

Research article

DEVELOPMENT OF SYNBIOTIC MARSHMALLOW USING INDIGENOUS PROBIOTIC *LACTOBACILLUS PLANTARUM* DAD-13 AND KONJAC GLUCOMANNAN

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Abstract

A synbiotic food is a dietary product that combines probiotic and prebiotic properties. People prefer healthy food and snacks that offer health benefits. A synbiotic marshmallow incorporating *L. plantarum* Dad-13 and konjac glucomannan has been developed, yet sensory acceptance and characterization have not been conducted. This study aimed to examine consumer acceptance and the effect of konjac glucomannan substitution on the characteristics and sensory acceptance of synbiotic marshmallows. A consumer survey was conducted to evaluate consumers' knowledge of probiotics, prebiotics, and synbiotics and their intention to buy the product. Synbiotic marshmallows were produced by combining a sugar solution (sucrose and glucose) with gelatin and konjac glucomannan in certain concentration ratios of P1 (9%:0%), P2 (8.5%:0.5%), P3 (8%:1%), P4 (7.5%:1.5%), and P5 (7%:2%) (w/v), followed by the addition of probiotic powder *L. plantarum* Dad-13. The experiment was designed using a Completely Randomized Design, and the non-parametric data were analyzed using Kruskal-Wallis followed by the Mann-Whitney U Test. Sensory evaluation, including Just-About-Right (JAR) and penalty analyses, and the viability of *L. plantarum* Dad-13, were also evaluated. Survey results indicated that consumers had knowledge of the health benefits of probiotics, prebiotics, and synbiotics. The substitution of gelatin and konjac glucomannan at 8.5%:0.5% was the most preferred formula for all sensory attributes (color, aroma, texture, and taste). The addition of konjac glucomannan did not affect the viability, which remained at 6.33 ± 0.07 log CFU/g. However, JAR and penalty analyses indicated that the sweetness intensity of P2 required adjustment to improve consumer acceptance.

1. Introduction

People who follow a modern diet prefer foods high in fat and low in fiber. This condition can alter the average balance of the microflora in the large intestine, leading to various

disorders. Consuming probiotics is one strategy to combat the disruption of the natural microbiota of the large intestine (Zhang et al., 2019). Probiotics have physiological effects, including antihypertensive, anticholesterol,

anticarcinogenic, anti-lactose intolerance, protection against digestive tract diseases, and allergy prevention (Kechagia et al., 2013). Most probiotic strains are lactic acid bacteria from *Leuconostoc*, *Lactobacillus*, *Lactococcus*, *Pediococcus*, and *Streptococcus* (Ringø et al., 2020). Probiotics reduce harmful bacteria by producing antimicrobial components and vying for resources and colonization sites (Chen et al., 2020a). Fermented foods, such as yogurt, kefir, and tape (fermented cassava), are well-known probiotic foods, particularly in Indonesia. The demand for fermented products has increased because consumers believe that only fermented foods can offer health benefits. To enhance diversity and creativity in probiotic foods, products that contain probiotics without requiring fermentation must be developed; however, this remains challenging.

Variations of popular products are common in nibbles, which are often consumed as snacks. Gummy probiotic *L. plantarum* Dad-13 has been developed and can be used as a carrier for undernourished children's treatment (Kamil et al., 2021, 2022). Further studies have investigated how confectionery items, such as chocolate (Rahayu et al., 2024) and jelly candy (Kahraman et al., 2023), can be used to deliver probiotics. In addition, marshmallow is a popular snack among the general population and are soft confections shaped like a light, soft, and chewy foam and come in various flavors, smells, and colors. Previous research has demonstrated the potential of marshmallows as a carrier matrix for probiotic bacteria, including *Lactobacillus rhamnosus* (Colmenares-Cuevas et al., 2024). Marshmallows are manufactured with gelatin, which can form gels and foams. Gelatin is a derivative protein from bone and skin collagen hydrolysis with gelling, stabilizing, emulsifying, thickening, and foaming properties (Mardani et al., 2019). To improve the texture of marshmallows, gelling agents can be added, including konjac glucomannan. Konjac glucomannan is a polysaccharide consisting of D-mannose and D-glucose at a ratio of 1.6:1 and β (1-4) linkages and can be used as a gelling agent and dietary fiber with reported prebiotic potential (Al-Ghazzewi & Tester, 2012).

Therefore, the concentrations of gelatin and konjac glucomannan influence marshmallow quality.

Probiotic products must have a desirable and viable probiotic cell. The efficacy dose of probiotic food is in the range of 6 to 9 log CFU/g or /mL (Barbosa et al., 2015). In addition, processing can affect bacterial cell viability (Tripathi & Giri, 2014). The combination of probiotics and prebiotics is defined as synbiotics, and in this research, *L. plantarum* Dad-13 and konjac glucomannan are used to develop synbiotic marshmallows. According to Indriyanti et al. (2015), a synbiotic product contains probiotics as living microorganisms and their substrates, namely, prebiotics, to promote the growth of probiotic bacteria. *L. plantarum* Dad-13 was utilized in this research because it is a local probiotic bacterium isolated from spontaneously fermented buffalo milk.

A marshmallow formulation incorporating konjac glucomannan and the probiotic *L. plantarum* Dad-13 has been successfully developed (Bintoro et al., 2024). The optimal composition consists of 8.5% gelatin and 0.5% konjac glucomannan. However, an evaluation of consumer acceptance for this product has yet to be conducted. Although konjac glucomannan is recognized for its potential prebiotic properties and its ability to act as a synbiotic when combined with probiotics, this evidence does not universally confirm its prebiotic functionality in all food formulations. Therefore, this research focuses on sensory evaluation relative to commercial marshmallows and the characterization of the optimal formula. Consumer acceptance surveys are necessary to determine whether the community can accept food products. This is because consumers are the focal point of the marketing process, and understanding their needs leads to appropriate and efficient product development (Montossi et al., 2013). Consumer expectations are believed to substantially influence product quality and satisfaction (Chen et al., 2020b). Therefore, this study aimed to evaluate the effect of two gelling agent combinations, gelatin and konjac glucomannan, on the characteristics of synbiotic marshmallows and their sensory properties.

2. Material and Methods

2.1. Material

The bacterial strain used in this study was a skim milk powder containing the probiotic *L. plantarum* Dad-13, which was supplied by the Centre for Food and Nutrition Studies, Universitas Gadjah Mada, Indonesia, and was produced following the method of Kamil et al. (2020). The production of skim milk powder containing *L. plantarum* Dad-13 involved mixing the *L. plantarum* Dad-13 pellet with 10% (w/v) skim milk and 1% (w/v) sucrose. The resulting suspension was frozen at -40°C for 24 hours, then freeze-dried for 72 hours. The initial viable cell count of the probiotic powder was 3×10^9 CFU/g, and the skim milk powder was stored at refrigerated temperature (4°C) before use. The ingredients for marshmallow production were as follows: bovine gelatin (Hakiki, Indonesia), konjac glucomannan (El Masta, Indonesia), sucrose (Gulaku, Lampung, Indonesia), glucose (Fortune, Indonesia). In addition, de Man, Rogosa, and Sharpe (MRS) agar (Merck, Germany) was used for lactic acid bacteria enumeration.

2.2. Methods

2.2.1. Synbiotic marshmallow production

Synbiotic marshmallows were prepared following the method of Bintoro et al. (2024). Bovine gelatin (Hakiki) and konjac glucomannan (El Masta) were soaked in 20 mL of warm water (35°C) for 15 minutes for each treatment: P1: 9:0 % w/v, P2: 8.5:0.5 % w/v, P3: 8:1 % w/v, P4: 7.5:1.5 % w/v, and P5: 7:2 % w/v. A sugar solution was prepared by boiling (105°C–115°C) 150 g sucrose (Gulaku), 45 g glucose (Fortune), and 45 mL water until they completely dissolved. The soaked gelatin and konjac glucomannan were added to the sugar solution and whipped at high speed with a mixer (Philips, China) until foaming was observed. Fifteen-gram skim milk powder containing *L. plantarum* Dad-13 was added to the mixture at 40°C, then slowly whipped until evenly incorporated. The mixture was then molded, left to cool at room temperature ($\pm 25^\circ\text{C}$) for 1 hour, and stored in the chiller (4°C) for 24 hours. The marshmallow was then cut and packed in an

aluminum-sealed pouch and stored until further use for analysis. The production was conducted 3 batches for each formula.

2.2.2. Consumer survey of synbiotic knowledge

A consumer survey was conducted following the method of Kamil et al. (2021). This survey aimed to determine consumers' knowledge regarding the health benefits of synbiotic products and consumers' intention to purchase synbiotic marshmallows. The survey was conducted using an online form targeting teenage to adult consumers (19–60 years old), as they represent the target consumer group. Before participating in the survey, respondents were informed that their personal data would be collected solely for research purposes, treated confidentially, and not disclosed to third parties. Participation was voluntary, and respondents provided their consent before completing the questionnaire. Each correct answer was scored 1, and each wrong answer was scored 0. The obtained score was then classified as good (>75% correct answers), fair (50%–75% correct answers), and low (<50% correct answers). Consumers' intention to buy the product was assessed using yes/no questions.

2.2.3. Viability of *L. plantarum* Dad-13

The viability of *L. plantarum* Dad-13 was quantified by the pour plate method. In brief, 1 g of the sample was homogenized with 9 mL of 0.85% NaCl. At the appropriate dilution series, 1 mL of bacterial suspension was placed in a Petri dish and covered with de Man, Rogosa, and Sharpe (MRS) agar medium (Merck). NaCl solution and MRS medium were sterilized using an autoclave (Hiramaya, Japan) before use. Once the medium solidified, the inoculated Petri dish was incubated at 37°C for 48 hours using an incubator (Mermmert, Germany).

2.2.4. Sensory evaluation of synbiotic marshmallows

Sensory evaluation of synbiotic marshmallows was conducted at the sensory laboratories of the food technology department, Universitas Diponegoro, in accordance with ISO 8586:2012, which provides guidelines for the selection, training, and monitoring of assessors and expert sensory assessors. Participation in the sensory evaluation was voluntary. Prior to the

test, participants were informed about the study objectives and provided their consent. The product tasting was not conducted for medical intervention purposes, but solely for sensory evaluation to obtain product descriptions and assess consumer acceptance by the panelists. All collected data were treated confidentially and used only for research purposes. All the panelists involved in this research had no allergies to the synbiotic marshmallows ingredients, i.e., gelatin and skim milk. They also had no history of lactose intolerance.

2.2.5. Hedonic and preference tests of synbiotic marshmallows

Hedonic and preference tests were conducted with 50 panelists aged 20 and older to evaluate the sensory attributes of synbiotic marshmallows. A preference test was conducted to determine the best formula. In both tests, no control sample (no addition of konjac glucomannan) was used to evaluate the effect of konjac glucomannan addition on the panelists' preferences. This was because the study was primarily designed to focus on the sensory acceptance and perception of marshmallows formulated with konjac glucomannan as the gelling agent, rather than to compare them with a conventional formulation. In the hedonic test, the panelists were served freshly made synbiotic marshmallows, each with three random codes. The panelists were asked to evaluate their overall liking regarding the specific sensory attributes of synbiotic marshmallows, namely, color, taste, texture, and flavor. The hedonic scale consists of seven levels: dislike very much (1), dislike (2), slightly dislike (3), neither like nor dislike (4), slightly like (5), like (6), and like very much (7). The hedonic data were represented as mean $\pm$ SD and categorized into three different groups following the study of Lim et al. (2022) to determine the panelists' liking: T3B liking (Top 3 Box Rating), B3B liking (Bottom 3 Box Rating), and neutral. The preference was determined by calculating the percentage of panelists who selected the formula.

2.2.6. Descriptive and penalty analysis of synbiotic marshmallows

A descriptive test was performed to evaluate the sensory profile of the selected synbiotic marshmallow formula. Penalty analysis was also conducted to determine specific sensory attributes that must be improved and to verify which sensory attributes are essential for product acceptability. In both tests, control (P1) and commercial marshmallow (Corniche) were used for comparison. The observed sensory profile reflected the sensory attributes the panelists expected from the products, based on the discussion. Twenty panelists were briefed before the actual evaluation and informed of the definition of evaluated sensory attributes for each sample, namely, appearance (balanced proportions, softness, glossiness, and brightness), texture (hardness, chewiness, gumminess, porosity, and sandy), flavor (sweet, vanilla, and foreign), and taste (sweet, milky, sour, fermented, and foreign). All the panelists had experience and were familiar with sensory evaluation. A five-point just-about-right (JAR) scale was used, following Lim et al. (2022), with 3 representing just right, 1 the lowest intensity, and 5 the highest. For example, for foreign taste, the JAR scale was as follows: 1, too weak; 2, slightly weak; 3, just right; 4, slightly strong; and 5, too strong. The JAR data were further analyzed using penalty analysis.

2.2.7. Proximate analysis of synbiotic marshmallows

Proximate analysis was performed on the most preferred formula and followed the method specified in the Indonesian Standard for Chewy Candy (SNI 3547.2-2008). The Gross energy of synbiotic marshmallows was estimated using Atwater's conversion factors.

2.2.8. Texture analysis of synbiotic marshmallows

Texture analysis was performed for the most preferred formula using texture profile analysis (Micro-Vickers Hardness Testing Machines), with the conditions as follows: trigger (2.0g), deformation (10 mm), and speed (1mm/s). The used probe was a cylindrical probe with dimensions (L: 20 mm, D: 38.1 mm).

2.2.9. Data analysis

Statistical analysis was conducted using IBM Statistics SPSS 26.0 for Windows. Analysis of non-parametric data was performed using Kruskal-Wallis followed by the Mann-Whitney U Test. Penalty analysis was performed using XLSTAT programs (version 2021.4; Addinsoft, Paris, France). Data were considered statistically different when the p-value <0.05.

3. Results and Discussion

3.1. Consumer behavior and synbiotic products knowledge

A total of 198 individuals (58.5% female and 41.5% male) with an average age of 21 years participated in this survey. The cumulative data from the survey indicated that most of the respondents (90.50%) had good knowledge regarding the health benefits of prebiotics, probiotics, and synbiotic, who received information from the Internet (56%), followed by television advertisements or social media (16.5%), product packaging (11%), books (7%), printed media (7%), and other resources (8.5%). According to Kamil et al. (2021), aggressive media information of the health benefits of probiotic consumption is affecting consumers' knowledge and awareness of a healthy lifestyle. Consequently, the trend in consuming probiotics, prebiotics, and synbiotics has expanded significantly. Lerner et al. (2019) stated that the probiotic market is still rising and will exceed 3 billion US dollars by 2024.

The questionnaire also asked respondents why they consume probiotics, prebiotics, and synbiotics. The results showed that 68.5% of respondents cited health benefits, and 22.5% cited good taste. Probiotics, prebiotics, and synbiotics are usually fermented products in the form of desserts and snacks (i.e., yogurt, kefir, and fermented cassava). The survey on snack consumption frequency indicated that 39.5% of respondents answered "frequently" (more than once a week), 27.5% answered "once a week," and 24% answered "rarely." By a margin of 33.5%, people preferred chips over other types of snacks. Confectionary products came in second (27%), followed by cake and bread (17.5%), biscuits (12.5%), and other types of

snacks (5%). This result indicated a promising future for the development of confectionery goods.

Furthermore, the intention to buy symbiotic marshmallows was high, with 86% of the 200 respondents indicating they would. The high degree of knowledge and customer intention to buy drives the development and introduction of novel synbiotic products to the market in the form of marshmallows. Therefore, innovations of marshmallow synbiotics are challenging yet have high potential.

3.2. Hedonic and preference tests of synbiotic marshmallows

Table 1 lists the results of the hedonic and preference tests for synbiotic marshmallows. No significant differences in any of the evaluated sensory attributes were observed among the treatments. The combination of gelatin and konjac glucomannan at an 8.5%:0.5% (P2) ratio scored higher on T3B liking for color, texture, and taste attributes than all other treatments. However, the highest T3B score for flavor characteristics was achieved by the treatment with P5, a combination of gelatin and konjac glucomannan at a 7%:2% ratio. Despite the lack of significant differences among gelling agent ratios, P2 was the most-liked synbiotic marshmallow among the panelists, as indicated by the T3B results. This finding also aligned with P2 receiving the highest percentage of preference. According to Samant et al., (2017), consumer preference could be used to characterize product acceptance. Therefore, P2 treatment was selected for further sensory profiling.

Color is one of the factors that determine product acceptance. Overall, the synbiotic marshmallows were white, indicating that advanced caramelization did not occur during production. According to Kurt et al. (2022), the brownish color of the confectionery product is a result of carbohydrate degradation, particularly sugar, at high temperatures. Whipped gelatin gave the synbiotic marshmallow a white color, which indicates its excellent quality (Koli et al., 2012). The absence of differences in color attributes suggested that the distinguishing

gelling-agent ratio has minimal effect on color and therefore does not influence the panelists' preference scores. The aroma of marshmallows comes from boiling sugar, which creates a

distinct flavor and aroma. In this research, the same sugar and vanilla flavor were used for all treatments. Therefore, no significant difference in flavor and taste was observed.

Table 1. Results of hedonic and preference tests of synbiotic marshmallows

		P2	P3	P4	P5
Color	B3B (%)	2	2	2	4
	Neutral (%)	22	32	28	28
	T3B (%)	76	66	70	68
	Mean $\pm$ SD ^{ns}	5.40 $\pm$ 1.03	5.32 $\pm$ 1.08	5.34 $\pm$ 1.12	5.22 $\pm$ 1.04
Flavor	B3B (%)	16	16	14	16
	Neutral (%)	26	20	38	10
	T3B (%)	58	64	48	74
	Mean $\pm$ SD ^{ns}	4.84 $\pm$ 1.35	5.12 $\pm$ 1.45	4.62 $\pm$ 1.29	5.12 $\pm$ 1.22
Texture	B3B (%)	20	32	28	26
	Neutral (%)	22	14	24	30
	T3B (%)	58	54	48	44
	Mean $\pm$ SD ^{ns}	4.76 $\pm$ 1.38	4.52 $\pm$ 1.42	4.38 $\pm$ 1.58	4.30 $\pm$ 1.30
Taste	B3B (%)	8	16	18	12
	Neutral (%)	10	12	18	16
	T3B (%)	82	72	64	72
	Mean $\pm$ SD ^{ns}	5.42 $\pm$ 1.18	5.08 $\pm$ 1.34	4.80 $\pm$ 1.43	4.94 $\pm$ 1.30
Preference		36%	24%	24%	16%

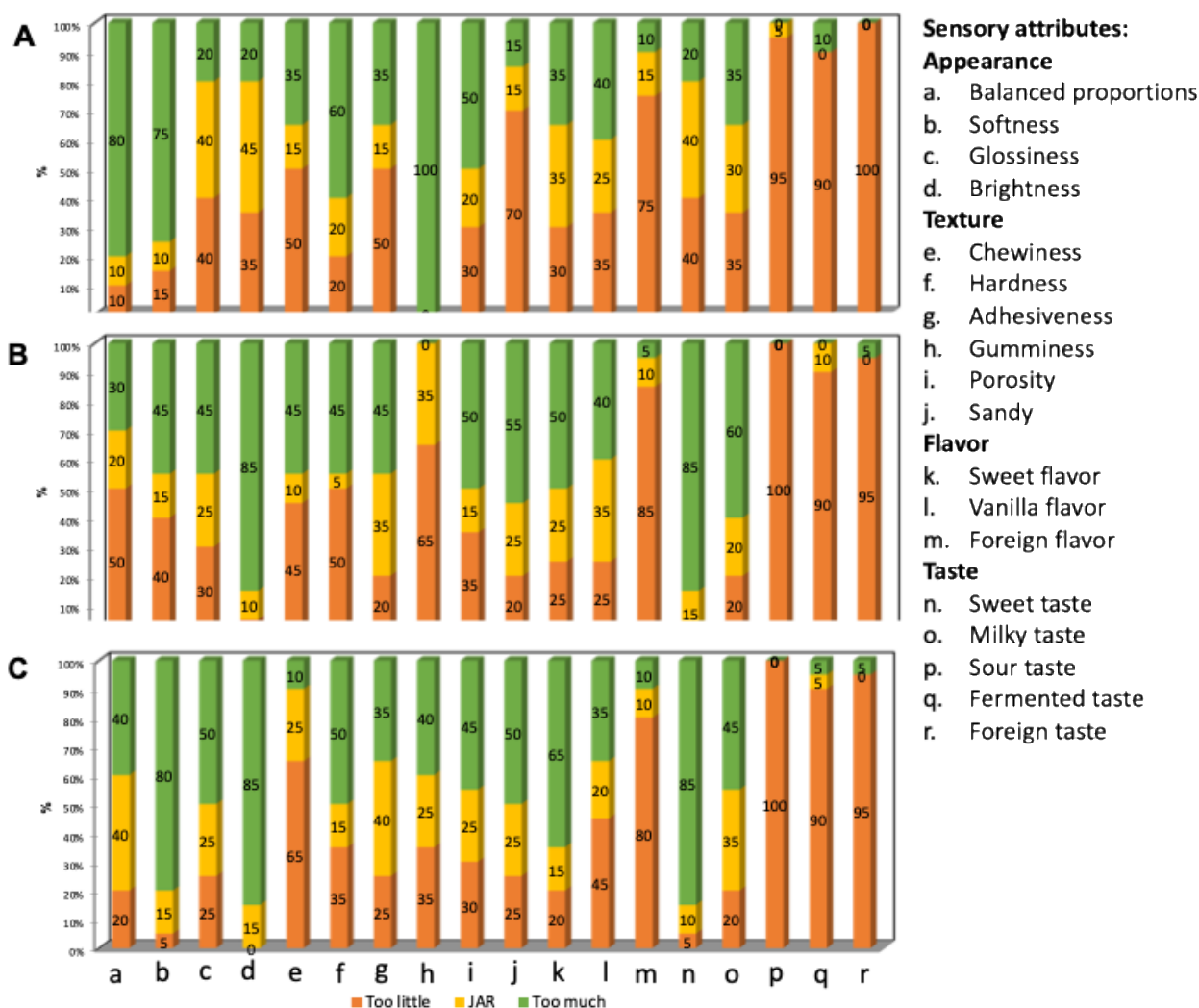
Data presented as mean $\pm$ standard deviation.

^{ns} mean no significant difference, analyzed by Kruskal-Wallis

P2 (8.5% gelatin:0.5% konjac glucomannan). P3 (8% gelatine:1% konjac glucomannan). P4 (7.5% gelatine:1.5% konjac glucomannan). P5 (7% gelatine:2% konjac glucomannan).

Gelatin, a common ingredient in marshmallows, acts as a gelling and foaming agent and provides a chewy and non-sticky texture (Lin et al., 2017). Despite its gelling ability, konjac glucomannan can stabilize the gel, thereby affecting texture properties (Jian et al., 2016). This polysaccharide also has a high water-holding capacity. The combination of two gelling agents can modify their rheological properties. Research by Tomczyńska-Mleko et al. (2014) indicates that when using the combination of konjac and gelatin gel, increasing the konjac glucomannan concentration elevated the elastic moduli but

slightly reduced the fracture stress. In addition, the increment in konjac glucomannan does not change the mixture gel's thermal properties. Therefore, the melt-in-mouth texture of the mixture gel can be retained. This phenomenon may explain the lack of a significant difference in the texture of synbiotic marshmallows across all treatments. The other result revealed that the obtained gelatin and konjac glucomannan gels were separated. Gelatin appeared as the continuous phase, and konjac glucomannan acted as large filler domains (Tomczyńska-Mleko et al., 2014).



3.3.Sensory profile and penalty analysis of synbiotic marshmallows

The panelists' favorable sensory attributes cannot be determined from the hedonic test results; therefore, a descriptive test is required for precise elaboration. According to Narayanan et al. (2014), an analysis using two types of data, namely, consumer preference data and descriptive data, is required to understand consumers' acceptance. The JAR scores for sensory attributes are shown in Figure 1. The high JAR scores for commercial marshmallows were obtained for the attributes of brightness, hardness, porosity, sweet flavor, and sweet taste. Meanwhile, most panelists rated the control marshmallows (P1) at the JAR level for

glossiness, adhesiveness, gumminess, vanilla flavor, and milky taste. In addition, balanced proportions, adhesiveness, vanilla flavor, and milky taste received the highest JAR score for marshmallows using an 8.5%:0.5% gelatin and konjac glucomannan combination (P2). However, the sensory attributes of sour, fermented, and foreign tastes received low scores across all samples. This finding indicated that most panelists could not recognize these sensory attributes across all samples. No fermentation was performed in this study, and only microencapsulated probiotics were used. The sensory acceptance of fermented foods may decline due to the formation of organic acids, volatile sulfur compounds, biogenic amines,

aldehydes, ketones, alcohols, and ammonia. At elevated concentrations, these compounds can impart excessively sour, bitter, rancid, pungent, or otherwise unpleasant sensory characteristics

(Hu et al., 2025; McFeeters, 2004). Therefore, the specific sensory attributes of the fermented-like products were not recognized.

Table 2. Penalty analysis results of commercial marshmallows, control, and synbiotic marshmallows

Samples	Variable	Level	Selection%	Mean (Liking scores)	Mean drops	Weighted penalty
Commercial marshmallows	Sandy	Too little	70.00%	5.000	1.000	1.118
		JAR	15.00%	6.000		
		Too much	<i>15.00%</i>	4.333	1.667	
	Sweet flavor	Too little	30.00%	4.667	1.048	1.022
		JAR	35.00%	5.714		
		Too much	35.00%	4.714	1.000	
P1	Brightness	Too little	<i>5.00%</i>	3.000	3.000	2.444
		JAR	10.00%	6.000		
		Too much	85.00%	3.588	2.412	
	Chewiness	Too little	45.00%	3.778	1.222	1.333
		JAR	10.00%	5.000		
		Too much	45.00%	3.556	1.444	
	Sandy	Too little	<i>20.00%</i>	3.500	1.900	2.133
		JAR	25.00%	5.400		
		Too much	55.00%	3.182	2.218	
	Milky taste	Too little	<i>20.00%</i>	4.500	0.250	1.188
		JAR	20.00%	4.750		
		Too much	60.00%	3.250	1.500	
P2	Sweet taste	Too little	<i>5.00%</i>	3.000	2.500	1.167
		JAR	10.00%	5.500		
		Too much	85.00%	4.412	1.088	

The weighted penalty and mean drop data below 1 are not shown. The complete results of the penalty analysis are available in the supplementary data. Weighted penalty indicates the rank of the most impactful sensory attributes for improvement. Data in italics indicate the percentage selection below or equal to the threshold (20%). P1 (9% gelatin:0% konjac glucomannan), P2 (8.5% gelatin:0.5% konjac glucomannan).

The sensory attributes that significantly affect the synbiotic marshmallows' acceptability were determined by penalty analysis and calculated as a mean drop (Figure 2 and Table 2). The dashed line is a 20% threshold, commonly used in the industry (Lim et al., 2022). Therefore, the penalty analysis did not consider the sensory attributes below the threshold. A high x value indicates that most panelists assumed that these sensory attributes

were too high or too low. Sensory attributes that have either high y or x mapping (critical corner) must be considered. According to Ortega-Heras et al. (2019), attributes with a mean drop higher than 1 can affect a product's acceptability. The upper-right-hand corner mapping (mean drop higher than 1) indicated low acceptability of sensory attributes and therefore the need for improvement.

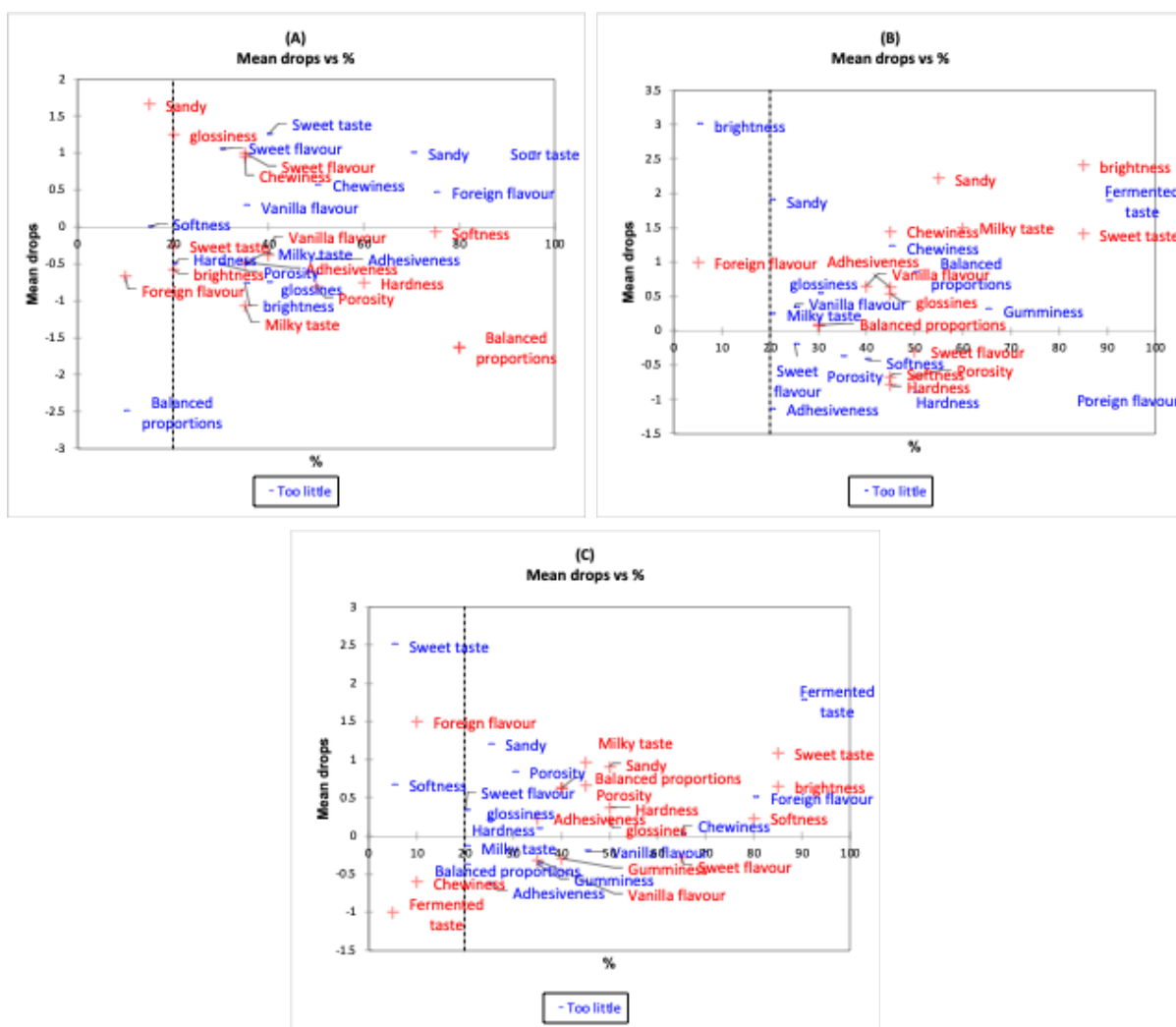


Figure 2. Mean drop plot.

A (Commercial marshmallows), B (P1: 9% gelatin:0% konjac glucomannan), and C (P2: 8.5% gelatin:0.5% konjac glucomannan). The dashed line represents 20% of the threshold.

According to the mean drop plot and penalty analysis, commercial marshmallows had two sensory attributes with penalty scores higher than 1: sandy and sweet flavor. However, only the mean drop value of “too little” for sweet flavor passed the threshold. Therefore, the most troublesome sensory attribute of commercial marshmallows was their sweet flavor. This attribute was rated “too little” by 30% of the panelists, with a mean drop value of 1.048 in the overall liking score. By contrast, for the control (P1), the following four sensory attributes required improvement: brightness, chewiness, sandy, and milky taste. Among these, brightness and sandy required the most improvement. Brightness was found to be “too much” with a mean drop value of 2.412. The sandy texture

was strongly penalized by the panelists as “too much” with a mean drop of 2.218. For chewiness, the panelists penalized it as “too much” with a mean drop of 1.444. Meanwhile, the milky taste was also penalized as “too much” with a mean drop of 1.500. The reformulation of the control by substituting 0.5% konjac glucomannan for gelatin still required some adjustments, primarily to the product's sweetness. Approximately 85% of the panelists considered the product (P2) as “too much” for sweet taste, with a mean drop value of 1.088.

Based on the mean drop and penalty analysis, the reformulation of marshmallows by substituting 0.5% konjac glucomannan improved the acceptance of “too much” brightness, chewiness, sandy, and milky taste.

Konjac glucomannan has low brightness on its own, and its addition may affect the product's brightness (Akesowan, 2016). In addition, using gelatin alone as a gelling agent produces a chewy texture, which can be modified by adding other gelling agents, such as carrageenan and konjac glucomannan, to improve texture, flexibility, and gel strength. Combining gelatin with konjac glucomannan reduces the product's hardness (Bintoro et al., 2024; Tomczyńska-Mleko et al., 2014). Chewiness is defined as the energy required to chew solid food until it is ready to be swallowed; this feature is calculated as a product of hardness, cohesiveness, and elasticity, as described by texture profile analysis. Therefore, a linear correlation exists between chewiness and hardness, such that a decrease in hardness is associated with a decrease in product chewiness (Smirnov et al., 2024; Vickers, 1982).

The sandy texture of the control sample results from sugar crystallization. Hence, high viscosity can delay crystallization by slowing the rate of mass transfer (Richard & Speck, 2015). Konjac glucomannan can retain water, thereby increasing the gel's viscosity (Tomczyńska-Mleko et al., 2014). Even though the reformulation of the control improved the acceptance of certain sensory attributes, the substitution of 0.5% konjac glucomannan still needs improvement regarding its "too much" sweet taste. This finding indicated that the use of sugar (sucrose and glucose) in the formulation must be further adjusted.

3.4. Synbiotic marshmallow characteristics

Table 3 shows the characteristics of the selected synbiotic marshmallow in terms of proximate composition, texture characteristics, and viable cells of *L. plantarum* Dad-13. In addition, the calorie intake from confectionery products should not be over 100 kcal/g.

Therefore, it can be assumed that the serving size of synbiotic marshmallows is 30 g/day (99.6 kcal/30g). The moisture and ash content of synbiotic marshmallows comply with the Indonesian Standard for chewy candy (SNI 3547.2-2008), with maximum limits of 20% and 3%, respectively. Gelatin, a main ingredient in marshmallows, can hold water. High moisture content affects the product's characteristics and shelf life. Since probiotics were incorporated into the marshmallows, the low moisture content is preferred to maintain their viability during storage.

Furthermore, the viability of *L. plantarum* Dad-13 is important to its efficacy, and marshmallow synbiotics meet the minimum viability required for probiotic products. However, there is a 3-log-cycle reduction in the number of viable cells relative to the initial level. The loss of probiotics' viability can occur during processing mainly due to high temperatures (Asaithambi et al., 2021). This finding is two log cycles lower than that reported for the viability of *L. plantarum* incorporated in gummy candy (Kamil et al., 2021). This is because during marshmallow production, high-speed mixing was used, which may increase the number of injured or dead cells. In this study, the microencapsulated probiotic was added to the mixture at 40°C to maintain bacterial viability. In addition, microencapsulation prevents the loss of probiotics' viability in harsh conditions. This technique extends the shelf-life of probiotics by protecting them with polysaccharides, proteins, and lipids (Kamil et al., 2020). Hence, further research is needed to assess the stability of *L. plantarum* Dad-13 viable cells during storage. Although it has no effect on probiotic viability, konjac glucomannan can still affect gut microbiota diversity and the probiotics inhabiting the colon.

Table 3. Characteristics of synbiotic marshmallows (P2: 8.5% gelatin:0.5% konjac glucomannan)

Proximate content	
Moisture (%)	16.69 ± 0.14
Ash (%)	0.50 ± 0.01
Crude fat (%)	0.06 ± 0.02
Crude protein (%) [#]	3.97 ± 0.01

Available carbohydrate (%)	78.78 ± 0.15
Energy (Kcal/g)	3.32 ± 0.01
Texture characteristics	
Hardness (g)	1155.00 ± 230.11
Gumminess	337.34 ± 45.48
Chewiness	1150.07 ± 155.63
Viability	
Log CFU/g	6.33 ± 0.07

Data presented as mean ± standard deviation and are obtained from 3 batches and replications.

#Conversion factor: 6.25

According to Zeng et al. (2018), konjac glucomannan has prebiotic properties in vitro and in vivo. Prebiotics can stimulate the growth of probiotic bacteria, and supplementing a product with prebiotics can boost their survival in the digestive tract. According to Peters et al. (2019), prebiotics are effective as substrates for probiotic bacteria and inhibit the growth of harmful bacteria in the intestine. When a high concentration of konjac glucomannan was added, the prebiotic activity in the digestive tract increased. According to Carlson et al. (2018), prebiotics can increase the number of *Bifidobacteria* and *Lactobacilli*, produce beneficial metabolites, help calcium absorption, and decrease the number of pathogenic bacteria. However, the investigation into the role of konjac glucomannan as a prebiotic and synbiotic in this product remains incomplete, which represents a limitation of this study. This research primarily concentrates on the sensory evaluation of the product.

4. Conclusion

Based on the results of this research, consumers demonstrated good knowledge of the health benefits of probiotics, prebiotics, and synbiotics, indicating an opportunity for the development of health-oriented food products. In this work, synbiotic marshmallows were developed by incorporating probiotic *L. plantarum* Dad-13 and konjac glucomannan. The developed product showed good consumer acceptance based on the consumer survey. The substitution of gelatin with konjac glucomannan did not compromise the viability of *L. plantarum* Dad-13, which remained within the minimum viable cell level required for probiotic products.

The formulation containing 8.5% gelatin and 0.5% konjac glucomannan was the most preferred among the evaluated formulations. However, JAR and penalty analyses indicated that the sweetness of the preferred formulation requires further adjustment. These findings demonstrate the potential of synbiotic marshmallows as a functional confectionery product that combines consumer acceptability with probiotic functionality. Further research is warranted to evaluate probiotic stability during storage, verify the prebiotic and synbiotic effects of konjac glucomannan, and investigate the use of low-calorie sweeteners as alternatives to sucrose and glucose. In vivo studies are also needed to confirm the functional effects of the product before its potential application for commercial development.

5. References

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