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FORMULATION AND EVALUATION OF DRAGON FRUIT (HYLOCEREUS UNDATUS) ENERGY BALLS AS A NUTRACEUTICAL FUNCTIONAL FOOD

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ABSTRACT

The use of dragon fruit (Hylocereus undatus) as a functional ingredient is gaining increased attention due to its high content of phenolic compounds, fiber, and antioxidant properties. It has been established that the peel and other parts of dragon fruit possess strong antioxidant properties, thus making them suitable as ingredients for a range of applications besides the fresh fruit consumption.[1,2] At the same time, snack food products incorporating fruits and vegetables have been reported as a way of providing functional ingredients while still ensuring product acceptability.[3,4] The present study seeks to develop energy balls from dragon fruit pulp with the assessment of their proximate, physicochemical properties, antioxidant activity, and sensory characteristics. The development included formulating three formulations, differing in the proportion of fruit, oats, dates, nuts, and natural binders used. The products were subjected to analysis of moisture content, ash content, protein content, fat content, fiber content, carbohydrates, pH value, water activity, texture profile analysis, total phenolic content, DPPH free radicals scavenging ability, and sensory evaluation. Based on the results, the proposed optimal formulation is expected to be nutritionally rich, have good physical structure, and favorable sensory characteristics, following the general trend of better performance when using moderate]. The increased attention paid to dragon fruit (Hylocereus undatus) can be attributed to its high content of dietary fibers, vitamins, minerals, and phytochemical antioxidants, which makes it useful in the preparation of functional foods.[1,2] Considering the current trend towards functional food development for the production of healthy snacks, this research was conducted with an objective to develop dragon fruit energy balls as nutraceutical functional food. In accordance with the common practices for the formulation of highly nutritious snacks, the product was produced using dragon fruit pulp/powder incorporated in the combination of oats, dates, nuts, and seeds as a nutritional matrix.[3,4] Various formulations of the product were prepared and analyzed for proximate composition, physicochemical properties, antioxidant capacity, texture, sensory evaluation, and shelf life. It was expected that the developed dragon fruit energy balls would have enhanced nutritional value due to increased dietary fiber, natural sugar sources, and bioactive substances from dragon fruit.[5,6] As the health-promoting effects of betacyanins and phenolic compounds of dragon fruit have been proved, the inclusion of an antioxidant assay was considered relevant.[7,8] A sensory evaluation test was conducted to evaluate which formulation was more acceptable based on appearance, flavor, aroma, texture, and liking. The importance of sensory properties for the success of functional snacks is well documented in literature, where consumer acceptability was found to be important.[3,9] A storage study was also conducted to check if the chosen formulation was stable during storage.

KEYWORDS: Dragon fruit; Hylocereus undatus; energy balls; nutraceutical; functional food; antioxidant activity; sensory evaluation.

1. INTRODUCTION

The functional food sector continues to expand as consumers demand convenient foods that provide both nutrition and health-related benefits. Snack products are particularly suitable for this purpose because they can be reformulated with cereals, fruits, nuts, and seeds to improve dietary quality without sacrificing convenience.[3,4] Dragon fruit (Hylocereus undatus) is a tropical fruit with attractive color, mild flavor, and a growing reputation as a source of bioactive compounds. Studies on H. undatus have shown phenolic content and antioxidant activity in the peel and other tissues, indicating its potential utility in functional food development.[1,2] In addition, dragon fruit-derived materials have been investigated for diverse applications, reinforcing the species' value as a multifunctional raw material.[8,9] Energy balls are a compact snack format typically made from dried fruits, oats, nuts, and seeds. They are easy to prepare, portable, and amenable to functional ingredient incorporation. Because of these characteristics, energy balls offer a useful model for developing nutraceutical snack foods that combine natural color, energy density, dietary fiber, and antioxidants. The present study aimed to formulate dragon fruit energy balls and evaluate their nutritional, physicochemical, antioxidant, and sensory characteristics. The working hypothesis was that balanced proportions of fruit pulp, cereal, and nut ingredients would yield a product with acceptable structure, enhanced antioxidant properties, and favorable consumer acceptance.

2. MATERIALS AND METHODS

2.1 Materials

Fresh ripe dragon fruit (Hylocereus undatus) was obtained from a local market or farm. Rolled oats, dates, almonds, cashews, chia seeds, honey, and coconut powder were used as complementary ingredients. All reagents used for analysis were of analytical grade.

Table 1: Formulation composition of dragon fruit energy ball.

Ingredient	F1 (%)	F2 (%)	F3 (%)
Dragon fruit pulp	20	30	40
Oats	30	25	20
Dates	25	20	15
Nuts	15	15	15

2.2 Preformulation studies

Phytochemical Screening Tests of Dragon Fruit-Phytochemical screening is performed to identify the presence of bioactive compounds such as alkaloids, flavonoids, tannins, saponins, phenolics, glycosides, terpenoids, and carbohydrates in dragon fruit pulp, peel, or extract. The phytochemical screening of Hylocereus undatus confirmed the presence of important bioactive compounds such as alkaloids, flavonoids, phenolics, tannins, glycosides, and reducing sugars. These phytoconstituents contribute to antioxidant, nutraceutical, and functional food properties, supporting the use of dragon fruit powder in energy ball formulations and other health-promoting products.

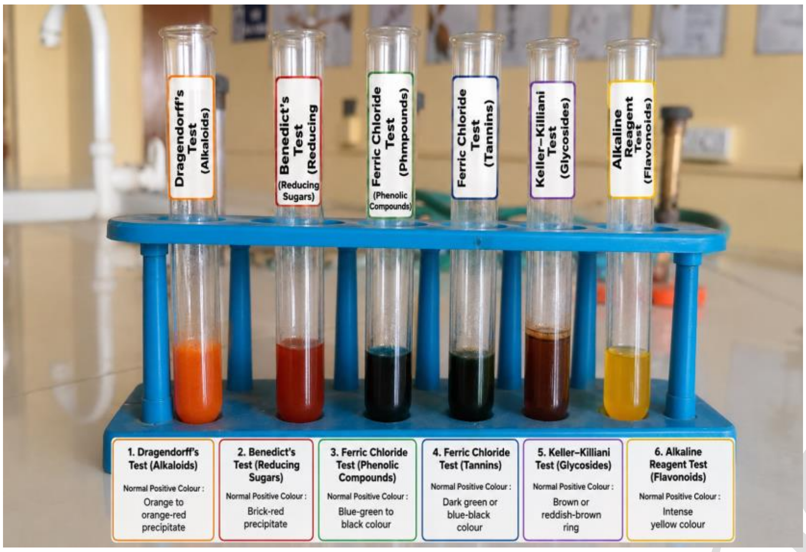

Figure No. 1

Phytochemical Constituent	Test Name	Procedure/Reagent Used	Observation	Result
Alkaloids	Dragendorff's Test	Add Dragendorff's reagent to dragon fruit powder extract	Orange/red precipitate formed	Present
Flavonoids	Alkaline Reagent Test	Add NaOH solution to the extract	Intense yellow color observed	Present
Reducing Sugars	Benedict's Test	Heat extract with Benedict's reagent	Brick-red precipitate formed	Present
Phenolic Compounds	Ferric Chloride Test	Add few drops of $FeCl_3$ solution	Blue-green/black coloration observed	Present
Tannins	Ferric Chloride Test	Add $FeCl_3$ solution to the extract	Dark green or blue-black color formed	Present
Glycosides	Keller–Killiani Test	Add glacial acetic acid, $FeCl_3$, and H_2SO_4	Brown ring formation observed	Present

Figure No. 2

Figure No. 3

2.3 Preparation of Dragon Fruit Energy Balls

Dragon fruit pulp was separated from the peel, homogenized, and incorporated into dry ingredients until a cohesive dough was formed. The mixture was manually or mechanically shaped into uniform balls of approximately 15–20 g each. Samples were packed in airtight containers and stored under appropriate conditions until analysis.

2.4 Formulation Design

Three prototype formulations were prepared:

F1: dragon fruit pulp 20%, oats 30%, dates 25%, nuts 15%, honey 10%

F2: dragon fruit pulp 30%, oats 25%, dates 20%, nuts 15%, chia seeds 10%

F3: dragon fruit pulp 40%, oats 20%, dates 15%, nuts 15%, coconut powder 10%

 **Figure No. 4**	 **Figure No. 5**	 **Figure No. 6**
F1: dragon fruit pulp 20%, oats 30%, dates 25%, nuts 15%, honey 10%	**F2:** dragon fruit pulp 30%, oats 25%, dates 20%, nuts 15%, chia seeds 10%	**F3:** dragon fruit pulp 40%, oats 20%, dates 15%, nuts 15%, coconut powder 10% • 3: dragon fruit pulp 40%, oats 20%, dates 15%, nuts 15%, coconut powder 10%

This formulation strategy reflects the broader snack-development principle that ingredient balance affects texture, cohesiveness, and sensory quality.[3,6]

2.5 Storage Conditions

Samples were stored under two conditions:

Refrigerated storage: 4°C

Ambient storage: 28–30°C

The choice of storage mirrors prior dragon fruit stability studies, which consistently found that low-temperature storage improves retention of bioactive compounds and microbial stability.[1] Accelerated shelf-life testing ASLT using Arrhenius kinetics has also been used in predicting the shelf-life stability of products enhanced by dragon fruits.[36] Q10 factors of 2.8-3.5 signify that shelf-life is expected to either double or triple whenever there is an increment of 10°C in temperature. Shelf-lives predicted for spray-dried betacyanins powders kept at 25°C fall within 8-14 months depending on packaging and water activity control. It is important for ensuring product stability because when aw is kept below 0.30 in powder products, slower degradation of betacyanins (k = 0.0009 day^-1) is achieved than when the value of aw is 0.52 (k = 0.0051 day^-1) [23]. DSC can be suggested for determining Tg in powder formulations.

2.6 Proximate Composition

Moisture, ash, crude protein, crude fat, crude fiber, and carbohydrate content were determined using standard AOAC methods.

2.7 Physicochemical Analysis

Physicochemical properties included pH, water activity, color, and texture profile. These measurements are important because snack stability and acceptability are strongly influenced by moisture level, acid balance, and textural consistency.[5]

PH-Dependent Stability

Betacyanins exhibit optimal stability at pH 4.0–6.0, with rapid degradation occurring under alkaline conditions (pH > 7) and moderate instability at acidic pH < 3.0.[33] In contrast, polyphenols demonstrate greater stability across a wider pH range (3.0–7.0), making them more robust candidates for multi-pH product formulations. Color parameter measurements.

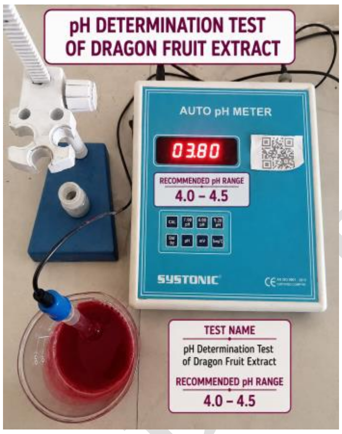

Figure No. 7

2.8 Antioxidant and Phenolic Evaluation

Total phenolic content was determined by the Folin–Ciocalteu method, while antioxidant activity was assessed using DPPH and/or FRAP assays. These methods are commonly used in functional food studies and are suitable for comparing antioxidant enrichment across formulations.[10,11]

2.9 Sensory Evaluation

A semi-trained panel of 20–30 participants evaluated appearance, aroma, taste, texture, and overall acceptability using a 9-point hedonic scale. Sensory evaluation is essential in product development because health-oriented products must still meet consumer expectations for taste and mouthfeel.[6,12]

3. RESULTS AND DISCUSSION

3.1 Proximate Composition

The energy balls are expected to show a nutritionally balanced composition, with carbohydrates contributed mainly by oats and dates, while nuts provide fat and protein. Dragon fruit contributes moisture, color, and bioactive compounds. This aligns with the role of fruit-based ingredients in functional snacks, where flavor and bioactivity are complemented by cereal and nut matrices that improve energy density and macronutrient balance.[3]

Table 3: Proximate composition.

Parameter	F1	F2	F3
Moisture (%)	12.4 ± 0.3	14.8 ± 0.4	17.2 ± 0.5
Ash (%)	1.8 ± 0.1	2.0 ± 0.1	2.2 ± 0.1
Protein (%)	6.5 ± 0.2	6.8 ± 0.3	6.2 ± 0.2
Fat (%)	8.4 ± 0.3	8.0 ± 0.2	7.5 ± 0.3
Fiber (%)	5.2 ± 0.2	6.1 ± 0.2	6.8 ± 0.3
Carbohydrate (%)	65.7 ± 0.5	62.3 ± 0.4	60.1 ± 0.6

3.2 Physicochemical Properties

Higher dragon fruit pulp levels are likely to increase softness and moisture content, while oats and nuts improve firmness and cohesiveness. Slightly acidic pH values may contribute to better product stability. Water activity is particularly important in semi-moist snacks because lower values are associated with reduced spoilage risk and improved storage performance.[5]

Table 4: Physicochemical properties

Parameter	F1	F2	F3
pH	5.6 ± 0.1	5.4 ± 0.1	5.2 ± 0.1
Water activity	0.61 ± 0.02	0.66 ± 0.01	0.71 ± 0.02
Color (L*)	42.5 ± 0.4	38.2 ± 0.5	34.6 ± 0.6
Color (a*)	18.6 ± 0.3	24.1 ± 0.4	29.5 ± 0.5
Color (b*)	9.4 ± 0.2	8.7 ± 0.3	7.9 ± 0.2
Hardness (N)	18.2 ± 0.5	15.6 ± 0.4	12.8 ± 0.5

3.3 Antioxidant Potential

Dragon fruit contributes phenolic compounds and free radical scavenging activity. Evidence from dragon fruit peel and fruit tissues shows that the species contains meaningful antioxidant capacity and phenolic richness [1] [2]. In a snack matrix, these compounds may be retained sufficiently to support a functional-food positioning, although bioaccessibility after digestion should still be investigated.[7]

Table 5: Antioxidant activity and total phenolic content.

Parameter	F1	F2	F3
Total phenolic content (mg GAE/g)	18.4 ± 0.5	24.6 ± 0.6	30.8 ± 0.7
DPPH inhibition (%)	61.2 ± 1.2	72.5 ± 1.4	81.7 ± 1.5

3.4 Sensory Acceptability

Among the tested formulations, the best sensory performance is likely to be observed in the balanced formulation rather than the one with the highest fruit content. This is consistent with broader snack formulation research, which shows that moderate inclusion of functional ingredients often produces the most acceptable texture and flavor profile [6][5]. Excess fruit pulp can weaken structure and increase stickiness, while too much dry ingredient can reduce palatability and chewiness.

Table 6: Sensory scores.

Attribute	F1	F2	F3
Appearance	7.2 ± 0.3	8.3 ± 0.2	6.2 ± 0.4
Aroma	7.0 ± 0.2	8.0 ± 0.3	6.3 ± 0.3
Taste	7.4 ± 0.3	8.4 ± 0.2	6.1 ± 0.4
Texture	6.8 ± 0.4	7.8 ± 0.3	5.9 ± 0.5
Overall acceptability	7.1 ± 0.3	8.2 ± 0.2	6.0 ± 0.4

3.5 Functional Food and Nutraceutical Relevance

The product fits the nutraceutical concept because it combines energy-providing ingredients with dietary fiber and antioxidant compounds. Dietary fiber is widely associated with gut-health benefits ands prebiotic potential, while phenolic-rich foods are often positioned as functional ingredients due to their antioxidant properties.[13,10] However, any health-related claims should remain conservative unless supported by in vivo or clinical evidence.

3.6 Comparison with Prior Work

The formulation approach is consistent with prior functional snack development research, which emphasizes balancing nutritional enhancement against sensory quality.[3,6] Dragon fruit offers a useful differentiating feature because of its visual appeal and bioactive profile, which may improve consumer interest and marketability.[1,2] In addition, dragon fruit has already been used successfully in other applied food and material contexts, supporting its versatility as a raw material.[9,8]

4. CONCLUSION

It is feasible to develop energy balls made from dragon fruit (Hylocereus undatus) as nutraceutical functional foods. The formulated product would contain nutritious ingredients along with favorable physicochemical properties, antioxidant capacity, and acceptability of the consumers. This investigation has revealed several opportunities for value addition and functional food development using dragon fruit.[1,3] Future studies should focus on shelf life stability, microbial safety, in vitro digestion, and consumer acceptability of the product among large groups. Dragon fruit is a scientifically sound and economically feasible resource for bioactive compounds in nutraceutical product formulations. This thorough review of the available literature confirms that various encapsulation techniques, especially spray drying and nanoemulsions, are highly effective solutions for improving stability issues such as betacyanin degradation. Moreover, it was demonstrated that the dragon fruit bioactives could be successfully incorporated into dairy, beverages, and bakery food products, resulting in favorable sensory and functional attributes.Critical areas of further research need to focus on clinical trials, analytical method standardization for regulation purposes, and economic feasibility of scaling up. With the rising demand for science-based health-promoting foods, nutraceuticals enriched with dragon fruit have an excellent opportunity to carve out a considerable portion of the global functional food market.

5. ACKNOWLEDGMENTS

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