ISSN Print: 2664-844X
ISSN Online: 2664-8458
NAAS Rating (2025): 4.97
IJAFS 2025; 7(11): 188-191
www.agriculturaljournals.com
Received: 03-08-2025
Accepted: 07-09-2025

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Development and nutritional evaluation of fortified pomelo peel candy as a functional confectionery product

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DOI: https://www.doi.org/10.33545/2664844X.2025.v7.i11c.957

Abstract
Pomelo *(Citrus grandis)*, an underutilized citrus fruit, is nutritionally rich, containing significant amounts of vitamin C, dietary fiber, pectin, and essential minerals such as potassium, magnesium, and calcium. The peel, often discarded as waste, is particularly abundant in bioactive compounds, including flavonoids, phenolic acids, and antioxidants. This study focuses on the nutritional enhancement of pomelo peel through its incorporation into a fortified candy product. The formulated candy was enriched with natural sources of key nutrients, including vitamin A, iron, protein, vitamin D, calcium, and zinc. Nutritional analysis of the product revealed a well-balanced composition of macronutrients and micronutrients, indicating the potential of pomelo peel candy as a functional, nutrient-dense confectionery.

Keywords: Pomelo peel, *Citrus grandis*, functional confectionery, fortified candy, bioactive compounds

1. Introduction
Pomelo *(Citrus grandis)*, a large citrus fruit native to Southeast Asia, is considered an underutilized crop despite its rich nutritional and functional potential. The fruit comprises two main parts: the pulp, which is the edible juicy segment, and the peel, which includes the thick outer rind and spongy inner albedo. The pulp of pomelo is widely consumed and is known for its refreshing flavor, high water content (approximately 89-91%), and its abundance of vitamin C, a key nutrient for immune support and collagen synthesis. It also provides β-carotene (provitamin A), dietary fiber, potassium, folic acid, and trace minerals such as magnesium and iron, contributing to its hydrating and nourishing qualities (Gorinstein *et al.*, 2004) [5].On the other hand, the peel—often discarded—holds significant promise due to its concentration of bioactive phytochemicals, including flavonoids (e.g., naringin, hesperidin), limonoids (e.g., limonin, nomilin), essential oils, pectin, and polyphenols. These compounds have been linked to various health-promoting effects, such as antioxidant, anti-inflammatory, antihypertensive, antimicrobial, and antidiabetic activities (Tripathi & Chandra, 2010; Zhang *et al.*, 2014) [15, 18].
Pomelo *(Citrus maxima)* holds significant importance in human nutrition as one of the largest and most widely cultivated citrus fruits. It is appreciated for its refreshing, mildly sweet to tangy flavor, thick rind, and versatile culinary applications ranging from fresh consumption to incorporation in beverages, salads, and desserts. Pomelo has earned a notable place in traditional medicine systems and contemporary diets alike, due to its nutritional density and functional health benefits (Tripathi & Chandra, 2010) [15].
Pomelo peel, which is typically discarded as waste, is gaining renewed attention for its high content of dietary fiber, flavonoids, and pectin, making it a valuable ingredient for developing functional food products. One such innovation is pomelo peel candy, a novel confectionery product that transforms underutilized peel into a flavorful, nutrient-dense treat. This value-added product is not only environmentally sustainable but also aligns with the growing demand for health-conscious sweets. Enriched with natural antioxidants, vitamins, and minerals, pomelo peel candy exhibits a pleasant citrus aroma, chewy texture, and vibrant appearance, offering a unique sensory experience. Recent studies have shown that

blanching and processing techniques effectively reduce the bitterness of pomelo peel (caused by compounds like naringin and limonoids) while preserving its nutritional quality (Li *et al*., 2006; Hussain *et al.*, 2020) [6, 8]. As a result, pomelo peel candy stands out as a promising functional confectionery product with potential health benefits and broad consumer appeal. This research aims to explore the nutritional composition of pomelo peel candy and assess its potential health benefits as a functional confectionery product.

2. Objectives

1. To formulate and optimize pomelo peel-based candy.
2. To evaluate the sensory attributes and nutritional composition of the developed pomelo peel candy.

3. Materials and Methods

3.1 Experimental site

The experimental work for product preparation was conducted in the Department of Food Nutrition and Public Health at Ethelind College of Community Science, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh.

3.2 Procurement of Samples

Fresh pomelo fruits were procured from local markets in Prayagraj, Uttar Pradesh, India. Other ingredients, including cornstarch, dates paste, jaggery, lemon juice, gelatin, and ghee, were sourced from verified local suppliers specializing in food-grade or organic products.

3.3 Preparation Method

The candy-making process begins with cleaning the pomelo peel, cutting it into small pieces, and blanching in boiling water for 5-7 minutes to soften its texture and reduce bitterness. After cooling, the peel is finely chopped or ground into a smooth paste. This pomelo peel paste is then combined with dates paste and jaggery as natural sweeteners, forming a flavorful base. Cornstarch is incorporated to thicken the mixture, while a pre-soaked gelatin solution is added to enhance binding and provide a desirable chewy texture. Lemon juice is included to balance flavor and act as a mild preservative, and a small quantity of ghee is added to improve mouthfeel, shine, and overall richness. The mixture is gently cooked over low heat with constant stirring until it thickens to the desired consistency. Additional heating ensures the mixture achieves the proper texture, similar to reaching a target total soluble solids (TSS) level in conventional candy-making. Once the candy mass is ready, it is poured onto prepared silicone molds, left to cool at room temperature, and then refrigerated for 2-3 hours to allow firm setting. Finally, the set candy is removed from the molds, evaluated for taste, texture, visual appeal, and shelf stability, and stored in airtight containers to maintain freshness over one week under ambient conditions.

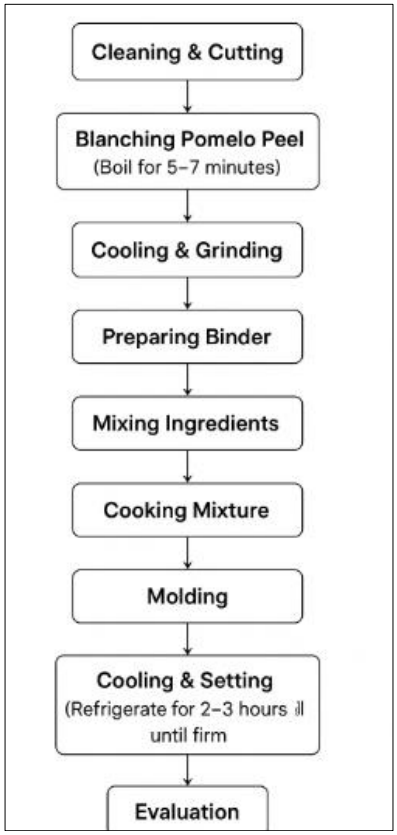

Fig 1: Flowchart of the Preparation of Pomelo Candy

3.4 Formulation of pomelo peel candy

Three variations were formulated, with percentage changes in pomelo peel, cornstarch, and dates paste.

Table 1: Formulation of Pomelo Peel Candy Treatments (T_1, T_2, T_3)

Treatments	T_1	T_2	T_3
Pomelo peel	35 g	35 g	40 g
Cornstarch	10 g	10 g	10 g
Dates paste	35 g	40 g	30 g
Jaggery	10 g	10 g	10 g
Lemon juice	5 g	5 g	5 g
Gelatin	3 g	3 g	3 g
Ghee	2 g	2 g	2 g

Fig 2: Pomelo peel candy

3.5 Sensory Analysis
The sensory evaluations of the prepared products were done by the panel of judges selected from the faculty member of the Ethelind College of Community Science. Products were judged by using the various sensory attributes like colour and appearance, consistency, flavour and taste and overall acceptability. The evaluation was done by on the 9 point Hedonic scale based score card (Srilakshmi 2015) [14].

3.6 Nutritional Analysis:
Nutritional Composition included moisture, ash, fat, protein, crude fiber were analyzed by the methods described by AOAC (2012) and carbohydrate was calculated by difference method. Mineral content includes calcium, and iron were estimated in ash by the method described by Rangana (2010) [11] with little modifications. Calcium in ash was determined volumetrically and the acidic extract was treated with ammonium oxalate at pH 4.0 which precipitates calcium as calcium oxalate (CaC_2O_4).Ferrous iron in acid solution reacts with the potassium thiocynate to form an intense red compound of ferric thiocynate. The compound is extracted with the organic potassium per sulphate and iron contents were measured calorimetrically at 560 nm.

4. Results and Discussion
4.1 Sensory Acceptability

Table 2: Sensory evaluation of pomelo peel candy formulations

Treatment	Taste	Flavour	Colour	Texture	Mouthfeel	Overall Acceptability
T_1	7.25	7.33	7.16	7.25	7.33	7.25
T_2	7.41	7.50	7.33	7.41	7.41	7.41
T_3	7.83	7.91	7.75	7.83	7.91	7.91

The sensory evaluation identified Treatment T_3 as the best formulation among the three developed pomelo peel candies based on its superior performance across all evaluated attributes. T_3 exhibited the highest values for taste (7.83), flavour (7.91), colour (7.75), texture (7.83), mouthfeel (7.91), and overall acceptability (7.91), followed by T_2. The formulation's success can be attributed to the optimal use of pomelo peel, which enhanced flavour, aroma, and colour, combined with the complementary sweetness of dates paste and jaggery, and the smooth texture provided by gelatin and ghee. This well-balanced and appealing candy formulation offers a delightful sensory experience, making it the preferred choice among the panellists.

4.2 Nutritional Analysis (Estimated per 100g)
The nutritional composition of the best fortified pomelo peel candy (T_3) per 100 g is as follows: moisture content is 16%, indicating suitable shelf stability. The crude protein content is 7.2 g, while the crude fat content is 10 g. The ash content, which represents total mineral content, is around 2.5%. The carbohydrate content is 64g, contributing to the energy value of the candy. The candy is also enriched with micronutrients, providing 750 µg RAE of vitamin A, 3.5 mg of iron, 1.5µg of vitamin D, 125mg of calcium, and 3.5 mg of zinc.

Table 3: Nutritional Composition of Pomelo Peel Candy

S.no.	Nutrient	Amount
1	Moisture (%)	16
2	Crude Protein (g)	7.2
3	Crude fat (g)	10
4	Ash (%)	2.5
5	Carbohydrates (g)	64
6	Vitamin A (µg RAE)	750
7	Iron (mg)	3.5
8	Vitamin D (µg)	1.5
9	Calcium (mg)	125
10	Zinc (mg)	3.5

5. Conclusion

The present study successfully developed a nutritious and appealing candy formulation by incorporating pomelo peel, dates paste, jaggery, and complementary ingredients such as cornstarch, gelatin, ghee, and lemon juice. Through a systematic approach, various combinations of these ingredients were explored, and Treatment T_3, containing 40 g pomelo peel, 30 g dates paste, and 10 g each of jaggery and cornstarch, emerged as the most promising formulation based on its superior sensory attributes, including taste, flavour, colour, texture, mouthfeel, and overall acceptability, followed by T_2 and T_1.The incorporation of pomelo peel and dates paste into the candy formulation significantly enhanced the nutritional profile by providing essential nutrients, including protein, carbohydrates, fats, vitamins A and D, calcium, iron, and zinc. The physicochemical properties of the developed candy were found to be desirable, with balanced moisture content, texture, and sweetness, contributing to overall product quality. The careful formulation allowed for a visually appealing colour and a pleasant texture, enhancing consumer acceptability.

Overall, this research successfully developed a functional and indulgent homemade candy that meets the growing demand for healthier snack options. The combination of pomelo peel, dates, and jaggery provides a nutritious treat with enhanced sensory appeal and bioactive potential. These findings lay the foundation for further research and potential commercial development of innovative and health-promoting candy products that align with contemporary consumer health trends

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