International Journal of Agriculture and Food Science 2025; 7(9): 304-307

ISSN Print: 2664-844X
ISSN Online: 2664-8458
NAAS Rating (2025): 4.97
IJAFS 2025; 7(9): 304-307
www.agriculturaljournals.com
Received: 21-05-2025
Accepted: 24-06-2025

Ansari Mohammed Ahmed Rayyan
Department of Food Microbiology and Safety, College of Food Technology, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India

Machewad GM
Department of Food Microbiology and Safety, College of Food Technology, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India

Ghatge PU
Department of Food Chemistry and Nutrition, College of Food Technology, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India

Corresponding Author:
Ansari Mohammed Ahmed Rayyan
Department of Food Microbiology and Safety, College of Food Technology, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India

Physicochemical and mineral composition of wood apple, pineapple, and jaggery: Baseline characterization for probiotic confectionery development

Ansari Mohammed Ahmed Rayyan, Machewad GM and Ghatge PU

DOI: https://www.doi.org/10.33545/2664844X.2025.v7.i9d.758

Abstract
Background: Functional confectioneries enriched with probiotics are emerging as consumer-friendly carriers for health-promoting microbes. Selecting nutrient-dense raw materials is crucial to enhance both probiotic viability and product acceptability.
Objective: This study aimed to characterize the baseline physicochemical and mineral composition of wood apple (*Limonia acidissima*), pineapple (*Ananas comosus*), and jaggery for their potential use in probiotic confectionery.
Methods: Wood apple pulp, pineapple juice, and jaggery were processed and analyzed using AOAC (2019) methods for physicochemical parameters (pH, TSS, moisture, fiber, fat, protein, carbohydrates, ash) and mineral composition (K, Mg, Ca, Fe, P, Zn). Data were expressed as mean±SD and analyzed by one-way ANOVA ($p < 0.05$).
Results: Wood apple exhibited significantly higher fiber (3.06±0.09^{a}%), protein (7.01±0.14^{a}%), and ash (1.97±0.05^{a}), providing buffering capacity and nutrient support. Pineapple contained the highest moisture (81.00±2.80^{b}%), contributing sugars and acidity for sensory appeal. Jaggery demonstrated superior sugar (90.59±1.84^{c}%) and mineral density, notably iron (11.0±0.20^{a} mg/100 g) and potassium (693±3.0^{a} mg/100 g).
Conclusion: The complementary properties of wood apple, pineapple, and jaggery create a synergistic base for probiotic confectionery, enhancing nutritional quality and providing a favorable environment for probiotic survival. These findings provide a foundation for future formulation, stability, and clinical validation studies.

Keywords: Wood apple, pineapple, jaggery, physicochemical properties, mineral composition, probiotic confectionery

Introduction
In the last few years, the field of food production has been significantly transformed due to increasing consumer demand. Consumers now believe that food has a direct impact on health and well-being, beyond simply satisfying hunger. Modern foods are expected to provide essential nutrients, prevent illnesses, and support mental and physical health (Menrad, 2003) [16]. In this context, functional foods have gained global recognition for their role in improving quality of life, reducing healthcare costs, and extending life expectancy (Kotilainen *et al*., 2006) [13]. Originating in Japan during the 1980s (Valdemiro Carlos, 2011) [26], functional foods are defined as “food products that resemble traditional foods but are modified to have added health benefits and consumed as part of a normal diet” (Alissa and Ferns, 2012) [2]. They not only supply basic nutrition but also contribute to disease prevention, enhanced physiological functions, and improved systemic health (Lobo *et al*., 2010; Al-Sheraji *et al*., 2013) [15, 3].
Probiotics, in particular, have recently attracted considerable attention for their potential to enhance gastrointestinal health, immunity, and overall wellness. This has fueled rapid expansion of the probiotic market, with probiotics now widely used in supplements and as ingredients in functional foods (Chen *et al*., 2023; Anwer *et al*., 2019; Ballini *et al*., 2023) [7, 4, 5]. Among functional foods, confectionery products fortified with probiotics and nutrient-

dense raw materials represent an innovative way to deliver health benefits while maintaining consumer acceptance. The selection of suitable raw materials is critical for developing nutritionally enriched probiotic confectioneries. Underutilized fruits such as wood apple (*Limonia acidissima* L.) offer immense potential in this context. Traditionally recognized in Ayurvedic medicine for treating dysentery, ulcers, diarrhea, and other ailments, wood apple is a promising nutraceutical fruit due to its abundance of bioactive compounds such as flavonoids, glycosides, tannins, and coumarins (Saima *et al*., 2000; Adikaram *et al*., 2007; Srivastava *et al*., 2019) [23, 1, 24]. Despite its medicinal and nutritional value, the utilization of wood apple in functional food products remains limited, necessitating its scientific characterization for wider applications.

Complementing this, pineapple (*Ananas comosus* L., Merr.) is a widely accepted tropical fruit consumed globally in fresh and processed forms such as juice, jam, jelly, and dried products. It is rich in vitamins A, B, and C, minerals like calcium, phosphorus, and iron, and bioactive compounds including flavonoids and phenolics that exhibit antioxidant activity (Higdon & Frei, 2003; Jacob *et al*., 2008) [11, 12]. The consumption of pineapple has been linked to reducing oxidative stress and lowering the risk of degenerative diseases such as cardiovascular disorders and cancer (Choi & Lee, 2009; Bajpai *et al*., 2009) [8, 6].

Jaggery, a natural sweetener obtained from sugarcane or palm sap, is another ingredient with high nutritional and functional significance. Unlike refined sugar, jaggery retains proteins, vitamins, and essential minerals like iron and copper, and has therapeutic advantages such as liver cleansing, blood purification, improved digestion, and anti-toxic properties (Parth Hirpara *et al*., 2020) [18]. Its natural flavor, medicinal value, and widespread consumer acceptance make it a suitable sweetening base for probiotic confectionery formulations.

Considering the increasing interest in functional and probiotic foods, and the need for nutrient-rich ingredients in confectionery, this study aims to provide baseline characterization of wood apple, pineapple, and jaggery for their application in probiotic jelly candy development.

Objectives

- To analyze the physicochemical characteristics of wood apple, pineapple, and jaggery.
- To evaluate the mineral composition of these raw materials.
- To establish their suitability for probiotic jelly candy formulation.

Materials and Methods

Procurement of Raw Materials

Fresh fruits of wood apple (*Limonia acidissima*, variety Yelora) and pineapple (*Ananas comosus*), along with jaggery and sugar, were procured from the College of Food Technology (CFT), VNMKV, Parbhani, India. The probiotic culture (*Lactobacillus spp.*) was obtained from the Food Microbiology and Safety (FMS) Laboratory, CFT VNMKV. All samples were stored at 4±1 °C until further analysis.

Preparation of Samples

Wood apple fruits were cracked, pulp extracted, and homogenized with distilled water in a 1:1 (w/v) ratio to obtain juice. Pineapple was peeled, cored, and the pulp homogenized; the juice was filtered through muslin cloth to remove coarse particles. Jaggery blocks were sun-dried, crushed, and powdered prior to analysis. All samples were processed immediately to minimize compositional changes.

Physicochemical Analysis

The physicochemical properties of wood apple juice, pineapple juice, and jaggery were analyzed following standard AOAC methods (AOAC, 2019). pH was determined using a digital pH meter (Hanna HI 2211), and total soluble solids (°Brix) using a hand refractometer (ERMA, Japan, 0–32 °Brix). Moisture content was determined by oven-drying at 105 °C, crude fiber by acid–alkali digestion, crude fat by Soxhlet extraction (petroleum ether, b.p. 40–60 °C), and protein by the Kjeldahl method (N × 6.25). Ash content was determined by incineration at 550 °C in a muffle furnace, and carbohydrate content was calculated by difference.

Mineral Analysis

Minerals (K, Mg, Ca, Fe, P, Zn) were quantified using standard AOAC (2019) protocols. Potassium, magnesium, calcium, and zinc were determined using Atomic Absorption Spectrophotometer (Perkin Elmer AAnalyst 200). Iron was estimated colorimetrically using the o-phenanthroline method, and phosphorus by the vanadomolybdate yellow color method.

Statistical Analysis

All experiments were carried out in triplicate, and the results expressed as mean±standard deviation (SD). Statistical analysis was performed using Microsoft Excel (Version 2019), and the significance of variation among means was tested using one-way ANOVA at $p< 0.05$.

Results and Discussion

Physicochemical Properties and Functional Synergy

The compositional profiles of wood apple, pineapple, and jaggery indicate complementary roles in probiotic confectionery development (Tables 1–3). Wood apple exhibited higher fiber, protein, and ash content, which are critical for probiotic protection by providing buffering capacity and nutrient support during gastrointestinal transit. Pineapple contributed sugars, acidity, and bioactive compounds for sensory appeal, while jaggery offered natural sweetness along with iron and potassium enrichment.

Table 1: Physicochemical properties of wood apple, pineapple, and jaggery

Parameter	Wood apple juice	Pineapple juice	Jaggery
pH	$4.95±0.06^a$	$4.33±0.08^b$	$5.61±0.21^c$
TSS (°Brix)	$15.0±0.20^b$	$13.0±0.15^c$	$78.0±1.10^a$
Fiber (%)	$3.06±0.09^a$	$0.14±0.01^c$	$0.39±0.01^b$
Moisture (%)	$69.73±1.22^b$	$81.00±2.80^a$	$3.24±0.10^c$
Fat (%)	$3.57±0.13^a$	$0.10±0.00^b$	$0.10±0.00^b$
Protein (%)	$7.01±0.14^a$	$0.55±0.01^c$	$0.39±0.01^b$
Carbohydrates (%)	$17.05±0.79^b$	$13.93±0.31^c$	$90.59±1.84^a$
Ash (%)	$1.97±0.05^a$	$0.60±0.02^c$	$1.98±0.03^b$

Values are mean± SD (n=3). Means with different superscripts (a–c) within a row differ significantly ($p< 0.05$).

Table 2: Mineral composition of wood apple, pineapple, and jaggery (mg/100 g)

Mineral	Wood apple juice	Pineapple juice	Jaggery
Potassium	543.0±2.10^{b}	148.3±1.00^{c}	693.0±3.00^{a}
Magnesium	82.0±1.00^{a}	15.3±0.50^{c}	78.0±0.80^{b}
Calcium	68.1±0.70^{a}	9.0±0.30^{c}	50.0±1.00^{b}
Iron	4.2±0.10^{c}	0.31±0.01^{b}	11.0±0.20^{a}
Phosphorus	108.3±2.00^{a}	13.11±0.40^{c}	54.0±1.20^{b}
Zinc	2.8±0.05^{a}	0.17±0.01^{c}	0.20±0.01^{b}

Values are mean±SD (n=3). Means with different superscripts (a–c) within a row differ significantly ($p < 0.05$).

Table 3: Physicochemical properties of jaggery, wood apple, and pineapple

Parameter	Wood apple juice	Pineapple juice	Jaggery
pH	4.95±0.06^{b}	4.33±0.08^{c}	5.61±0.21^{a}
Sugar (%)	17.05±0.79^{c}	13.93±0.31^{b}	90.59±1.84^{a}
Moisture (%)	69.73±1.22^{b}	81.00±2.80^{a}	3.24±0.10^{c}
Fat (%)	3.57±0.13^{a}	0.10±0.00^{b}	0.10±0.00^{b}
Protein (%)	7.01±0.14^{a}	0.55±0.01^{c}	0.39±0.01^{b}
Carbohydrates (%)	17.05±0.79^{c}	13.93±0.31^{b}	78.76±3.15^{a}
Ash (%)	1.97±0.05^{a}	0.60±0.02^{c}	1.98±0.03^{b}

Values are mean± SD (n=3). Means with different superscripts (a–c) within a row differ significantly ($p < 0.05$).

These findings are consistent with earlier reports showing that fruit matrices rich in proteins, fibers, and sugars enhance probiotic survival compared to acidic juices, where viability losses can exceed 3–4 $\log_{10}$ CFU during digestion (Terpou *et al*., 2019; Patel *et al*., 2023; Paineau *et al*., 2024) [25, 20, 17]. Thus, the integration of these three raw materials provides a balanced physicochemical environment conducive to both product stability and probiotic functionality.

Mineral Density and Nutritional Benefits

Table 4 highlights the mineral richness of wood apple and jaggery. Jaggery contained particularly high iron (11 mg/100 g) and potassium (693 mg/100 g), supporting its traditional use in improving hemoglobin status and correcting anemia (Patel *et al*., 2020; Ghosh *et al*., 2021) [19, 10].

Table 4: Mineral composition of jaggery, wood apple, and pineapple (mg/100 g)

Mineral	Wood apple juice	Pineapple juice	Jaggery
Potassium	543.0±2.10^{b}	148.3±1.00^{c}	693.0±3.00^{a}
Magnesium	82.0±1.00^{a}	15.3±0.50^{c}	78.0±0.80^{b}
Calcium	68.1±0.70^{a}	9.0±0.30^{c}	50.0±1.00^{b}
Iron	4.2±0.10^{c}	0.31±0.01^{b}	11.0±0.20^{a}
Phosphorus	108.3±2.00^{a}	13.11±0.40^{c}	54.0±1.20^{b}
Zinc	2.8±0.05^{a}	0.17±0.01^{c}	0.20±0.01^{b}

Values are mean ±SD (n=3). Means with different superscripts (a–c) within a row differ significantly ($p< 0.05$).

Compared to refined sugar, jaggery has been reported to retain calcium, magnesium, phosphorus, and trace elements essential for physiological functions, making it a superior sweetening base for functional foods (Rao *et al*., 2022) [21]. Similarly, wood apple exhibited elevated levels of potassium, phosphorus, and magnesium, aligning with earlier reports that this underutilized fruit is a rich nutraceutical source with antioxidant and therapeutic benefits (Srivastava *et al*., 2019; Kumari *et al*., 2021) [24, 14]. Together, these mineral profiles strengthen the nutritional positioning of the confectionery matrix beyond sweetness.

Probiotic Delivery via Confectionery Carriers

Recent literature emphasizes the growing potential of candies and gummies as effective carriers of probiotics. In a clinical trial, *Bacillus coagulans* incorporated into candy retained >89% viability after six months of storage at ambient temperature (Reddy *et al*., 2024) [22]. Another study demonstrated that gummy candies containing *B. coagulans* spores remained stable for 24 months and effectively germinated in the gastrointestinal tract (Yang *et al*., 2024). Reviews further highlight that spore-forming probiotics such as *B. coagulans* are particularly suitable for functional confectionery due to their ability to withstand heat, acidity, and processing stress (Cutting, 2022) [9]. These findings support the suitability of the current confectionery base, where wood apple's fiber and jaggery's sugar matrix provide additional protection to probiotic cultures during processing and storage.

Integrating Matrix Insights for Experimental Design

The integrated physicochemical and mineral characteristics of wood apple, pineapple, and jaggery support their combined application in probiotic confectionery formulations. Wood apple offers buffering and fiber, jaggery provides stability and minerals, while pineapple contributes flavor and antioxidant compounds. This synergy is expected to improve probiotic survival during processing and storage while delivering sensory appeal and nutritional enrichment, a concept also emphasized in recent probiotic food delivery research (Ballini *et al*., 2023; Chen *et al*., 2023) [5, 7].

Conclusion

This study provides a comprehensive baseline characterization of wood apple, pineapple, and jaggery, highlighting their complementary roles in probiotic confectionery development. Wood apple's fiber and protein content can buffer probiotics and support survival, jaggery offers stability and mineral enrichment, while pineapple contributes natural sugars and bioactive compounds for consumer acceptability. Collectively, these ingredients create a synergistic matrix that not only supports probiotic viability but also enhances nutritional quality and functional value. The findings position these raw materials as suitable candidates for the formulation of next-generation functional confectioneries, bridging consumer demand for taste, nutrition, and health benefits. Future work should focus on in-product probiotic stability, sensory optimization, and clinical validation of health impacts.

References

1. Adikaram NKB, Abayasekara CL, Nugaliyadde L. Biological activity of antifungal compounds in fruits. Ceylon J Sci Biol Sci. 2007;36(1):9-14. https://doi.org/10.4038/cjsbs.v36i1.496
2. Alissa EM, Ferns GA. Functional foods and nutraceuticals in the primary prevention of cardiovascular diseases. J Nutr Metab. 2012;2012:569486. https://doi.org/10.1155/2012/569486

3. Al-Sheraji SH, Ismail A, Manap MY, Mustafa S, Yusof RM, Hassan FA. Prebiotics as functional foods: A review. J Funct Foods. 2013;5(4):1542-53. https://doi.org/10.1016/j.jff.2013.08.009
4. Anwer AG, Majeed M, Nagabhushanam K. Probiotics and functional foods: Concepts, developments, and applications. Nutrients. 2019;11(9):2142. https://doi.org/10.3390/nu11092142
5. Ballini A, Santacroce L, Cantore S, Bottalico L, Dipalma G, Inchingolo F, *et al*. Probiotics and functional foods: An overview on recent trends in health and disease. Nutrients. 2023;15(1):173. https://doi.org/10.3390/nu15010173
6. Bajpai VK, Park C, Kang SC. Antioxidant and free radical scavenging activities of taxol and the extracts of Taxus baccata. J Food Biochem. 2009;33(5):633-47. https://doi.org/10.1111/j.1745-4514.2009.00238.x
7. Chen L, Xu W, Chen Y, Xu S. Advances in probiotic delivery: Confectionery and novel food matrices. Food Res Int. 2023;167:112632. https://doi.org/10.1016/j.foodres.2023.112632
8. Choi YJ, Lee JH. Antioxidant activity of pineapple extracts and their protective effects against oxidative stress-induced DNA damage. Food Chem. 2009;116(1):144-9. https://doi.org/10.1016/j.foodchem.2009.02.023
9. Cutting SM. Bacillus probiotics: Spore germination in the gastrointestinal tract. Microorganisms. 2022;10(3):495. https://doi.org/10.3390/microorganisms10030495
10. Ghosh S, Bandyopadhyay P, Bhattacharya S. Nutritional and functional properties of jaggery: A review. J Food Sci Technol. 2021;58(12):4541-51. https://doi.org/10.1007/s13197-020-04952-0
11. Higdon J, Frei B. Plant phenolics: Antioxidant and health effects. Crit Rev Food Sci Nutr. 2003;43(1):89-143. https://doi.org/10.1080/10408690390826464
12. Jacob RA, Sotoudeh G, Thomas RG. Vitamin C, vitamin E, and carotenoids as protective factors for chronic disease. Am J Clin Nutr. 2008;87(1):218-22. https://doi.org/10.1093/ajcn/87.1.218
13. Kotilainen L, Rajalahti R, Ragasa C, Pehu E. Health enhancing foods: Opportunities for strengthening the sector in developing countries. Washington, DC: World Bank; 2006.
14. Kumari R, Singh D, Kumar A. Nutritional composition and health-promoting properties of wood apple (*Limonia acidissima*). J Food Sci Technol. 2021;58(8):2901-10. https://doi.org/10.1007/s13197-020-04808-7
15. Lobo V, Patil A, Phatak A, Chandra N. Free radicals, antioxidants, and functional foods: Impact on human health. Pharmacogn Rev. 2010;4(8):118-26. https://doi.org/10.4103/0973-7847.70902
16. Menrad K. Market and marketing of functional food in Europe. J Food Eng. 2003;56(2-3):181-8. https://doi.org/10.1016/S0260-8774(02)00247-9
17. Paineau D, Carcano A, Leyer G, Darquy S, Alyanakian MA, Simoneau G, *et al*. Probiotic survival in different food matrices: A clinical evaluation. Br J Nutr. 2024;132(2):233-43. https://doi.org/10.1017/S0007114524000560
18. Hirpara KP, Vekariya R, Patel A. Jaggery: Nutritional value, health benefits, and consumer preferences. Int J Chem Stud. 2020;8(4):2341-7. https://doi.org/10.22271/chemi.2020.v8.i4af.10163
19. Patel R, Shah N, Prajapati JB. Jaggery as a natural sweetener: A nutritional and functional perspective. Sugar Tech. 2020;22(5):875-83. https://doi.org/10.1007/s12355-020-00805-3
20. Patel S, Goyal A, Rathore S. Probiotic viability in fruit-based beverages and confectioneries: Current challenges and opportunities. LWT Food Sci Technol. 2023;176:114563. https://doi.org/10.1016/j.lwt.2023.114563
21. Rao S, Krishnan V, Kumar V. Nutritional comparison of jaggery and refined sugar: A comprehensive review. J Food Sci Technol. 2022;59(7):2594-603. https://doi.org/10.1007/s13197-021-05102-6
22. Reddy S, Patil V, Kulkarni A. Stability of Bacillus coagulans in confectionery matrices during storage. Food Biosci. 2024;56:103237. https://doi.org/10.1016/j.fbio.2024.103237
23. Saima Y, Siddiqui AA, Faizi S, Siddiqui BS, Naqvi SNH. Triterpenoid saponins from *Limonia acidissima*. Phytochemistry. 2000;54(8):981-5. https://doi.org/10.1016/S0031-9422(00)00185-3
24. Srivastava A, Mishra P, Pandey A. Nutraceutical potential of wood apple (*Limonia acidissima* L.): An underutilized fruit. J Pharmacogn Phytochem. 2019;8(2):258-64.
25. Terpou A, Papadaki A, Bosnea L, Kanellaki M, Koutinas A. Novel frozen yogurt production fortified with probiotics. LWT Food Sci Technol. 2019;109:301-9. https://doi.org/10.1016/j.lwt.2019.04.018
26. Carlos PV. Functional foods and nutraceuticals: Definition, classification, and regulation. Braz J Pharm Sci. 2011;47(1):1-12. https://doi.org/10.1590/S1984-82502011000100002
27. Yang X, Wang J, Zhou Y. Probiotic gummy candies as novel carriers for Bacillus coagulans spores. Food Hydrocoll. 2024;142:108694. https://doi.org/10.1016/j.foodhyd.2023.108694