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Development and Sensorial Acceptability of Nutrient Dense Date and Seed Balls Incorporated with Citrus Peel Powder

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ABSTRACT

Polycystic ovary syndrome (PCOS) is a common endocrine condition that affects women's reproductive and metabolic health. The utilization of functional foods high in fibre, antioxidants, and essential nutrients has been demonstrated to help manage symptoms. This study involves producing nutrient-dense snack balls with date paste, seeds (flax, pumpkin, sunflower), and citrus peel powder. The use of citrus peel not only improves nutritional characteristics, but it also encourages sustainable food practices by reusing fruit waste. Orange peel powder was added in different amounts to the formulations (0, 5, 10, and 15%). Among other treatments, the 10% treatment (T_2) scored significantly higher ($P<0.05$) for taste, colour, aroma, appearance, and texture in sensory evaluation. This treatment received further analysis to determine quality attributes. It had a moisture content of 20.52±0.07%, fiber 5.30±0.03%, protein 3.0±0.04%, fat 2.00±0.04%, carbohydrate 67.2±3.84%, and ash 1.98±0.04%. pH (6.01±0.02) indicated product stability and safety. Antioxidant activity (27.44±0.07%) and total phenolic content (9.24±0.06 mg GAE/100 g) indicated the existence of bioactive chemicals in orange peel and seeds. Synthetic ingredients were avoided, preserving the natural sweetness and smooth texture. These seed and fruit-based snack

balls present a viable clean-label solution that addresses current nutritional demands, consumer preferences for natural ingredients, and environmentally sustainable food innovation.

Keywords: *Functional snack, citrus peel, date paste, antioxidants, PCOS, sensory evaluation*

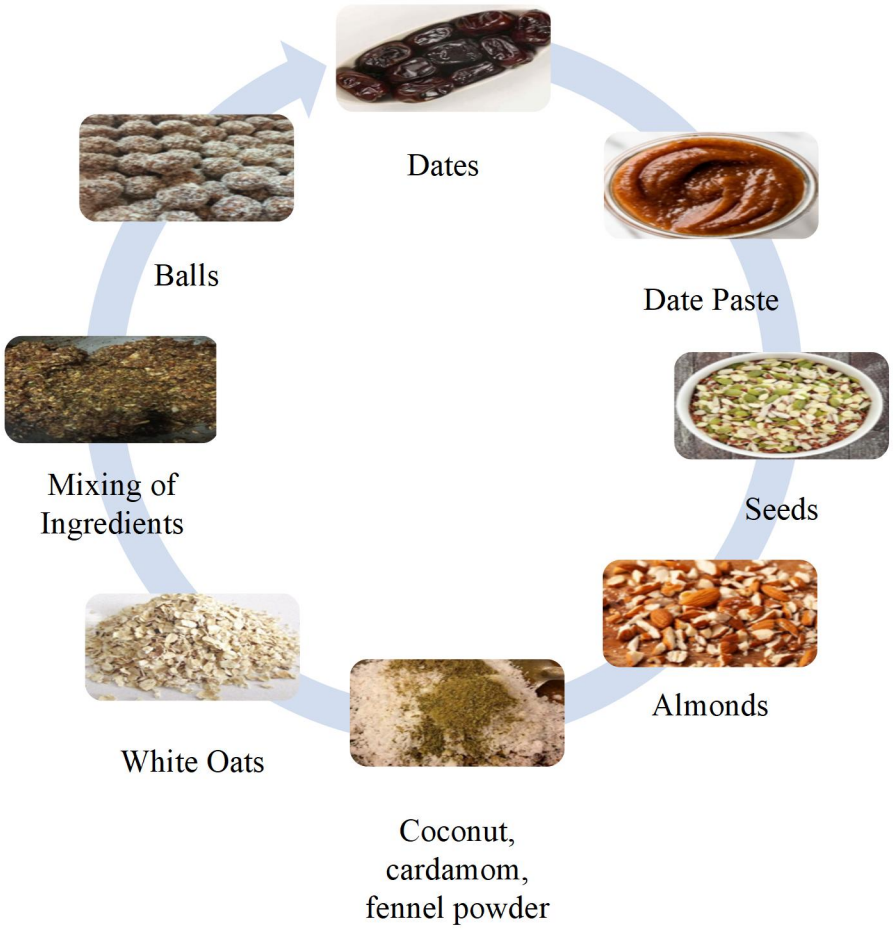

Figure 1. Graphical abstract for the development of nutrient dense date and seed balls

INTRODUCTION

There is growing demand for convenient and healthy snacks, especially among young adults with hectic lifestyles, emphasizes the need for quick protein and energy sources (Alsuhebani *et al.,* 2025). Today's consumers are looking for clean-label products that provide essential nutrition but could also have additional health benefits. The current research is exploring a nutrient-dense, preservative-free product made with date paste, edible seeds, and citrus peel powder. These ingredients were selected for flavor, texture, and nutrition, but they have the added sustainability aspects of diverting fruit from the waste stream (Kajla et al., 2015).

Date fruit (Phoenix dactylifera) is widely popular due to its nutritional and medicinal properties and has been a prominent ingredient in functional food products. Dates are an excellent nutriant source because they are rich in important minerals such as iron, potassium, and calcium, among others, all of which aid in muscle function, hemoglobin synthesis and nerve impulse transmission (El-Far et al., 2019). Dates have a

high content of phenolic compounds, flavonoids, and tannins, serving many roles as antioxidants, antibacterial, and anti-inflammatory agents, promoting digestive health and overall immune function (Attri et al., 2024). There are also functional benefits to dates in food systems, as they also act as natural binders and sweeteners, assisting in textural aspect of the meal and is a means to cut down reliance on refined sugars (Almuzaini et al., 2024).

Pumpkin seeds (Cucurbita pepo) are a nutritionally dense ingredient, which tend to be recognized for their health benefits. Pumpkin seeds comprise healthy fats, carbs, protein, and fiber, all of which contribute to daily macronutrient ratios as well as digestive and metabolic functions. Pumpkin seeds contains omega-3 fatty acids and omega-6 fatty acids, which are important in the cardiovascular health and in inflammation control. Pumpkin seeds have fiber which is beneficial because it increases satiety, decreases constipation and it may also regulate glucose levels in the blood (Chaudhary *et al.,* 2024). Pumpkin seeds are rich in vitamins, minerals and antioxidants. Zinc and omega-3 fatty acids, which are abundant in pumpkin seeds, can help control hormone production and lower hyperandrogenic symptoms like extra facial and body hair in women with PCOS (Rasheed *et al.,* 2023).

Sunflower seeds (*Helianthus annuus*) has essential nutritional importance having beneficial unsaturated fats, mineral, proteins and phytochemicals (Pal, 2011). Sunflower seeds have been associated with beneficial effects for many clinical illnesses (Mannepalli *et al.,* 2024). Sunflower seeds consists of linoleic fatty acid and omega-6 fatty acid. Sunflower seeds are rich in fibre, which helps in digestion and improves gut health. Moreover, they supply such minerals as magnesium, iron, selenium, zinc, and copper, which also help to keep bones strong, enhance immunity, and prevent hypertension. Vitamins present in sunflower seeds are vitamin E that is important in providing antioxidant protection in cells and B vitamins like folic acid and thiamine that aid in promoting energy metabolism (Puraikalan & Scott, 2023). The bioactive compounds of sunflower seeds have antibacterial, anti-inflammatory, and antioxidant actions that can help both the prevention and treatment of chronic diseases which include diabetes, cardiovascular diseases, and neurological problems (Laaraj *et al.,* 2025).

Flaxseeds *(Linum usitatissimum)* are often regarded as an important part of a healthy diet because of their rich nutrient content and multiple health properties, especially in the health of women. They are a rich source of alpha-linolenic acid (ALA), and contributes to inhibition of inflammation and cardiovascular health. Besides the healthy fats, flax seeds are also rich in protein and dietary fiber, which aids satiety, and digestive health, and healthy blood sugar levels (Chunilal & Sudhakar, 2021). All omega-3 fatty acids (ALA, EPA and DHA) are known to maximize health benefits associated with numerous conditions such as cardiovascular disease, hypertension, atherosclerosis, diabetes, cancer, arthritis, osteoporosis, autoimmune, and neurological diseases (Goyal *et al.,* 2014). Flaxseeds can reduce the extent of menopausal and constipation symptoms.

Citrus is an important fruit crop in Pakistan, with an annual production of over 115 million tons in which 50% end up as citrus peel after industrial processing (Kamatchi Devi, 2024; Abadi *et al.,* 2021)). Citrus peel, particularly from oranges (*Citrus sinensis*), contains dietary fibre, essential oils, vitamin C, folic acid, potassium, pectin, and flavonoids. These bioactive substances have strong antioxidant, antibacterial, and lipid-lowering capabilities, making citrus peel an important ingredient in functional food production. Citrus peels can be used to prepare pectin, flavonoids (narirutin), phenolics, and antioxidants, natural colorants and dietary products. The flavonoids present in citrus peel lowers blood cholesterol level, reduces inflammation and helps prevent high cancer levels (Kamatchi Devi, 2024). Incorporating citrus peel powder into food products not only increases nutritional and functional quality, but also supports sustainable practices by reducing fruit processing waste (Sabeel *et al.,* 2024).

MATERIALS AND METHODS

Procurement of Raw Material

Raw materials utilized in processing of the date and seed balls were hand-selected based on their richness, quality, freshness and nutritional value. Ingredients were sourced at trusted local suppliers in Lahore, Pakistan and were home-processed when needed. A grocery shop was used to obtain white oats which were free of additives and preservatives. A local organic store was used to get almonds, flax seeds, sunflower seeds and the pumpkin seeds. After fruit consumption, fresh orange peels were collected.

Preparation of Orange Peel Powder

Fresh, high-quality orange peels were collected rinsed and, then dried in a shady, ventilated room for 5-7 days to maintain nutrients and color. Once completely dry and crisp, they were crushed into fine powder with a clean grinder and kept in airtight containers in a cold, dry place.

Figure 2. Flow chart of making orange peel powder

Product Development

Four treatments were developed to determine the effectiveness of orange peel powder. Dates, oats, almonds, sunflower seeds, pumpkin seeds, flaxseeds, coconut powder, fennel, and cardamom were all included in each formulation, with the only difference being the proportion of citrus peel powder.

Table 1. Treatment plan for development of date and seed balls

Treatment	Orange Peel Powder (%)
T_0	0
T_1	5
T_2	10

T_3	15

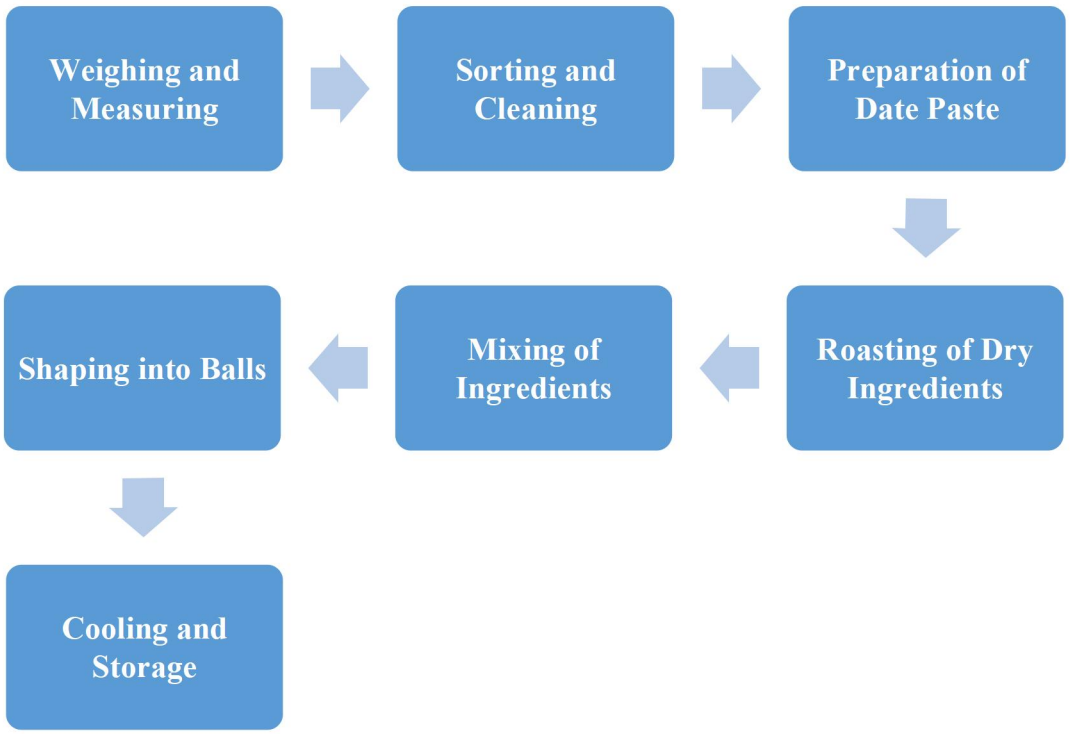

Figure 3. Flow chart of making date and seed balls

To maintain uniformity among treatments, all the raw materials were weighed accurately on a digital scale or weighing balance. Dates, seeds, and nuts were sifted and washed to remove any contaminants. Soft dates were deseeded, chopped, and crushed into a smooth paste that acted as a natural binder and sweetener. Chopped almonds, sunflower seeds, pumpkin seeds, and oats were all roasted individually over low heat to improve flavor and texture. Roasted components were blended with coconut powder, cardamom, fennel, and citrus peel as directed, then combined with date paste and softly cooked to achieve appropriate binding. The mixture was allowed to cool before being hand-shaped into homogeneous balls.

Shelf Life Analysis

A 45-day storage study was done to determine the shelf life of dates and seed balls. All four treatments (T_0, T_1, T_2, and T_3) were refrigerated in airtight containers. Sensory attributes such as colour, taste, aroma, appearance, and overall acceptability were measured at 0, 15, 30, and 45 days to monitor quality changes. This study found that the product remained stable and therefore in condition for up to 45 days in refrigeration, and 7 days at room temperature (Chunilal & Sudhakar, 2021).

Proximate Analysis

Date and seed balls were evaluated for moisture, ash, fat, fiber and protein levels, which is indicative of date and seed balls functionality with respect to nutrition. Crude protein from date and seed balls was

determined using the Kjeldahl method. A 2 g sample was digested in concentrated H_2SO_4, and heated at 250-300 °C for 2 to 4 hours until it turned clear followed by cooling the digest and diluting to a final volume of 50 mL with distilled water. The solution was made alkaline by adding 50 mL 40% NaOH, and the ammonia released was trapped in boric acid and titrated with 0.1N acid. Nitrogen was calculated and multiplied by 5.80 to determine protein content (Ansari *et al.,* 2021).

$$\text{Nitrogen (\%)} = \frac{\text{Volume of 0.1N suphuric acid used} \times 0.0014 \times 250}{\text{Sample weight} \times \text{Aliquot volume}} \times 100$$

$$\text{Crude protein} = \text{Nitrogen (\%)} \times 5.80$$

For determining crude fiber of date and seed balls, 5 g of the defatted sample was placed in 500 ml of 1.25% H_2SO_4 and boiled for 30 minutes and the residue was dried and ignited in a muffle furnace at 550 °C. The fiber content was determined by subtracting the weight of the ash from the dry weight (Ansari et al., 2021).

$$\text{Crude fiber (\%)} = \frac{\text{Weight (after drying) - Weight (after ashing)}}{\text{Sample weight (g)}} \times 100$$

Crude fat was quantified by Soxhlet extraction. Once a 2 g sample was weighed, it was extracted with n-hexane for 4-6 h. After drying and cooling, the sample was weighed to calculate the fat content based on the amount of waxy material changed from flask weight. Crude fat content was calculated using the following formula (Asaro et al., 2017).

$$\text{Crude fat (\%)} = \frac{\text{Weight of hexane extract (g)}}{\text{Sample weight (g)}} \times 100$$

Moisture content was assessed using the hot air oven method. A 5 g homogenized sample was dried at 105±5°C for 4 hours until a constant weight was achieved. The sample was cooled in a desiccator and moisture content was calculated based on weight loss (Nadeem et al., 2018).

$$\text{Moisture (\%)} = \frac{\text{Fresh sample weight (g)-Dried sample weight (g)}}{\text{Fresh sample weight}} \times 100$$

For the determination of ash content in date and seed balls, the samples (3 g dry weight) were ignited at a temperature of 550-600 °C in a muffle furnace for 4-5 hours. Initial combustion was conducted on a hotplate before being placed in the muffle furnace. The ash was cooled in a desiccator and weighed in order to find the total mineral content. We used the following formula, after documenting all weights to determine ash content (Hassan et al., 2024).

$$\text{Ash (\%)} = \frac{\text{Weight of ash (g)}}{\text{Weight of sample (g)}} \times 100$$

Nitrogen-free extract was utilized to measure carbohydrate amounts in both date and seed balls by subtracting the amounts of moisture, ash, fiber, fat, and protein from the total weight of all samples taken. Total carbohydrates were determined using this equation (Parvez, Baker and Farber, 2025).

NFE%= 100- (Crude fat%+ Crude protein%+ Crude fiber%+ Moisture% + Ash %)

Physicochemical Analysis

To determine quality and stability of the manufactured date and seed balls, we tested various physicochemical properties, including pH and color. Tests were done according to standard AOAC (2023) methods. pH was done with a calibrated digital pH meter. Five grams of fractionated powder was mixed with 45mL of distilled water to make a homogeneous suspension. After mixing, the pH measurement was

taken by placing the pH electrode in the homogeneous solution. The added mixing step was done to get valid and reliably measured values of the acidity of the product (AOAC, 2023).

The visual characteristics of the date and seed balls were acquired with a digital colorimeter. The color values were recorded using the CIE lab system with L being the degree of lightness, value a* being the red-green hue, and value b* being the yellow-blue hue. The samples measured were taken on a flat, clean surface to ensure values were consistent for accuracy in determining color (AOAC, 2023).

Phytochemical Analysis

The phytochemical analysis of date and seed balls were conducted to measure total phenolic content and DPPH radical scavenging activity using standard methods.

The total phenolic content (TPC) of date and seed balls was assessed based on internationally recognized standards using the Folin-Ciocalteu colorimetric method. A mixture of 125 µL extract and 500 µL distilled water in a test tube was mixed with 150 µL Folin-Ciocalteu reagent briefly and then diluted after a few seconds to bring the volume up to 3 mL. The test tube was then mixed with 1.25 mL 7% Na_2CO_3 and incubated for 90 minutes at room temperature. Absorbance was measured at 760 nm with a UV-Visible spectrophotometer using blank reagent as a comparison. TPC, which is expressed in mg GAE/100 g dry weight, was calculated using the following formula on the TPC of date and seed balls (Alolyan et al., 2024).

$$C=c\ xV/m$$

Where;
C=Gallic acid concentration derived from calibration curve in mg/mL
c= TPC expressed in mg GAE/g of extract

DPPH radical scavenging activity of date and seed balls was determined to evaluate their phytochemical antioxidant capacity. The sample was powdered, and centrifuged at 6000 rpm for 5 min at 15 °C. To prepare a diluted extract, 0.5 mL of 80% ethanol and 0.1 mL of the supernatant was mixed. After adding 0.5 mL of DPPH solution, the mixture was thoroughly vortexed. It was incubated in the dark at room temperature for 15 minutes. The absorbance was measured at 517 nm with a UV-Visible spectrophotometer. Scavenging activity was calculated using the following formula (Akomolafe, 2021).

$$\text{Scavenging activity} = 1 - A_f / A_o \times 100$$

The absorbance values of the sample and blank are denoted by A_f and A_o, respectively.

Sensory Evaluation

Sensory attributes such as appearance, color, flavor, aftertaste, texture, and overall acceptability were assessed for the date and seed balls. Ten semi-trained participants were selected from the academic staff members who were experienced in sensory evaluation to take part in the evaluation. Using a standardized 9-point Hedonic scale, each panelist scored the product on a scale of 1 ("dislike extremely") to 9 ("like extremely"). Each sensory response was noted separately on standard scorecards, and the information was collected for analysis in order to determine consumer acceptance (Chunilal & Sudhakar, 2021).

Statistical Analysis

To determine the significance level the information collected was statistically analyzed. Treatments were conducted in triplicate, and results were expressed as mean ± SD. Statistical analysis were performed

using Statistix version 8.1. The ANOVA was used to determine the significant differences among treatments (Parvez *et al.,* 2025).

RESULTS AND DISCUSSION

The effect of varying concentrations of orange peel powder (0, 5, 10, and 15%) on the sensory, nutritional, physicochemical, and antioxidant attributes of date and seed balls was evaluated. Sensory evaluations were performed at intervals of 0, 15, 30, and 45 days. Amongst all treatments, the formulation containing 10% orange peel powder (T_2) demonstrated better performance in maintaining appearance, aroma, color, taste, and overall acceptability throughout the storage period and selected for further analysis. The incorporation of citrus peel significantly improved the nutritional and functional properties, while also contributing to better stability and shelf life.

Sensory Analysis

Color

Sensory results showed in Figure 4 that the effect of treatment on color was statistically highly significant (P<0.05). A clear decreasing trend was observed from day 0 to 45 for all samples. A gradual decline in color scores was noted across all treatments during storage. T_2 (10% orange peel powder) maintained the most favourable color score (6.50±0.03), whereas the control (T_0) recorded the lowest value (4.90±0.04). These results imply that moderate inclusion of orange peel powder supported better color retention, while the control exhibited greater visible deterioration. According to studies, adding orange peel powder to bakery products helps maintain color during storage due to the natural pigments and antioxidants present in citrus peels. Concentrations of 5-10% improved the appearance of biscuits and cookies when compared to control samples, whereas higher levels caused darkening or bitterness, indicating that low inclusion rates improve visual quality without causing adverse effects (Belose *et al.,* 2021; Al-Janabi & Yasen, 2022). Similar studies in extruded snacks and fruit bars show that the optimal amount of orange peel powder maintain brightness and acceptance over time. These comparisons confirm the current study's finding that appropriate quantities of orange peel powder increase and maintain visual appeal in diverse snack products (Zaker *et al.,* 2017; Youssef, 2023).

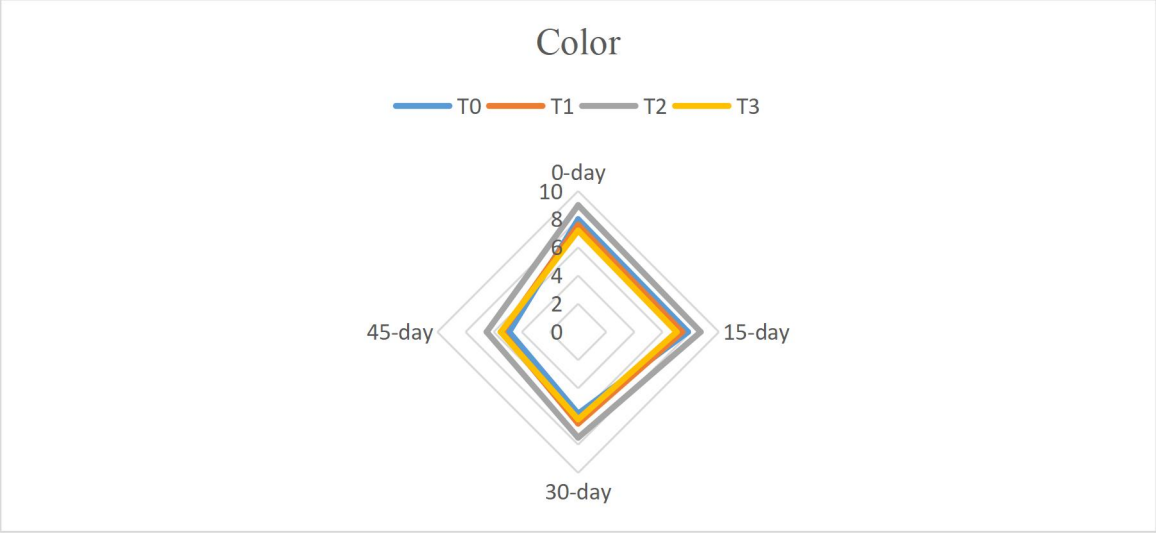

Figure 4. Graphical Representation of Color of Date and Seed Balls

Taste

The sensory data demonstrated in Figure 5 that the treatments had a significant (P<0.05) impact on taste. A gradual decline in taste scores was recorded across all treatments during storage. T_2 (10% orange peel powder) retained the highest taste score (6.50±0.02), showing a balanced and acceptable flavor, T_3 (15%) produced a stronger and less preferred taste, while the control (T_0) showed the lowest score (4.50±0.03), suggesting that a moderate amount of peel helped improve taste quality, while excessive levels reduced acceptability. Studies have shown that orange peel powder improves the taste and consumer acceptability of biscuits and other baked goods. Most often, a substitution level of 10% adds an appealing citrus note without overpowering the flavour profile of the product. However, going over this optimal level may result in a strong or bitter flavour that negatively impacts consumer preference (Zaker *et al.,* 2017; El-Makhzangy *et al.,* 2024). According to another study, moderate amounts of orange peel powder added to cakes and cookies improved their flavour quality over time. This promotes the use of natural citrus components for both functional and sensory purposes. When properly packaged and stored, products containing orange peel powder retained a desirable flavour and taste for several weeks (Shin, 2015; Kumari & Kumari, 2020).

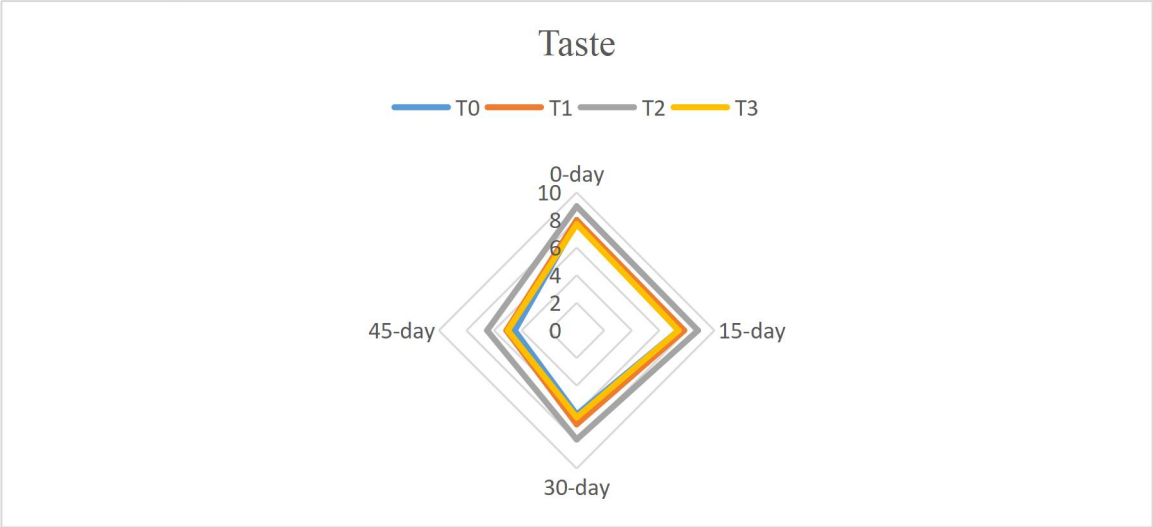

Figure 5. Graphical Representation of Taste of Date and Seed Balls

Aroma

The evaluation of aroma revealed in Figure 6 that treatment differences were significant (P<0.05). A steady decline in aroma scores was noted for all treatments over the storage period. T_2 (10% orange peel powder) maintained the highest aroma score (6.30±0.01), indicating an acceptable and balanced citrus note. T_3 (15%) showed a more pronounced orange aroma, which was perceived as too strong and less acceptable, while T_1 (5%) had moderate retention (5.70±0.03). The control sample (T_0) recorded the lowest score (4.50±0.02), reflecting a greater aroma loss. According to research, adding citrus by-products to baked goods in modest amounts improved the aroma profile, while higher amounts resulted in an overpowering citrus fragrance, whereas biscuits with 5-10% orange peel powder had the best aroma and acceptability scores (Kumari & Kumari, 2020). In another study sponge cakes with 13% orange peel powder had a decent flavor and an appealing citrus aroma, but excess of it produced a strong odor (El-Makhzangy *et al.,* 2024).

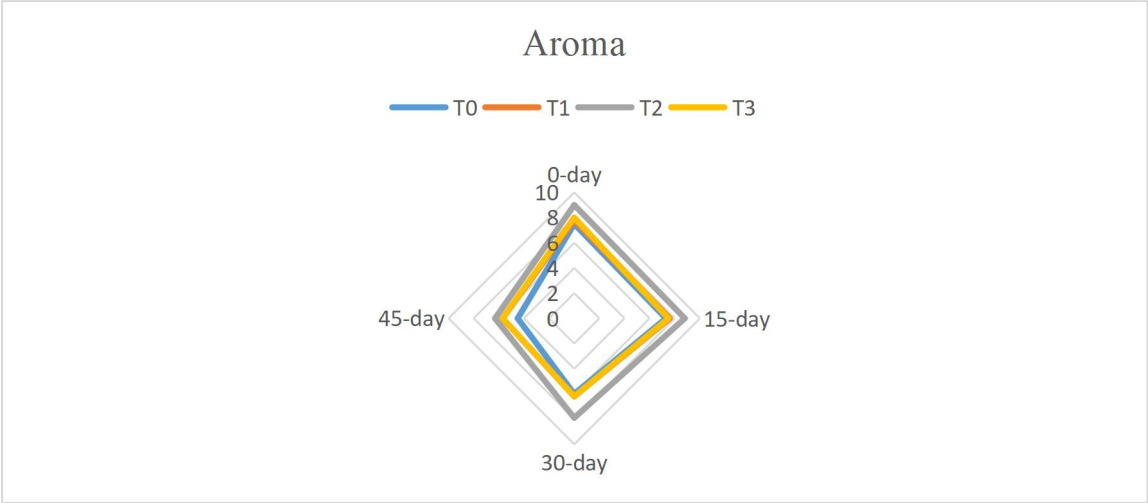

Figure 6. Graphical Representation of Aroma of Date and Seed Balls

Appearance

Sensory results showed in Figure 7 that the effect of treatment on appearance was statistically significant (P<0.05). A decreasing trend was observed. T_2 (10%) retained the highest appearance score (6.80±0.04) at day 45, while T_1 (5%) and T_3 (15%) recorded intermediate values (5.90±0.02 and 5.70±0.02). The control (T_0, 0% peel) had the lowest score (4.80±0.01). This highlights that the presence of orange peel powder helped maintain surface quality, while the control showed greater decline. According to studies, cakes and biscuits containing 5-10% orange peel powder retained better appearance scores over time but cakes and biscuits containing greater amounts of orange peel powder sometimes developed dark spots or a rough surface (Kumari & Kumari, 2020; El-Makhzangy et al., 2024).

Citrus by-products have also been shown to impede moisture migration which helps to reduce visible defect, such as cracks - particularly when used with moisture-proof packaging to minimize potential color degradation due to oxidation. Similarly, cakes with pomegranate and orange peel powders showed more stable surface texture and visual quality over time (Koubaier et al., 2021; Gómez & Martinez, 2018).

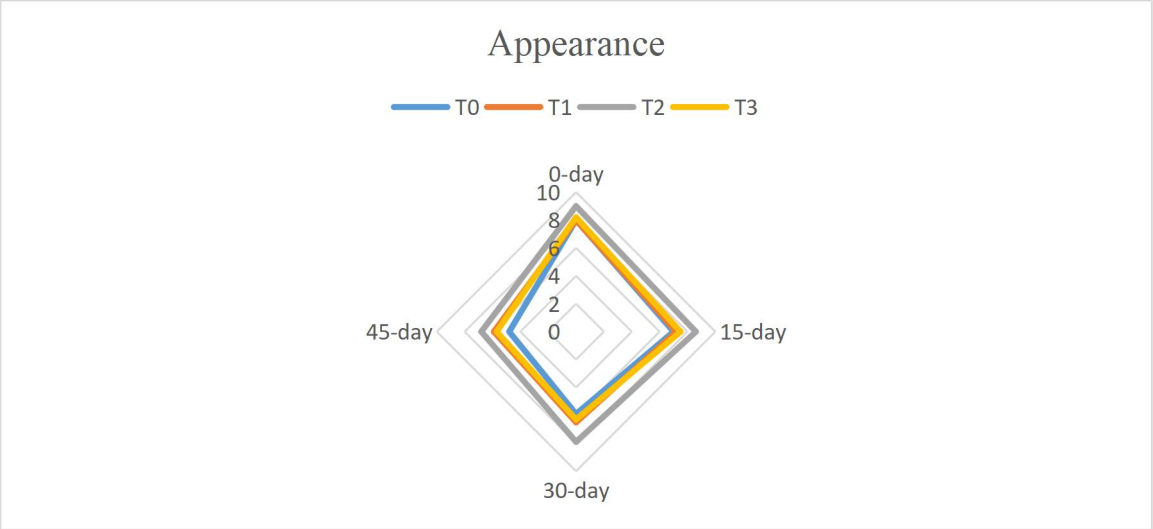

Figure 7. Graphical Representation of Appearance of Date and Seed Balls

Overall Acceptability

Based on the data analysis in Figure 8, differences in overall acceptability were significant ($P<0.05$) by treatment. For overall acceptability the T2 (10%) with a mean score (6.70±0.02) had higher overall acceptability mean score than all of the treatment overall mean scores; however the control (T0) was also within acceptable mean scores and T3 (15%) had the lowest acceptability mean score suggesting that too much peel may not be favorable to consumer preferences. It has been found that incorporating healthy fibers and antioxidants into food products in relatively low quantities without compromising on flavor or texture would increase consumer acceptability. The biscuit with 5-10% orange peel powder provided ratings for higher overall acceptability, and also provided high motivation interest level for healthy snacking (Belose et al., 2021). Furthermore studies show that using by-products of citrus food products have higher acceptability based upon positive attitudes about sustainability and reducing waste. Several recent studies, have found that consumers provide overall acceptability ratings in a more favorable manner because of the perceived health and environmental benefits of natural fruit waste (Sahni & Shere, 2018).

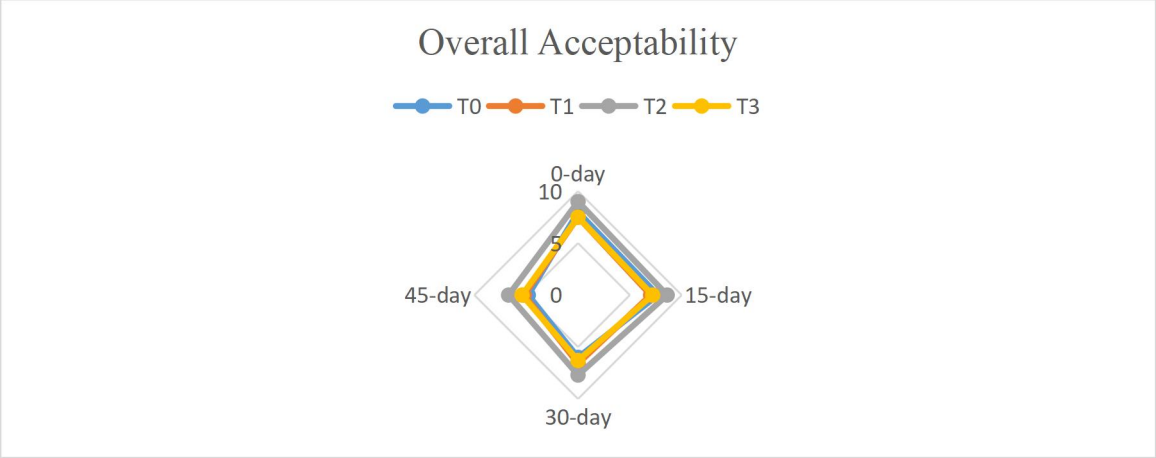

Figure 8. Graphical Representation of Overall Acceptability of Date and Seed Balls

Proximate Analysis of Date and Seed Based Balls

Protein Content

The sample formulation, which included 10% orange peel powder, showed a noticeable difference in protein content, with a final crude protein value of 3.0±0.04%. The balance between the naturally low-protein dates and the seeds that contribute protein is reflected in this moderate level. Previous research on flaxseed-enriched dry fruit balls revealed a significantly higher protein content of 7.08%, demonstrating how adding more seeds or nuts to similar snack products increases their protein content (Chunilal & Sudhakar, 2021). According to another study creating value-added date bars, the amount of groundnut flour added affected the protein content, which ranged from 4.14 to 6.36%. This implies that the selection and amount of ingredients high in protein have a significant impact on the finished product (Irshad, 2025).

Fiber Content

The date and seed ball had a crude fibre content of 5.3±0.03%. This indicated a great increase in dietary fibre level, largely due to the addition of orange peel powder and seed elements. It has been previously reported that dietary fibre levels for using orange peel powder in cookie formulations varies from 8.33 to 13.33% based on the amount of peel added that provides dietary fibre to the product. Among other trials of digestibility, soluble fibre ranged from 2.82% to 6.00%, and insoluble fibre ranged from 5.43 to 7.36%. These responses support the use of citrus peel powder to enhance the dietary fibre content of treatment and also demonstrate its fiber-op enhancing effect (Rani et al., 2020). There have been several studies on date base snack bars which reported fibre level results that were similar to crude fibre levels noted in the present trail. The crude fibre content in one trial of high-protein bars prepared from date paste and legume flour was between 5.81 (4.71) and 7.16 (6.37)% crude fibre depending on the formulation. A second study of apricot-date bars showed observation levels between 5.55 and 6.14% crude fibre. The previous two study results for crude fibre levels from date formulations, particularly exploring of the effects of other factors including levels of orange peel powder, present further support for the reported success of orange peel powder containing high dietary fibre content while consistent with other findings in relation to functional products of a similar nature (Jabeen et al., 2022).

Fat Content

The date and seed balls containing 10% orange peel powder had a fat value measured at 2.00±0.04%. A moderate amount of fat is desirable because it contributes to the smooth texture and palatability of the snack product, in addition to not creating a greasy texture or high total lipid value. A study investigated dry fruit balls which included a % flaxseed, and measured a fat value of 7.08± 0.02%, which is higher than the current value. The reason the fat measurement is greater than the present value is that a higher % flaxseed was used, as flaxseed is known for its lipid content (Chunilal and Sudhakar, 2021). Research on cookies made with orange peel, noted that the fat value resulted in a decrease with increases in orange peel infusion, going from 20.0% fat in the control to 17.1% fat at the 10% inclusion with orange peel powder. This furthers support the theory that citrus peel lowers lipids in total formulations, as citrus peel is relatively low in fat (Rani et al, 2020).

Moisture Content

The moisture content of the date and seed-based ball formulation containing 10% orange peel powder was recorded as 20.52±0.07%. This value places the formulation within the intermediate-moisture category, which typically falls between 15-25% for fruit and seed-based snack products. Such a moisture level contributes positively to softness, chewability, and overall acceptability. A research study showed that date-seed energy bars developed with fruit-based ingredients had moisture contents of 22.0% and 21.4%, which are comparable to the current result (Eid *et al.,* 2025). Another study reported that when 10% orange peel powder was added to biscuit formulations, the moisture content increased significantly from 2.30% in the control to 5.53% in the fortified sample (Rani *et al.,* 2020). Previously, a study observed that sun-dried orange peel powder itself had a moisture content of 9.2%, supporting its water-holding capacity and ability to influence hydration levels in composite food systems. These findings support the result observed in the present product, where the inclusion of orange peel powder contributed to maintaining a desirable moisture level (Zaker *et al.,* 2016).

Ash Content

The date and seed balls, had an ash content of 1.98±0.04%. The level of ash in any food product is affected by a combination of factors (the type and proportion of products used). The level of total mineral matter in a food product is determined using ash content. The formulation of the balls consisted of many

ingredients which contained minerals (especially with the inclusion of dates, seeds, and powdered orange peel), hence the ashed value was reflective of these mineral-containing ingredients. The ash content for a similar study of dry fruit balls with flaxseed supplementing the liquid, was 2.01±0.11%, indicating that date-based snack products using seeds would have an ash value of around 2% (Chunilal and Sudhakar, 2021). Another study illustrated that dried orange peel powder, had an ash content of 2.53±0.12%, noting this would contribute to overall mineral levels when added to functional food formulations (Rani et al., 2020).

Nitrogen Free Extract (NFE)

The nitrogen-free extract (NFE) of the sample which indicates the digestible carbohydrates primarily from the natural sugars in dates and the lower starch fraction from seeds is reported as 67.2±3.84%. Another study looking at the novel way of creating dry fruit balls using flaxseeds reported that all carbohydrates were 72.66%, showing that the addition of nuts & seeds increases carbohydrate levels in fruit derived snacks (Chunilal & Sudhakar, 2021). The carbohydrate in date bars containing germinated flaxseed showed total carbohydrates of 70.91% which supports that most date-based products have a significant portion of accessible soluble sugars that are already present (Alfheeaid et al., 2023).

Physicochemical Analysis of Date and Seed Based Balls

Ph

The pH of the date and seed balls containing 10% orange peel powder was 6.01±0.02. In fiber-rich snack systems, a pH value just above 6 denotes a slightly acidic environment that promotes both microbial stability and sensory appeal. This acidity level helps to preserve the flavour and freshness of the product. According to a study, the pH values of date moringa composite bars were 6.03±0.33%, which is quite similar to the acidity found in sample (Eid *et al.,* 2025). In another study date-apricot protein bars showed pH values of 5.84-6.63, suggesting that fortification levels and ingredient composition only slightly alter acidity. These results verify that samples pH remains constant within the usual range for bar products made from fruit (Jabeen *et al.,* 2022). According to a previous research investigation, the control sample (100% wheat flour) began at 7.61 and dropped to 6.31 during the same time period. The initial pH of biscuits containing 10% orange peel was 7.08, which subsequently dropped to 5.86 by the end of storage. These results demonstrate that the addition of citrus peel initially raises pH in comparison to formulations made entirely of wheat, and that acidity gradually develops. Orange peel powder contributes to a neutral to slightly acidic profile that evolves moderately, as indicated by the pH of 6.01 measured in sample, and validates that citrus peel helps maintain stable pH in functional snack products (Nwosu & Akubor, 2018).

Color

Color analysis of the date and seed balls yielded CIELAB coordinates of L=2.8±0.03, a*=0.4±0.04, and b*=1.9, indicating a distinctly dark product with low chromatic intensity. The exceptionally low L value reflects significant light absorption. The slightly positive a* and b* values suggest the presence of subtle reddish-yellow tones, likely resulting from the pigment composition of dates and the inclusion of orange peel powder. A research study showed that date-based sports energy gels exhibited considerably lighter and more vibrant color profiles, with L values ranging from 30.38 to 32.42, a* from 3.72 to 8.20, and b* from 6.29 to 27.80. These elements emphasise the impact of formulation and processing on colour expression in fruit-based snacks (Baroyi *et al.,* 2023). According to previous studies, adding orange peel powder to cookies significantly decreased their lightness (L), which went from 87.95±0.50 in the control group to 70.67±0.32 at 20% inclusion. At the same time, redness (a*) increased from –0.34±0.14 to

3.59±0.22, and yellowness (b*) from 9.31±0.05 to 33.98±0.16, confirming the ability of citrus peel to intensify product coloration (Al Saab & Gadallah, 2021).

Antioxidant Analysis of Date and Seed Based Balls

DPPH

The DPPH scavenging activity of sample, formulated with 10% orange peel powder, was recorded at 27.44±0.07%, indicating moderate antioxidant potential. This is due to the presence of natural phenolics from dates and seeds, as well as bioactive compounds from citrus peel. Research has have shown that, depending on the seed variety and extraction technique, the DPPH activity in date seed extracts can vary from 21.39 to 81.88%. Ruthana, for instance, exhibited the highest radical scavenging capability (Zarie *et al.,* 2023). Previous studies reported that incorporating orange peel flour into millet-based biscuits reduced EC_{50} values significantly from 2.38 mg/mL in control samples to 1.71 mg/mL in formulations with 20% orange peel. This enhancement in DPPH activity directly supports the functional role of citrus by-products. Since sample contains 10% orange peel, the observed 27.44% DPPH activity aligns well with such enrichment levels and confirms the antioxidant efficacy of peel inclusion in non-baked, high-moisture snack formats (Obafaye & Omoba, 2018).

Total Phenolic Content (TPC)

Date and seed balls exhibited a total phenolic content of 9.24±0.06 mg GAE/100 g. Phenolics are associated with antioxidant defence, inflammation control, and metabolic support, making their presence in functional foods highly desirable. Their presence in the sample not only increases its nutritional value but also helps to extend its shelf life and maintain its flavour under ambient conditions. According to research, Moroccan date cultivars like "Mejhoul" and "Aziza Bouzid" have total phenolic content levels that range from 209.25 to 496.09 mg GAE/100 g dry weight (Ouamnina *et al.,* 2024). A previous study found that aqueous date seed extracts contained TPC levels ranging from 63.2±0.1 to 271.2±3.7 mg GAE/g dry matter, with an average of 154.2±1.3 mg GAE/g. The findings indicate an emphasis on the high level of phenolics in raw seeds upon formulation. During formulation, the phenolics are diluted naturally, but still provide a reasonable functional base. The final product had phenolics of 9.24 mg GAE/100 g, which is to be expected for a whole-food bar with these bioactive components (Swaidan et al., 2023).

Table 2. Mean Table for Proximate Analysis of Date and Seed Balls

Protein (%)	Fiber (%)	Fat (%)	Moisture (%)	Ash (%)	NFE (%)
3±0.04	5.3±0.03	2.0±0.04	20.52±0.07	1.98±0.04	67.2±3.84

Table 3. Mean Table for Physicochemical Analysis of Date and Seed Balls

pH	L	a^*	b^*	C^*	H^*

6.01±0.02	2.8±0.03	0.4±0.04	1.9±0.02	1.9±0.04	79.3±3.92

Table 4. Mean Table for Antioxidants of Date and Seed Balls

DPPH (%)	TPC (mg GAE/100 g)
27.44±0.07	9.24±0.06

CONCLUSION

This research shows that creating a healthy and acceptable snack using simple, natural ingredients and unutilized fruit by-products may help support food sustainability and personal health goals. The overall sensory acceptance and storage stability of the treatment with orange peel powder (10% addition) was rated highest by the panelists. Based on these findings, we can develop functional snacks that may help manage health conditions such as Polycystic Ovary Syndrome (PCOS) that naturally support dietary fibre, antioxidants and plant-based vitamins, according to consumer sensory acceptance. Citrus peel powder represents a good example of how the waste from the processing of fruits can be processed via fruit by-products into ingredients that improve nutritional value while reducing waste. Overall, the research highlights the impact of creating an intersection of waste and nutrition as food products. The research results provide support to continue testing related product concepts, combinations of ingredients and shelf-life studies, and provide creative opportunities to increase consumer awareness and market development for modern functional food that meets both sustainability and health objectives.

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