

Development of probiotic fruit juice powder using foam-mat drying and tablet form

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Abstract

Probiotic food components, such as living bacteria, and bioactive ingredients from fruit, are considered functional foods that provide health benefits. This study investigated the properties of probiotic-supplemented juice foam under different hot air-drying temperatures and durations, focusing on the survival of probiotic cells during foam-mat drying. Additionally, the study explored the production of probiotic fruit juice tablets and their impact on the quality of the final product. The juice foam with the addition of *Lactobacillus plantarum* MG32 and *Pediococcus pentosaceus* MG12, methylcellulose (MC) 1.5% (w/v) and egg albumin (EA) 3% (w/v) displayed the lowest foam density and drainage volume, according to the foam properties. Additionally, the probiotic juice powder demonstrated water activity (a_w) values of 0.26 to 0.28. Maltodextrin 6% (w/w) combined with 32% (w/w) finely powdered white sugar and 2% (w/w) coconut oil, then the probiotic fruit juice powders were added. The antioxidant of DPPH radical scavenging capabilities (49.06-79.31 mg Trolox eq./g), pH (3.5-4.4), and ascorbic acid concentration (18.44-169.15 mg/100g) were found in the probiotic juice tablets. Then, the storage time of tablets in a refrigerator (4-10°C) and room temperature (30-35°C) for 90 days was determined. The result found that more than 6 to 7 log CFU/g of probiotic cells survived in juice tablet products. The probiotic juice tablets have the potential to be used as non-dairy functional products for dairy allergies.

1. Introduction

Thailand boasts a wide variety of fruits that offer distinct flavours and are rich in essential nutrients, particularly vitamin C. Some examples are guava, orange, papaya, and tomato. Fruits are commonly consumed when they are fresh and in season, but they can also be processed into other culinary products like juices, jams, jellies, nectar, squash, concentrated juices, and pickled fruits (Zea *et al.*, 2013).

Lactic Acid Bacteria (LAB) are a type of probiotic that is utilized in fermented foods and is known to be safe (generally regarded as safe, or GRAS). Probiotics are typically included in dairy products due to the rising number of people suffering from lactose intolerance, milk protein allergy, galactosemia, and hypercholesterolemia. Non-dairy food matrices have been researched as viable carriers for these probiotics (Rivera-Espinoza and Gallardo-Navarro, 2010). Since fruit juices are high in vitamins, minerals, and antioxidant components and so have a strong health appeal, they may serve as an ideal delivery system for

probiotic cultures in this context (Peres *et al.*, 2012). Probiotics have been added to various fruit juices, according to studies (Fonteles *et al.*, 2012; Costa *et al.*, 2013; Pimentel *et al.*, 2015), to create functional beverages. Producing successful probiotic vegetable and fruit products can be challenging since the existing epiphytic microbiota, depending on their growth rates and acid tolerance, may outperform an introduced probiotic culture. Non-fermented vegetable and fruit items that have been acidified can also serve as carriers for delivering enough specific probiotics. The study conducted by Tanganurat *et al.* (2015) found that *L. plantarum* MG32 and *P. pentosaceus* MG12 are the most common species of LAB found in fruit and vegetable fermentation that acid tolerance.

Foam-mat drying (FMD) is a potential method for generating dehydrated foods while preserving bioactive ingredients and natural qualities. In this method, liquid-solid foods are combined with stabilizing and/or foaming agents to create a stable foam. The mixture is then spread out on a tray and dried by air at temperatures between 40

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and 80°C before being scraped, ground, and sieved to produce powders (Abbasi and Azizpour, 2016; Shaari *et al.*, 2017). The benefits of the FMD method include its simplicity, lower drying temperatures, shorter drying time (reducing energy consumption), and more porous particles, which have better rehydration capacity, and a favorable sensory profile (Franco *et al.*, 2015). Some dairy products, including milk, yogurt, cream, and cheese (Izadi *et al.*, 2020), and fruit juice (Sansomchai *et al.*, 2023), have been successfully treated with FMD. To the best of our knowledge, the application of FMD for the manufacturing of non-dairy probiotic products presents a difficulty for the food sector despite the technique's well-documented benefits. Due to this, it has been suggested that foam-mat methods might be used to create fruit powders at a lower cost utilizing simple, low-cost equipment (Karim and Wai, 1999). However, there is little evidence that foam-mat techniques could be used to dry meals containing probiotic reinforcement. Based on the investigation, FMD does not impact the viability of lactic acid bacteria in dried yoghurt products. In addition, it serves to preserve the product's flavor, texture, and nutritional composition, including antioxidants (Krasaekoopt and Bhatia, 2012).

The goal of the study was to investigate the effects of producing probiotic-infused juice as non-dairy probiotic products using a foam-mat drying technique on the probiotics' ability to survive and the physicochemical properties of powder products. As a result, the development of fruit juice probiotic tablets under ideal circumstances, the probiotics' survival, the product's physicochemical quality, and antioxidant activity. The shelf life and consumer approval of the fruit juice tablets with probiotics were also examined.

2. Materials and methods

2.1 Materials

Food-grade methylcellulose (MC) and egg albumin (EA) were obtained from Chemipan Corporation Co., Ltd. (Bangkok, Thailand). These studies made use of the probiotic properties of fermented fruits and vegetables (Tanganurat *et al.*, 2015), *Lactobacillus plantarum* MG32 and *Pediococcus pentosaceus* MG12 for non-dairy products. Papaya, tomato, orange, and guava were purchased from the local market. (Pathum Thani, Thailand). Culture media and all other analytical-grade chemicals were purchased from Merck (Darmstadt, Germany).

2.2 Preparation of juice powder with probiotics

2.2.1 Juice preparation

The papaya, tomato, orange, and guava underwent a process of washing, peeling, and subsequent cutting into

pieces before being incorporated into the blender. The mixture was thoroughly processed using a juicer extractor (Sharp, SK-400) and then strained through a nylon mesh filter (400 micron). It was then heated to a temperature of 72°C and pasteurized for 15 min, performed in triplicate.

2.2.2 Probiotic cultures preparation

Lactobacillus plantarum MG32 and *P. pentosaceus* MG12 were cultured in MRS medium at 37°C for overnight. Following this, the cells were centrifuged for 5 mins at a speed of 5,000 rpm (Centrikon T-324, Kontron Instrument, Germany), and the cell pellets were further washed twice with 10 mL of saline solution (0.9% w/v). The cell suspension (9 log CFU/mL) will be utilized as culture (1:1) and filled into the juice by transplanting 5% (v/v) of each strain.

2.3 Foam-mat drying

The foaming experiment was designed with the foaming agent carboxymethyl cellulose (MC) (1.5 %w/v) and egg albumin (1, 2, and 3 % w/v). About 200 mL of homogenized juice was taken in a 1000 mL graduated transparent fiberglass container. The juices were whipped at the maximum speed (1200 rpm) for 15 mins using an electric mixer (Philips HR-3705/10 300 W Hand mixer) to obtain consistent foam before 2-5 mm of foam was applied on a Teflon-coated plate. After being hot air dried at 55°C (hot air oven) until the moisture content of the powdered product was 2-4% by AOAC Official Method 930.15 (AOAC INTERNATIONAL, 2000), the total acidity was determined by titratable acidity based on lactic acid, the pH was measured with a pH meter (Mettler Toledo, Switzerland), the water activity (Aqualab 4TE, Meter group, USA) was examined next to the product was packaged and stored.

The foam properties were characterized, such as foam expansion, foam stability, and foam density (Kumar *et al.*, 2022).

2.3.1 Foam expansion

Foam expansion or overrun refers to the amount of air contained in the juice when it is whipped along with the foaming agent. The foam expansion was determined by subtracting the initial volume of fruit pulp from the final volume of whipped foam, and then expressing the result as a percentage.

2.3.2 Foam stability

A volume of approximately 100 mL of juice foam was collected in a Bichner filter with a diameter of 80 mm. The filter was covered with filter paper and placed on a graduated cylinder at room temperature for 30 min.

The liquid juice volume that separated from the foam due to drainage, as well as the decrease in foam volume, was assessed as the foam stability expressed as a percentage.

2.3.3 Foam density

Approximately 50 mL of juice froth was put into a graduated measuring cylinder. Efforts were made to prevent the occurrence of air entrapment and the collapse of the foam structure. The weight and volume of foam were quantified, and the foam density was computed (g/cm^3).

2.4 Preparation of tablets

The different concentrations of maltodextrin at 2, 4, and 6% (w/w) combined with 32% (w/w) finely powdered white sugar and 2% (w/w) coconut oil, then the probiotic fruit juice powders were added (64, 62, and 60 %w/w). They were completely blended in a shaker mixer for 15 min and then formed into tablets by direct compression in a hand tablet press (Billion Nine, Thailand). The tablet's thickness was 6 mm, the average weight was 1.5 g, and its diameter was 1.5 cm. The solubility, antioxidant activity DPPH, vitamin C content, water activity, color measurements using the colorimeter in the Hunter unit ($L^* a^* b^*$), hardness tester, and the viability of lactic acid bacteria were all determined.

2.4.1 Color analysis

The color attributes were assessed based on the L^* , a^* , and b^* values using a chromameter (Konica Minolta, CR-410, Japan).

2.4.2 Solubility

One gram of the formulated tablet powder was mixed with 100 mL of distilled water and agitated on a magnetic stirrer at 600 rpm for 5 min. The resulting dispersed mixture was transferred to centrifuge tubes and centrifuged at $4000 \times g$ for 10 min. The supernatant was then subjected to drying at 105°C until a constant weight was achieved. The solubility percentage of the powder was determined by calculating the difference between the weights of the initial and residual dry substances (Caparino *et al.*, 2012).

2.4.3 DPPH scavenging activity

The antioxidant activity of the juice tablet was evaluated using spectrophotometry and the DPPH free radical scavenging method, following the procedure outlined by Tuan Azlan *et al.* (2023) with slight adjustments. In brief, 0.4 mL of a diluted sample was mixed with 5.6 mL of methanolic DPPH solution. The methanolic DPPH solution was prepared by dissolving

24 mg of DPPH in 100 mL of methanol. The solution was agitated at a speed of 2000 rpm for a duration of 1 min, followed by placement in a water bath set at a temperature of 37°C for a period of 30 mins. The UV-Vis spectrophotometer (Merck Spectroquant Pharo 300 Spectrophotometer, Germany) was utilized to measure the absorbance at a wavelength of 517 nm. Methanol was employed as a blank. A calibration curve was generated by utilizing a Trolox standard solution with concentrations varying from 0 to 1.0 mmol. The antioxidant activity was quantified as mmol TE (Trolox Equivalent) /100 mL.

2.4.4 Determination of vitamin C content

The vitamin C content in the juice tablet was assessed using the colorimetric method outlined by Mgaya-Kilima *et al.* (2014) with minor adjustments. In brief, 2 g of each sample were mixed with 0.2 mL of 10% Trichloroacetic acid (TCA) and diluted to 10 mL with distilled water. After thorough mixing, the mixture was left to stand for 1 min and then filtered with filter paper. The filtered sample (2 mL) was combined with 6 mL of distilled water and 0.8 mL of Folin-Ciocalteu reagent, followed by incubation in the dark at room temperature for 10 min. The absorbance was measured at 760 nm using a UV-Vis spectrophotometer (Merck Spectroquant Pharo 300 Spectrophotometer, Germany) with distilled water used as a blank. A standard curve was constructed using an ascorbic acid standard solution ranging from 0 to 25 mg/100 mL, and the vitamin C content in the sample was expressed as mg/100 mL.

2.4.5 Water activity

Water activity was determined using a water activity meter (Aqualab 4TE, Meter Group, USA).

2.4.6 Mechanical strength test

Tablet hardness was measured by a hardness tester (Scilution, Thailand).

2.5 Stability of the probiotics juice tablets during storage

Probiotics were determined using microbial count studies of samples taken both before and after drying. The tablets were stored and determined for three months at room temperature ($30\text{-}35^\circ\text{C}$) and refrigerator ($4\text{-}10^\circ\text{C}$) on 0, 30, 60, and 90 days of microbial viability obtained by the pour plate technique on MRS Agar (Merck) culture medium. A 1 g amount of powder or tablet was added to 9 mL of buffered peptone water (BPW). After 2 mins, a 1 mL aliquot was collected to prepare a serial dilution. The probiotics log CFU count was then obtained after incubation at 37°C for 72 h. All experiments were conducted in triplicate.

2.6 Experimental design and statistical analysis

This experiment used a Completely Randomized Design (CRD) to analyze the data. All experiments were repeated at least three times. Results are reported as mean \pm standard deviation using the SPSS Statistics program. The statistical significance among various samples was evaluated with one-way ANOVA at a significant level ($p < 0.05$).

3. Results and discussion

According to the chemical quality analysis of four juices: guava, orange, papaya, and tomato, the results are shown as shown in Table 1. The chemical characteristics of fruit juices were analyzed for pH, TSS, total acidity, and vitamin C content. The result showed that the guava juice provided the highest vitamin C content (169.15 mg/100 mL) followed by papaya juice (102.87 mg/100 mL), tomato juice (32.23 mg/100mL), and orange juice (18.44 mg/100 mL), respectively. The ascorbic acid content in fruit juices plays an important role in human health and is considered an indicator parameter of quality. Hence, careful quantification of the level of vitamin C in fruit juices is of great importance (Devolli *et al.*, 2021). The pH ranged from 3.60-5.17, total acidity ranged from 0.17-0.64% and total soluble solids (TSS) contained 4.70-11.10 °Brix. Guava juice has the lowest pH, and orange juice has the highest total soluble solids, while the total acid content in citric form showed that tomato juice was the highest, and the ascorbic acid content by titration showed that the guava juice was statistically the highest ($p < 0.05$).

Afterwards, the foam was prepared with vegetable and fruit juice with methylcellulose (1.5 w/v) and egg white powder (1, 2, and 3 w/v), then whipped the foam for 15 mins with the highest speed blender. The foam qualities and stability were assessed by analyzing the foam characteristics, as depicted in Figure 1. The objective was to identify the optimal conditions that result in the foam having the lowest density and most stability, or the lowest drainage volume. It was found that 1.5% methylcellulose and 3% egg white powder provided the best foam properties. Increasing the concentration of EA reduces surface tension due to the

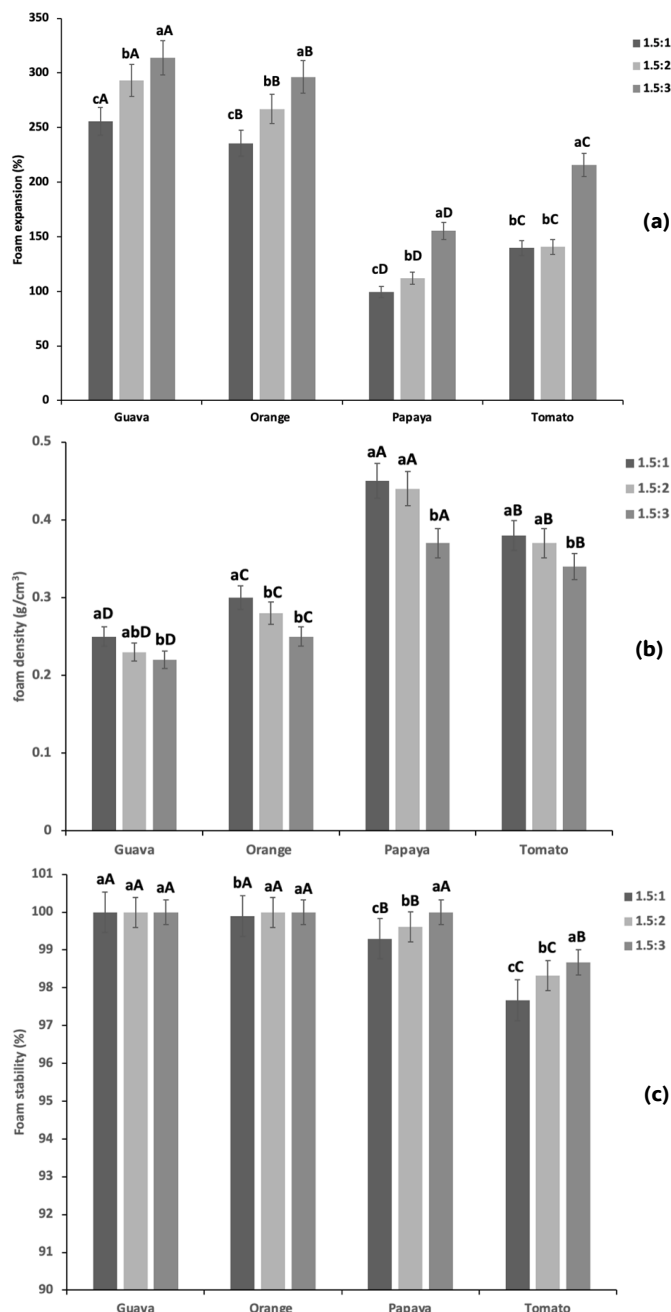


Figure 1. Effect of methylcellulose (MC) and egg albumin (EA) concentration on foam properties in various juices: (A) foam expansion, (B) foam density and (C) foam stability. Bars with different lowercase superscripts among fruits and different uppercase superscripts in the MC:EA ratio are statistically significantly different.

movement of foam ingress from the liquid phase to coordinate the air and liquid parts. This mechanism leads to an increase in foam ingress and reduced density, which is consistent with the research of Falade *et al.*

Table 1. pH, Total soluble solid, total acidity, and ascorbic acid content of juices.

Juices	pH	Total soluble solids (°Brix)	Total acidity (%)	Titrateable ascorbic acid (mg/100 mL)
Guava	3.53 \pm 0.03 ^d	9.70 \pm 0.05 ^c	0.63 \pm 0.01 ^a	169.15 \pm 0.02 ^a
Orange	3.80 \pm 0.01 ^c	11.10 \pm 0.10 ^a	0.13 \pm 0.01 ^d	18.44 \pm 0.02 ^d
Papaya	4.47 \pm 0.02 ^a	10.50 \pm 0.10 ^b	0.57 \pm 0.01 ^b	102.87 \pm 0.03 ^b
Tomato	4.06 \pm 0.01 ^b	4.70 \pm 0.15 ^d	0.24 \pm 0.01 ^c	32.23 \pm 0.02 ^c

Values are presented as mean \pm SD. Values with different superscripts in the same column are statistically significantly different ($p < 0.05$).

(2003) and Krasaekoopt and Bhatia (2012) for yogurt powder produced by foam-mat drying methods, and when increasing the concentration of methylcellulose increases, the flow rate decreases due to increased viscosity. The outcomes demonstrated that the foam volume escalated in correlation with higher concentrations of egg albumin (1%, 2%, and 3%, respectively). Nevertheless, the stability of air bubbles at lower egg albumin concentrations wasn't consistent due to the inadequacy of forming an interfacial film. The augmentation in foam volume could be attributed to the creation of a solid interfacial film, achieved by denaturing egg albumin's protein molecules during the whipping process. This phenomenon results in the interfacial film's heightened capacity to catch and retain larger amounts of air, ultimately leading to the expansion of the foam. On the other hand, a decrease in the amount of foam can be linked to the application of mechanical force on the foam bubbles, leading to their collapse. The phenomenon described here is consistent with findings reported by Kumar *et al.* (2022) in their study on mango pulp, Kandasamy *et al.* (2014) in their investigation of papaya pulp, Franco *et al.* (2015) in their analysis of yacon juice, and Shaari *et al.* (2017) in their examination of pineapple fruit. In all these studies, it was observed that the foam expansion increased as the concentration of the foaming agent increased during the whipping process.

The findings indicated a noteworthy reduction in foam density as the concentration of egg albumin increased. Furthermore, a significant decrease in foam density was observed when the egg albumin concentration increased for all kinds of juice. The foam densities of guava, orange, papaya, and tomato ranged from 0.22-0.25, 0.25-0.3, 0.37-0.45, and 0.34-0.38 g/cm³ were recorded, for MC:EA ratios of 1.5:1, 1.5:2, and 1.5:3.

A consistent trend of decreasing foam density was observed with higher levels of foaming agents. However, incorporating methylcellulose and egg albumin beyond 1.5:1, 1.5:2, and 1.5:3 leads to a non-significant foam density and foam stability. The decreased foam density at greater egg albumin concentrations might be attributed

to the extensive air entrapment within the juice during whipping. This process subsequently diminishes the surface and interfacial tension of the liquid, facilitating the formation of an interfacial film exceeding the critical thickness. Consequently, the optimal foaming condition appeared to be 1.5% methylcellulose and 3% egg albumin, yielding a foam density of 0.23-0.37 g/cm³ depending on the kinds of juice. Similar trends of decreasing foam density were noted for cowpea (Falade *et al.*, 2003), bael fruit (Bag *et al.*, 2011), pineapple fruit (Shaari *et al.*, 2017), and mango pulp (Kumar *et al.*, 2022). The literature suggests that the density of food foams for foam-mat drying typically falls within the range of 0.3–0.6 g/cm³ (Kumar *et al.*, 2022). In addition, increased viscosity prevents the tearing of the thin film layer of bubbles formed inside the foam (Abbasi and Azizpour, 2016). Then, the range of conditions that cause the most foam stability to dry the foam mat and the properties of foam in different juices when adding 1.5% methylcellulose (w/v) and 1-3% egg white powder (w/v) were investigated. The foam in guava juice does not contain any liquid that is separated from the foam at all, and tomato juice has the most drainage volume from the foam compared to other juices.

Considering the physicochemical properties of different powdered juices at the 1.5% methylcellulose and 3% egg white powder conditions, which cause the most stable foam for foam mat drying, were examined. According to Table 2, the moisture content in the samples was between 2.83 to 3.50. The water activity of the powdered juice ranged from 0.21 to 0.30, indicating that the powder is stable concerning microbial activity (water activity < 0.6) (Naji-Tabasi *et al.*, 2021). A crucial requirement for expediting the drying process, achieving porous dried goods, and preserving the nutritional value of the final product is the presence of foam that is both low in density and steadfast (Kumar *et al.*, 2022). Hence, Guava exhibited the most robust foam stability under identical conditions of foaming agent, whipping duration, and drying time, leading to the lowest moisture content.

The total soluble solids in orange juice were higher than in guava, papaya, and tomato juice, respectively.

Table 2. Moisture content, water activity, total soluble solids, and pH of powdered juice from foam-mat drying at MC:EA (1.5:3).

Juice powder	Moisture (%) ^{ns}	Water activity ^{ns}	Total soluble solids (°Brix)	pH
Guava	2.83±0.34	0.28±0.02	12.37±0.06 ^b	3.53±0.01 ^c
Orange	2.97±0.02	0.30±0.01	15.02±0.00 ^a	3.97±0.01 ^b
Papaya	3.38±0.18	0.31±0.00	12.23±0.06 ^b	4.42±0.01 ^a
Tomato	3.50±0.21	0.36±0.01	5.40±0.00 ^c	4.04±0.01 ^b

Values are presented as mean±SD. Values with different superscripts in the same column are statistically significantly different (p<0.05).

The pH and TSS values for each fruit type align with those of the juice before the drying process, suggesting that they are likely to remain consistent throughout. Table 3 displays color values that seem to be influenced by the inherent characteristics of papaya and tomatoes, including beta-carotene and lycopene content. As a result, a* color value is higher in these fruits compared to guava juice.

Table 3. Color value of powdered juice from foam-mat drying.

Juice powder	Color		
	L*	a*	b*
Guava	84.87±0.08 ^a	1.37±0.10 ^c	16.35±0.19 ^d
Orange	80.87±0.06 ^b	12.93±0.17 ^b	38.16±0.64 ^a
Papaya	71.23±0.12 ^d	19.07±0.29 ^a	35.68±0.36 ^b
Tomato	74.90±0.05 ^c	13.93±0.18 ^b	26.97±0.36 ^c

Values are presented as mean±SD. Values with different superscripts in the same column are statistically significantly different ($p < 0.05$).

The probiotic fruit tablet, which includes a probiotic supplement, consists of maltodextrin (2%, 4%, and 6%), finely crushed white sugar, and coconut oil, blended with fruit juice powder (60-64%). The tablet's resistance to fracture during storage, transport, and transfer prior to use is contingent upon its hardness. The tablet hardness is a significant and influential feature in the disintegration process, serving as an indicator of the density of the tablet components. The fruit tablets exhibited a hardness of 39-40 N. The study found that there was no significant difference in hardness between the juice powder, which accounted for 60-64% of the mixture, and the maltodextrin, which accounted for 2-6% of the mixture. Nevertheless, the tablet's hardness was found to be positively correlated with the quantity of juice powder used (Naji-Tabasi *et al.*, 2021). Maltodextrin functions as a firmness modifier, exerting an impact on the texture. The hardness should be at least 30 N, as recommended by Nagashima *et al.* (2013). Therefore, the formula utilizing 6% maltodextrin was selected for the analysis of physical and chemical quality, as shown in Table 4.

Table 4 displays the physicochemical characteristics of various probiotic juice tablet products, indicating that

Table 4. Solubility, water activity, titratable ascorbic acid, and DPPH scavenging activity of probiotic juice tablets.

Juice Tablet	Solubility (%) ^{ns}	Water activity ^{ns}	Titratable ascorbic acid (µg/mL)	DPPH scavenging activity (mg Trolox eq./g)
Guava	65.00±0.01	0.33±0.00	106.72±0.03 ^a	79.31±0.01 ^a
Orange	69.99±0.01	0.34±0.00	10.24±0.31 ^c	49.06±0.04 ^c
Papaya	63.88±0.12	0.32±0.00	81.38±0.17 ^b	58.03±0.01 ^b
Tomato	67.36±0.14	0.37±0.00	16.40±0.29 ^c	55.06±0.02 ^b

Values are presented as mean±SD. Values with different superscripts in the same column are statistically significantly different ($p < 0.05$).

the solubility percentage did not show any statistically significant differences. Regarding ascorbic acid and DPPH antioxidant activity, Guava exhibited the highest vitamin C content compared to other fruit tablets. Nonetheless, the vitamin C content of the tablet product showed a 50% reduction in comparison to that of fresh juice. The study also investigated the survival of probiotic cells in the product during storage for 90 days using aluminum box packaging with moisture-proof envelopes in a refrigerator (4-10°C) and room temperature (30-35°C).

Figure 2 displays the outcomes of assessing the viability of probiotics (*L. plantarum* MG32 and *P. pentosaceus* MG12) in powdered and tablet forms after being stored at 4-10°C and 30-35°C for a period of 90 days. In the case of the probiotic powder, the findings reveal only a minor decline in microbial concentration during the foam-mat drying period and resulting in a 1.0-1.3 logarithmic decrease (Figure 2A). In the previous study, Krasaekoopt and Bhatia (2012) observed a little reduction of 0.5 Log-CFU in foam mat-dried yogurt when dried in an oven at 60°C. The final product had bacterial counts ranging from 10⁷ to 10⁸ CFU/g. This drying method offers the advantage of quick drying at lower temperatures. In addition, *L. plantarum* MG32 and *P. pentosaceus* MG12 originated from plant sources; thus, both species held a better level of viability in the fruit juice. Except for the papaya and tomato tablets, a noteworthy reduction in microbe concentration (about 0.5 logarithmic cycles) was seen for the probiotic juice tablets. In contrast, the probiotic juice tablets saw a notable reduction in the concentration of microorganisms (about 2-3 logarithmic cycles) when stored at temperatures between 30-35°C for a duration of 90 days (Figure 2C). A temperature of 37°C can result in a substantial decrease in cell viability. Furthermore, the presence of oxygen and moisture might have a negative impact on dry cultures. The study conducted by Jannah *et al.* (2022) compared the cell viability of vacuum-packed and non-vacuum probiotic instant coffee at various storage temperatures. The results showed that the vacuum-packed probiotic instant coffee exhibited higher cell viability compared to the non-vacuum samples. Figure 2 (B, C) indicates that the probiotic juice tablets

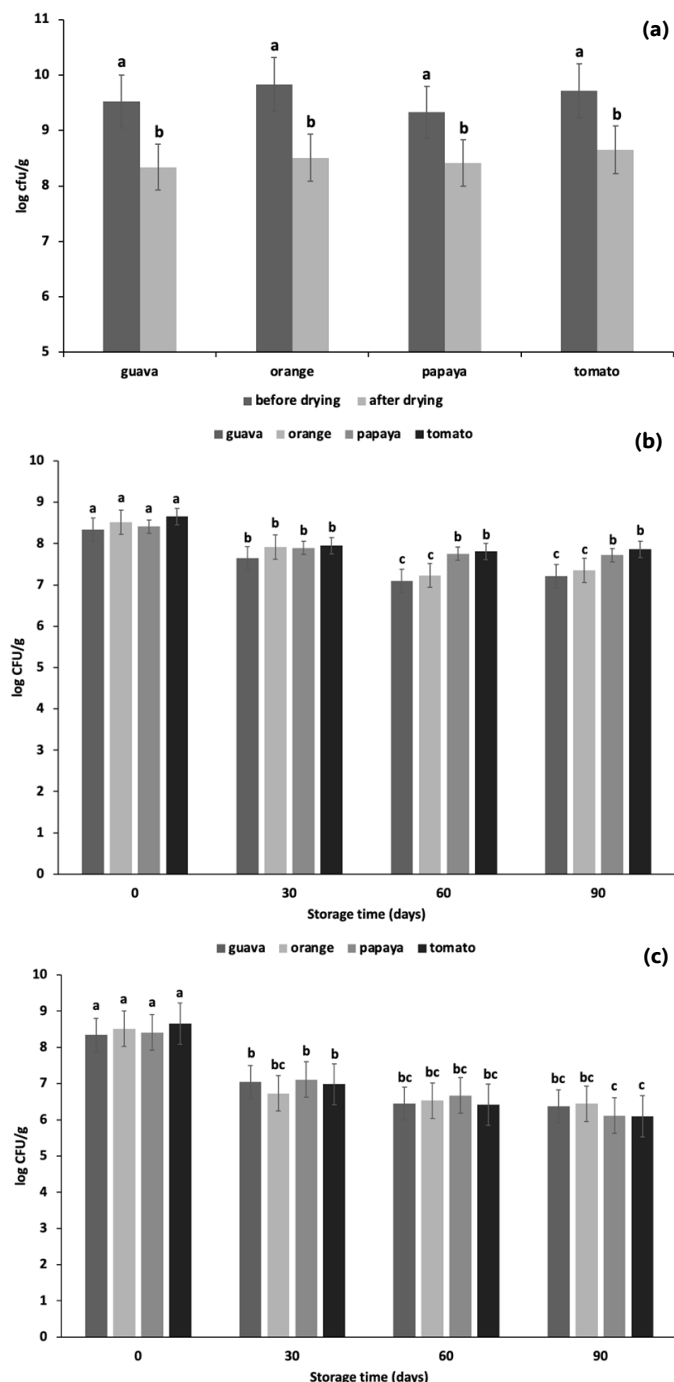


Figure 2. Survival of probiotics in juice tablets during storage: (A) drying, (B) refrigerator and (C) room temperature. Bars with different notations are statistically significantly different ($p < 0.05$).

held at 4°C exhibited the maximum vitality (7-8 log CFU/g) compared to the other treatments stored at 30-35°C. Cells are held at temperatures near 0°C to minimize the occurrence of detrimental chemical reactions. Probiotics are believed to produce therapeutic benefits when they are viable and present in high concentrations, typically at least 10^8 - 10^9 per gram of product (Shah, 2001). Furthermore, the inclusion of O₂ in the packing leads to the oxidation of membrane lipids and denaturation of proteins, which ultimately leads to the breakdown of macromolecules within bacterial cells (Jannah *et al.*, 2022). Hence, it has been noted that the

survival of *L. acidophilus* and *S. boulardii* in effervescent powder and tablet forms remained stable when stored at 25°C for 60 days. The effervescent probiotic powder showed only a slight decrease in microbial concentration during storage, less than 0.3 logarithmic cycles, for both probiotic strains. In contrast, the effervescent probiotic tablets experienced a more significant reduction in microorganism concentration, around 2.3 logarithmic cycles. This decline was associated with higher compression forces applied to the tablets, which may have impacted the microorganisms' viability (Nagashima *et al.*, 2013). Nevertheless, it was documented that the viability of probiotic strains added to various juices declined by approximately 3 to 4 log CFU/g during storage. It is evident that the survivability of lactic acid bacteria differs among strains, but it is also greatly influenced by the type and quality of the carrier medium (Nguyen *et al.*, 2019). The appearance of probiotic juice products is depicted in Figure 3.



Figure 3. The appearance of probiotic pellet juice products.

In conclusion, the development of probiotic juice in the form of tablets offers a convenient and easily consumable option for obtaining fruits with probiotic microorganisms. The research involved studying various aspects, such as fruit types, foaming agents, tablet ingredients, and the characteristics of the fruit pellets to ensure the survival of probiotics and maintain the physicochemical and antioxidant activity of the product. Through experimentation, it was determined that the most stable foam conditions were achieved by drying the foam mat in different juices, incorporating 1.5% methylcellulose (w/w) and 3% egg albumin powder (w/w). Probiotic tablets were formulated with different fruit powders and 6% maltodextrin. This research revealed that probiotics remained viable at levels above 6-7 log CFU/g and persisted in the tablet products for 3 months, this complies with the standard for probiotic supplements. The results of our study demonstrated the creation of a foam-mat drying technique using probiotic-infused juice in tablet form. Hence, it is necessary to

enhance the viability of probiotics in various fruit tablet packaging to optimize storage conditions.

Conflict of interest

The authors affirm that the study was carried out without any commercial or financial affiliations that might be interpreted as a possible conflict of interest.

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