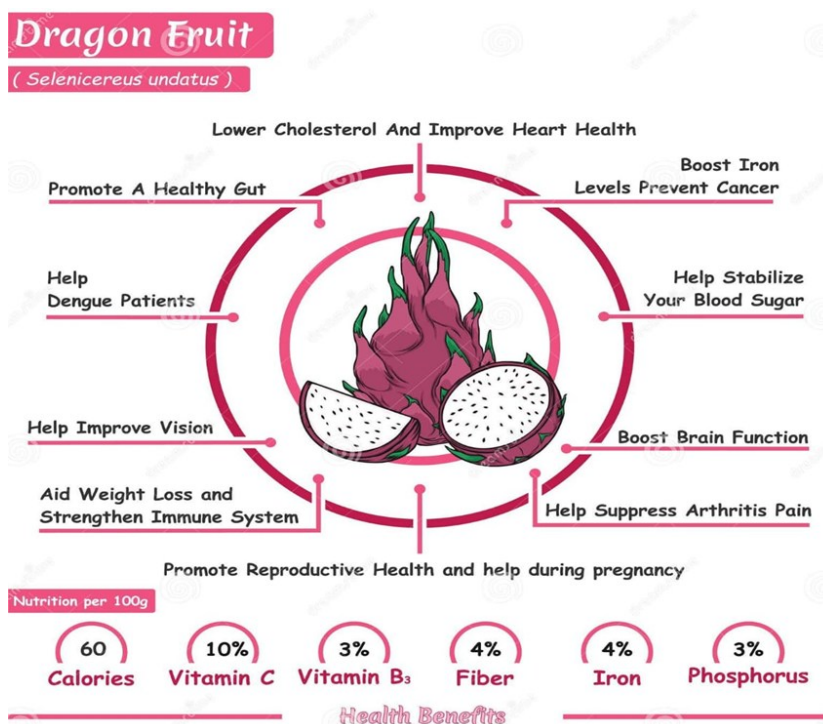


Macronutrients	micronutrients
Carbohydrates: 9–13g, chiefly simple sugars	Vitamin C: ~26–30mg
Protein: 0.4–0.5g	Potassium: 399.5mg
Fat: 0.1–0.6g (mostly in seeds)	Calcium: 8.5mg
Crude fiber: 1.3g	Iron: 1.9mg
Water: ~83–90%	Magnesium: 26.6mg

3. Nutritional and Functional Value

Carbohydrates from dates, oats, and fruit provide immediate and sustained energy; β -glycan's

contribute to satiety. Proteins from nuts/seeds and optional protein powders support muscle repair. Healthy lipids (MUFA/PUFA) contribute essential fatty acids. Dietary fiber supports digestive health and moderates glycaemic response. Antioxidants (vitamin C, polyphenols, betalain, plus phenolic compounds from nuts/dates) contribute radical-scavenging capacity. Micronutrients include magnesium, potassium, iron, and zinc; vitamin C aids iron absorption[1][2][3][4][5].



4. Phytochemical Composition and Biological Activities

- Phytoconstituents: polyphenols, betalain, carotenoids, flavonoids, and dietary fibers.
- Functional properties: antioxidant potential evaluated via DPPH radical scavenging activity and total phenolic content assays.
- Pharmacological insights: anti-inflammatory, antidiabetic, antimicrobial, and lipid-lowering activities.

5. Utilization of Hylocereus peel and pulp in formulation

The peel and pulp of *Hylocereus Undatus* (dragon fruit) are both considered desirable ingredients in functional food products due to their high content of natural antioxidants, dietary fiber, and bioactive compounds. The peel, frequently viewed as a waste product, is rich in polyphenols, betalain, and fibers and provides excellent antioxidant properties and a natural color in foods. Using dragon fruit peel powder in baked goods or snack recipes will improve nutritional value by raising fiber content and providing natural antioxidants that prevent lipid oxidation, increasing shelf-stability and health benefits.

The pulp provides vitamins, minerals, and bioactive compounds, including flavonoids and phenolic acids, with anti-inflammatory and metabolic benefits. Both peel and pulp powders will be used in energy balls, baked products, and snacks for added functional properties while still being sensorially appealing. Utilizing dragon fruit peel and pulp in recipes helps reduce waste while adding value to the fruit processing sector and represents sustainable ingredients for healthy food innovations.

6. Formulation and preparation of energy buster balls

Overview

Energy balls are minimally processed, nutrient-dense snacks that are convenient and provide an instant and quick energy boost. They are typically made by combining natural, whole-food ingredients such as nuts, seeds, and dried fruits, plus natural sweeteners, to provide proteins, healthy fats, fibers, and carbohydrates. They are quick and easy to make, often without baking, by combining or pulsing the ingredients into a sticky dough that can be easily formed into small, bite-sized balls.

The key ingredients are typically a binding agent, such as nut butter or syrup, for holding the mixture together; oats or grain flour for texture and fiber; and dried fruits for natural sweetness and chewiness.



Optional additions could include nutritional boosters such as seeds (chia, flax), spices (cardamom, vanilla), or protein powders. The energy balls are made by combining the ground nuts and seeds with the chopped dried fruits, sweeteners, and binding agents, and rolling the mixture into small balls. They are stored in air-tight containers in the refrigerator, staying fresh for a few days to a week or longer if kept in a cool area, or not opened, depending on the ingredients.

This style of snack also provides energy restoration with nutrient robustness, so they are a suitable snack for a sport, a break at work, or a healthy snack on the go.

Materials and Ingredients

Selection and Sourcing of Ingredients

- Dragon fruit puree: Fresh white or pink-fleshed *Hylocereus Undatus*, ripe for pureeing.
- Nuts: Cashews, almonds, walnuts—rich in healthy fats and protein.
- Seeds: Chia seeds or flaxseeds, for fiber and omega-3 fatty acids.
- Natural sweeteners: Coconut sugar, palm jiggery, or dates to add sweetness without refined sugar.
- Binding agents: Multigrain powder (roasted jowar, quinoa, oats, flaxseed) or protein powder.
- Additional: Desiccated coconut for texture and coating.

Step-by-Step Preparation Methods

- Preparation and Cleaning: Clean fresh dragon fruit well. Peel and chop into pieces for pureeing.
- Pureeing: Puree dragon fruit flesh to a smooth puree.
- Preparation of Dry Ingredients: Grind nuts (cashew, almonds, and walnuts) and dried fruits (raisins, dates) to a fine powder or coarse mix.
- Blending of Ingredients: Mix ground nuts, seeds, multigrain powder, coconut sugar, and desiccated coconut in a mixing bowl.
- Incorporation of Puree: Add dragon fruit puree gradually and mix well until the dry mix comes together in a dough-like consistency.

- Shaping: Roll small portions of the mixture into bite-sized balls.
- Coating: Optionally roll the balls in desiccated coconut or extra multigrain powder to avoid stickiness.
- Storage: Store energy balls in an airtight container in the refrigerator. Best consumed within a week for freshness.

Variations and Customization Possibilities

- Vegan: Employ plant sweeteners such as agave or coconut sugar; do not use dairy protein powders.
- Gluten-Free: Employ gluten-free multigrain powder (e.g., quinoa, oats, amaranth) or almond flour.
- Protein-Rich: Mix in plant or whey protein powder to increase protein levels.
- Flavor Enhancements: Incorporate natural extracts (vanilla, almond) or mix-ins such as mini chocolate chips.
- Binding Variation: Employ nut butters (e.g., cashew or almond butter) for denser texture and binding.

This technique produces a nutrient-dense, no-bake snack that captures the antioxidant and vitamin-dense properties of *Hylocereus Undatus*, supplemented with sustained energy from nuts, seeds, and natural sweeteners.



9. Experimental Design and Optimization (Research-Ready)

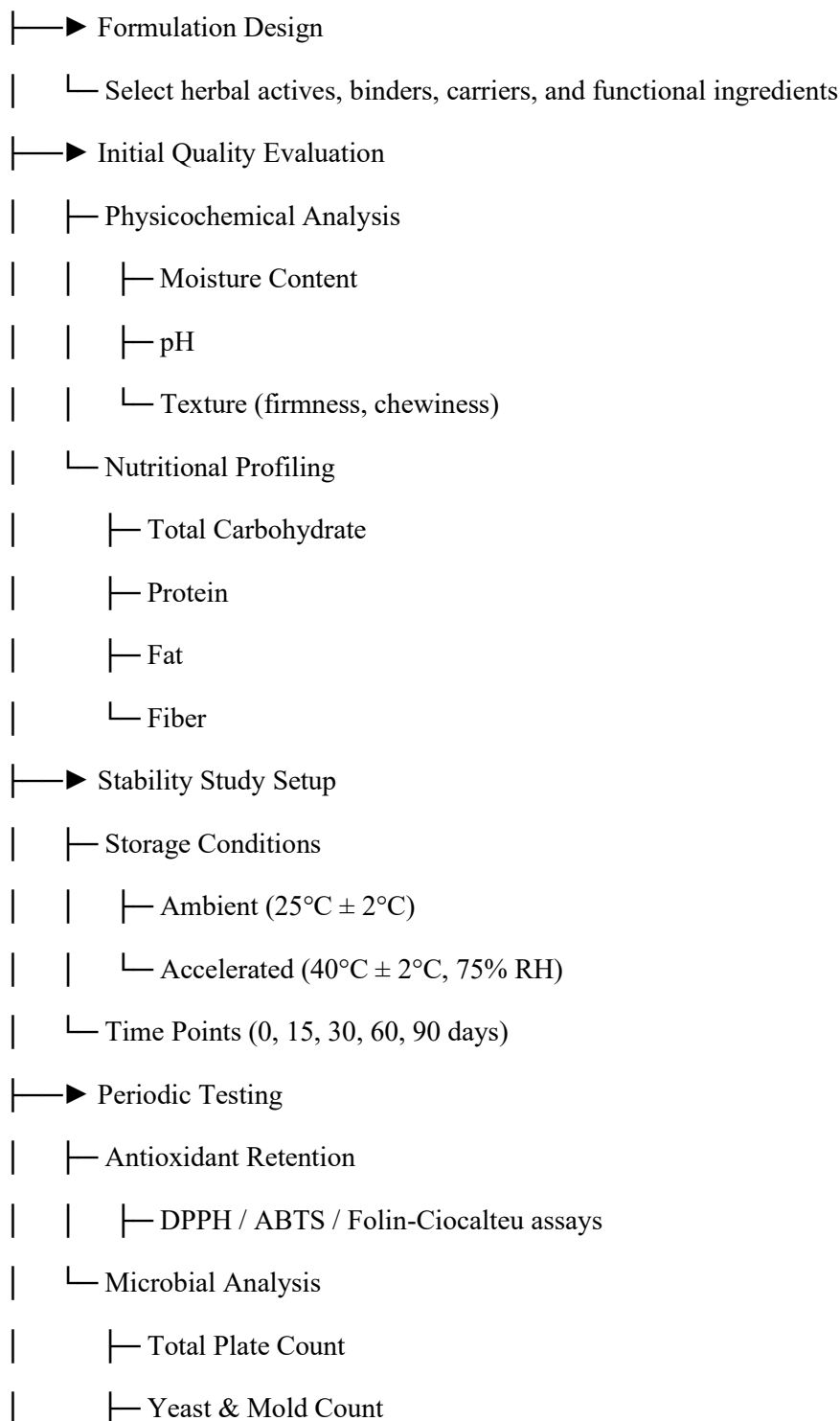
Screening: 2-level factorial for key variables (pulp% %; oat% %; nuts/seeds% %; added protein% %) to identify drivers of texture.



Optimization: Response Surface Methodology (RSM) to target simultaneous goals—maximize sensory score and antioxidant retention; minimize aw; maintain protein $\geq X$ g/100 g. This mirrors multiparameter optimization widely established in AI-assisted discovery workflows[1][2][3][4][5].

Data handling: Curate datasets, define ground truth for each response, and apply cross-validated

Start



predictive modeling to avoid overfitting and ensure reproducibility—principles emphasized for robust inference and translation.

10. Quality Assessment of Energy Balls from *Hylocereus Undatus*

Analytical Methods for Nutritional Quality Evaluation



- | └─ Pathogen Screening (optional)
- | └─► Data Analysis
- | └─ Statistical comparison across time points (ANOVA, regression)
- | └─► Shelf-Life Estimation & Reporting
- | └─ Finalize nutritional label and antioxidant profile
- | └─ Recommend packaging and storage guidelines

- **Macronutrient Analysis:**

- Determination of proteins by the micro-Kjeldahl method.
- Fat content analyzed using Soxhlet extraction.
- Carbohydrates estimated by difference and sugars by HPLC.
- Moisture, ash, and crude fiber content measured by standard AOAC protocols.

- **Antioxidant Assays:**

- Total phenolic content measured by the Folin-Ciocalteu method.
- DPPH radical scavenging assay and ABTS assay used to assess antioxidant activity.
- Quantification of specific phytochemicals (betalain, flavonoids) by spectrophotometry or chromatography.

- **Shelf-life Studies:**

- Monitoring changes in moisture level, lipid oxidation, and microbial growth over time under refrigerated storage.
- Sensory and physicochemical attributes (color, texture, pH) evaluated at intervals to determine product stability

Sensory Evaluation and Consumer Acceptability

- Organoleptic evaluation includes testing for:
 - Appearance (color, shape uniformity).
 - Texture (firmness, chewiness).
 - Flavor (sweetness, aftertaste).
 - Overall acceptability assessed using hedonic scales by trained panelists or consumers.
- Consumer acceptability studies often incorporate:
 - Demographic targeting according to dietary preferences (vegan, gluten-free).
 - Feedback on the likelihood of repeat purchase and perceived health benefits.

Analytical Methods for Nutritional Quality

- Macronutrients (protein, fat, carbohydrates) are analyzed by standard methods such as the micro-Kjeldahl method for protein, Soxhlet extraction for fat, and different methods for carbohydrates and fiber.
- Antioxidant content and activity can be evaluated by assays like Folin-Ciocalteu for total phenolic, DPPH, and ABTS assays for free radical scavenging activity, and chromatographic techniques for specific bioactive compounds like betalain and flavonoids.
- Shelf-life studies monitor moisture content, lipid oxidation, microbial load, and changes in sensory attributes under refrigerated storage to ensure product stability and safety.

Sensory Evaluation and Consumer Acceptability

- Organoleptic properties assessed include appearance, texture (firmness, chewiness), flavor (sweetness, aftertaste), and overall acceptability using hedonic scale ratings by trained panels or consumers.
- Consumer studies may focus on preferences relating to dietary needs (vegan, gluten-free) and perceived health benefits, impacting acceptance and marketability.

8. Applications and Future Prospects of Dragon Fruit Energy Balls

Use in Special Diets and Sports Nutrition

- Dragon fruit energy balls are nutrient-dense snacks rich in antioxidants, fiber, vitamins, and minerals, making them suitable for special diets such as vegan, gluten-free, and diabetic-friendly nutrition.pmc.ncbi.nlm.nih+1



- Their low glycemic index and high fiber content support blood sugar regulation, ideal for diabetic and weight management diets.
- The natural sugars from dragon fruit puree combined with nuts and seeds provide sustained energy release, making these balls excellent for sports nutrition to replenish energy and support recovery.

Pharmaceutical Food Products

- Dragon fruit's bioactive compounds, such as betalain, polyphenols, and flavonoids, offer antioxidant, anti-inflammatory, antimicrobial, and anticancer benefits.
- Energy balls can be developed as functional foods with medicinal claims targeting metabolic syndrome, cardiovascular health, immune support, and cancer adjunct therapies.
- The fruit's safety profile and therapeutic potential enable incorporation into dietary supplements, nutraceuticals, and probiotic formulations aimed at enhancing gut and overall health.

Potential for Large-Scale Manufacturing

- Advances in food technology, IoT-enabled smart sensors, and automated quality control systems can optimize production processes, ensuring consistency, safety, and nutritional quality of dragon fruit energy balls on an industrial scale.
- Sensors can monitor parameters such as moisture content, temperature, and microbial load in real-time during manufacturing and storage, enhancing product shelf life.
- Integration with smart packaging can provide consumers and manufacturers with freshness and quality data, improving trust and usability in the retail market.

The versatility of dragon fruit energy balls as a functional, health-enhancing snack, along with technological innovations, promises a growing role in health food markets, sports nutrition, and pharmaceutical food sectors in the near future.

CONCLUSION

The preparation of energy balls using *Hylocereus Undatus* (white-fleshed dragon fruit) integrates the fruit's rich nutritional and phytochemical profile with the functional benefits of nuts, seeds, and natural sweeteners to create a nutrient-dense, antioxidant-rich snack. Key findings highlight the fruit's wealth of vitamins (B-complex, C), minerals (potassium, magnesium, iron), fiber, and potent antioxidants like betalain and flavonoids, which contribute to its hypocholesterolaemia, anti-inflammatory, anticancer, antimicrobial, and prebiotic properties. These qualities make dragon fruit energy balls promising functional foods for special diets, sports nutrition, and pharmaceutical applications.

Preparation methods emphasize simple, no-bake processes that preserve bioactive compounds while allowing flexibility in ingredient substitution for vegan, gluten-free, and protein-rich variations. Quality assessment involves comprehensive nutritional analysis, antioxidant activity assays, sensory evaluation, and shelf-life studies, ensuring product safety and consumer acceptability.

Future research directions may focus on optimizing large-scale manufacturing using IoT and smart sensor technology for enhanced quality control, developing targeted therapeutic formulations, and expanding clinical studies on health benefits. This review establishes a comprehensive framework combining scientific, nutritional, and technological perspectives, positioning *Hylocereus Undatus* energy balls as innovative functional food products with significant commercial and health potential.

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