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Encapsulation of *Dadih* with Maltodextrin and Gum Arabic: Effect on Nutritional and Sensory Properties of Probiotic Instant Milk

Novelina*, Daimon Syukri, Mahfuzatul Khairani

Department of Food Technology and Agricultural Product, Faculty of Agricultural Technology, Universitas Andalas, Padang, Indonesia

*Corresponding author, Email: novelina@ae.unand.ac.id

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ABSTRACT

The conversion of dadih, a traditional Indonesian fermented buffalo milk, into a probiotic instant milk powder can enhance its shelf life and commercial potential. This study aimed to evaluate the impact of encapsulating dadih using maltodextrin (MD) and gum Arabic (GA) on the physicochemical properties and sensory characteristics of the resulting probiotic instant milk. The dadih was encapsulated with varying MD and GA ratios (100%:0%, 80%:20%, 70%:30%, 60%:40%, 50%:50%) and processed using freeze drying. Moisture, ash, protein, fat content, and lactic acid bacteria (LAB) viability were analyzed. The results showed that higher gum Arabic content increased moisture and ash, while maltodextrin contributed to higher protein and fat retention. The highest LAB count was observed in the 100% MD formulation, indicating that maltodextrin was more effective in preserving probiotics. Sensory evaluation indicated that the 70% MD and 30% GA formulations provided the best texture and flavor making them the most preferred among consumers. This study concludes that the encapsulation ratio of MD and GA plays a crucial role in optimizing the physicochemical properties, probiotic survival, and sensory quality of the probiotic instant milk, offering valuable insights for improving product stability and consumer acceptance.

KEYWORDS

Dadih; Encapsulation; Instant milk; Maltodextrin; Probiotic

1. INTRODUCTION

Pregnant women represent a unique population with specific nutritional needs and vulnerabilities. During pregnancy, adequate intake of probiotics and functional nutrients can support maternal health, enhance immune function, and promote a healthy gut microbiome, which may also benefit fetal development [1], [2]. However, physiological changes during pregnancy can increase susceptibility to digestive disturbances and infections. Therefore, developing probiotic products tailored to pregnant women is important to ensure safety, efficacy, and nutritional support during this critical period [1].

Fermented dairy products have gained increasing attention due to their potential health benefits, particularly those containing probiotic microorganisms. *Dadih*, a traditional Indonesian fermented buffalo milk, is a rich source of probiotics and bioactive compounds [3], [4]. However, its liquid form and high moisture content make it highly perishable, limiting its shelf life and commercial potential [5]. To address these challenges, converting *dadih* into a powdered form, such as probiotic instant milk, offers a practical solution for extending its stability and enhancing usability [6]. Similar approaches have been successfully applied to other fermented products, such as yogurt and kefir, which have been transformed into powder using drying techniques like spray drying and freeze drying, preserving their probiotic viability and nutritional qualities. In addition to extending shelf life, converting *dadih* into powder also facilitates easier transportation, storage, and consumer accessibility [7], [8]. This transformation enables *dadih* to reach

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broader markets, including regions where fresh products are less feasible due to logistical constraints. Moreover, the powdered form can be conveniently rehydrated, making it an attractive option for consumers seeking a quick and easy source of probiotics [9].

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Liquid probiotic products, such as *dadih*, are often converted into powder form to enhance shelf life, ease of handling, and formulation flexibility. This transformation is commonly achieved through various drying methods. Among these, encapsulation is a widely used technique to protect probiotic bacteria from environmental stressors such as oxygen, heat, and moisture, while maintaining their viability during processing and storage [12]. Encapsulation involves enclosing core materials such as probiotic bacteria within a protective wall material to shield them from adverse environmental conditions and to control their release. The choice of wall material is crucial, as it directly affects encapsulation efficiency, stability, and functionality of the final product. Among various encapsulating agents, maltodextrin and gum Arabic are commonly utilized due to their excellent film-forming properties, stability, and ability to enhance the survival of probiotics [13]. Maltodextrin, a carbohydrate derived from starch hydrolysis, provides a good balance between solubility and protective function, while gum Arabic, a natural gum, contributes to improved emulsion stability and encapsulation efficiency [13], [14].

Several studies have explored the impact of different encapsulating agents on probiotic viability and product characteristics [11]. However, limited research has focused on the combined effect of maltodextrin and gum Arabic in the encapsulation of *dadih* for producing probiotic instant milk. Understanding the optimal ratio of these agents is crucial to achieving desirable physicochemical properties, including solubility, and moisture content, as well as maintaining the organoleptic quality of the final product [14], [15].

Given the growing consumer demand for functional dairy products with enhanced stability and probiotic benefits, this study aims to investigate the impact of encapsulating *dadih* using maltodextrin and gum Arabic on the nutritional and sensory characteristics of probiotic instant milk**.** The findings are expected to provide valuable insights into optimizing encapsulation conditions to improve product quality and commercial feasibility.

2. MATERIALS AND METHODS

2.1. Materials

The materials used in this study included *dadih*, a fermented buffalo milk product sourced from West Sumatra, Indonesia. The *dadih* was fermented for 48 hours to develop probiotics and improve nutritional content. Maltodextrin (MD) and gum Arabic (GA) were added as carrier agents to protect probiotics during freeze drying. Skim milk powder was incorporated by dry mixing it directly with the *dadih* powder after the encapsulation and drying processes. This step ensured a uniform blend, simulating a fortified probiotic instant milk product for pregnant women. For nutritional analysis, protein content was measured using the Kjeldahl method, fat content was measured using a Soxhlet apparatus, and MRS agar was used to determine probiotic viability. These materials were selected to ensure accurate analysis of nutritional content and sensory characteristics in the fortified powdered *dadih*.

2.2. Drying Process

Before freeze drying, the mixture is blended with maltodextrin and gum Arabic in specific ratios for encapsulation, preventing clumping and enhancing texture. This mixture is frozen at -40 °C for 24 hours, then dried using a freeze dryer at a pressure of 0.1 bar and a temperature of -50 °C for 48 hours to ensure proper powder formation while preserving nutritional content. After drying, the powdered *dadih* is mixed with 80 g of skim milk to enhance its nutritional value. The final product is then packaged for further testing and sensory evaluation. The probiotic instant milk after drying process can be seen at Figure 1.

(a) (b) (c) (d) (e)

Figure 1. Probiotic instant milk with different encapsulant ratios. (a) 100% MD:0% GA, (b) 80% MD:20% GA, (c) 70% MD:30% GA, (d) 60% MD:40% GA, (e) 50% MD:50% GA.

2.3. Moisture Content Analysis

The drying method can be used to determine the moisture content in a food sample. First, take the sample and weigh its initial mass using an analytical balance. Next, place the sample in an oven preheated to a specific temperature (typically 105 °C) and leave it for a set duration, usually 3 hours, to ensure that all moisture has evaporated. After drying, remove the sample from the oven and allow it to cool in a desiccator to prevent moisture absorption from the air. Once the sample has cooled, weigh it again to obtain the final mass. This analysis [16] provides essential information about the quality and shelf life of food products.

2.4. Ash Content Analysis

The procedure for ash content analysis [16] begins by weighing approximately 2 g of a dried sample and placing it in a ceramic crucible. The crucible is heated in a furnace at 550 °C for 4–6 hours until all organic matter is burned off, leaving only the inorganic residue. After incineration, the crucible is removed and cooled in a desiccator to prevent moisture absorption. Once cooled, the weight of the crucible containing the ash is measured. This procedure provides information about the mineral content and purity of the material.

2.5. Protein Content Analysis

The procedure for protein content analysis [16] begins by weighing 1 g of the sample into a Kjeldahl flask, followed by adding a catalyst mixture and 25 mL of concentrated sulfuric acid. The mixture is then heated until the solution becomes clear. Once cooled, the solution is diluted with distilled water, and 75 mL of 30% NaOH is added to make it alkaline. The solution is then filtered, and the released nitrogen is captured in a boric acid solution. Afterwards, the solution is titrated with 0.1 N HCl to determine the nitrogen content. The protein content is calculated by multiplying the nitrogen content obtained by the appropriate conversion factor, providing information about the protein content in the sample.

2.6. Fat Content Analysis

The procedure for fat content analysis [16] begins by weighing approximately 1 g of a dried sample and placing it into an extraction flask. Next, a solvent (n-hexane) is added to the flask, and extraction is performed using a Soxhlet apparatus for several hours. After the extraction process, the solvent evaporates, leaving the dissolved fat behind. The remaining fat is then weighed to determine its mass. This procedure provides information about the fat content in the analyzed sample.

2.7. Total Lactic Acid Bacteria Analysis

The procedure for analyzing total lactic acid bacteria (LAB) [17] begins by preparing a sample dilution, where 1 mL of the sample is diluted in 9 mL of a physiological solution to obtain the initial dilution. Serial dilutions are then performed until the desired level (e.g. 10^{-7}, 10^{-8}, and 10^{-9}). From each dilution, 0.1 mL of the solution is pipetted onto MRS agar in sterile petri dishes using the spread plate method. The plates are then incubated upside down at 37 °C for 48 hours. After the incubation period, the colonies that grow are counted using a colony counter, and the total lactic acid bacteria in the sample are calculated in CFU/g based on the number of colonies detected. This procedure provides information about the number of lactic acid bacteria in the sample.

2.8. Sensory Evaluation

The probiotic instant milk sample was prepared by dissolving 50 g of the powdered product in 200 mL of warm water at approximately 45 °C. This preparation method was chosen to simulate typical consumer use and to ensure optimal solubility and reactivation of probiotic bacteria. Serving the sample in liquid form also allowed for consistent evaluation of its sensory and functional properties. Trained panelists are then asked to evaluate the samples based on characteristics such as color, aroma, taste, and texture using a hedonic scale, where one indicates "dislike very much," and 5 indicates "like very much." Each panelist has a form to record their evaluations, and drinking water is available to cleanse the palate between samples. The sample was prepared by dissolving 50 g of probiotic instant milk powder in 200 mL of warm water (approximately 45 °C), simulating typical consumer preparation and allowing for consistent sensory evaluation [18].

2.9. Experimental Methods

The fermented *dadih* was initially characterized to determine the content of probiotics, fat, protein, water content, and ash content protein. The *dadih* was then homogenized with the carrier using a high-speed mixer for 5 minutes at the following ratio, A (100% MD:0% GA), B (80% MD:20% GA), C (70% MD:30% GA), D (60% MD:40% GA), E (50% MD:50% GA).

2.10. Statistical Analysis

The statistical analysis procedure begins with the collection of data from conducted experiments or observations, such as results from organoleptic tests or chemical analyses. The obtained data are then organized into tables to facilitate analysis. Next, an analysis of variance (ANOVA) is performed to test for significant differences between treatment groups using statistical software such as SPSS. If ANOVA indicates a significant difference, post-hoc tests, such as Duncan's New Multiple Range Test (DNMRT), are applied to determine which groups differ significantly. The results of the analysis are presented in graphs or tables to facilitate visual comparisons between treatments. This procedure ensures that conclusions are based on valid and statistically accountable data.

3. RESULTS AND DISCUSSION

3.1. Nutritional Quality of Probiotic Milk

Encapsulation of probiotic *dadih* using maltodextrin (MD) and gum Arabic (GA) significantly impacts the nutritional characteristics of the resulting probiotic instant milk. Based on the data from Table 1, the moisture content of the product varied slightly across the different formulations, with values ranging from 1.47% for formulation A (100% MD) to 2.16% for formulation E (50% MD and 50% GA). As the ratio of gum Arabic increased, the moisture content also tended to rise, which is not entirely in line with the typical behavior of maltodextrin. Maltodextrin generally reduces moisture by binding free water, but gum Arabic, with its higher molecular weight and stronger interactions with water molecules, tends to retain more water [19]. This can result in higher moisture content in the final product when gum Arabic is added in larger amounts, suggesting that the encapsulation balance between MD and GA should be carefully optimized to achieve desired moisture levels [14], [20]. A moisture content above 4% is generally considered undesirable for powdered probiotic products, as it can negatively affect shelf life, promote microbial growth, and reduce probiotic viability during storage.

Table 1. Nutritional quality of probiotic milk.

MD:GA Ratio	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	LAB (CFU/mg)
A (100%:0%)	$1.47^{a} \pm 0.21$	$3.47^{a} \pm 0.17$	$18.84^{a} \pm 0.15$	$2.99^{a} \pm 0.27$	8.8×10^{9}
B (80%:20%)	$1.65^{ab} \pm 0.00$	$3.61^{ab} \pm 0.01$	$20.19^{b} \pm 0.05$	$3.82^{b} \pm 0.22$	8.8×10^{9}
C (70%:30%)	$1.67^{ab} \pm 0.01$	$3.65^{b} \pm 0.02$	$20.29^{bc} \pm 0.01$	$3.94^{b} \pm 0.08$	8.0×10^{9}
D (60%:40%)	$1.82^{b} \pm 0.14$	$3.67^{b} \pm 0.01$	$20.36^{c} \pm 0.05$	$4.07^{b} \pm 4.07$	6.8×10^{9}
E (50%:50%)	$2.16^{c} \pm 0.03$	$3.88^{c} \pm 0.02$	$21.42^{c} \pm 0.03$	$4.34^{c} \pm 0.29$	7.6×10^{9}

The ash content, which reflects the mineral composition of the product, also demonstrated variation across formulations [21]. The ash content increased with the higher percentage of gum Arabic, with formulation E (50% MD:50% GA) showing the highest ash content at 3.88%. On the other hand, formulation A (100% MD) had the lowest ash content at 3.47%. This increase in ash content with the addition of gum Arabic can be explained by the mineral salts it contains, such as calcium, magnesium, and potassium, which contribute to the overall ash content [21]. Maltodextrin, being a polysaccharide, does not introduce significant minerals, so the higher levels of gum Arabic lead to an increase in the mineral content of the product [22].

In terms of protein content, significant differences were observed across the formulations. The protein content in the product increased as the amount of maltodextrin increased. Formulation A (100% MD) showed the highest protein content at 18.84%, while formulation E (50% MD:50% GA) had the lowest protein content at 21.42%. This trend is consistent with the fact that gum Arabic does not contribute to the protein content, and its presence at higher ratios may affect protein retention during encapsulation [23]. Maltodextrin, a non-protein polysaccharide, does not interfere with protein content but may allow for better retention of protein in the encapsulated product [24].

In terms of fat content, significant differences were observed across the formulations. The fat content increased as the proportion of gum Arabic decreased, with formulation A (100% MD) showing the highest fat content at 2.99%, and formulation E (50% MD:50% GA) showing the lowest at 4.34%. This result suggests that the ratio of maltodextrin to gum Arabic influences the fat content of the encapsulated product. In a maltodextrin-based formulation, with its relatively simple polysaccharide structure, it may not interact as strongly with fat molecules, allowing more fat to remain in the product [25], [26]. On the other hand, a gum Arabic-based formulation, which has a more complex structure and higher molecular weight, might trap more fat within its matrix, reducing its release into the final product [27].

The effect of the drying process further explains the relationship between fat content and the ratio of MD to GA. The freeze drying method, used in this study, can influence the fat retention in the product [28]. Lower concentrations of gum Arabic may result in less binding of fat molecules, allowing them to remain in the final product [29]. However, higher concentrations of gum Arabic might lead to better encapsulation and retention of fat within the matrix, which could affect the sensory and nutritional characteristics of the probiotic instant milk. This observation underscores the importance of carefully balancing the ratios of maltodextrin and gum Arabic to optimize the fat content, as well as the sensory appeal and nutritional quality of the final product.

Regarding the total lactic acid bacteria (LAB) count, the highest LAB count was found in formulation A (100% maltodextrin) at 8.8×10^{9} CFU/mg, while the lowest was observed in formulation E (50% MD:50% GA) at 7.6×10^{9} CFU/mg. The higher concentration of gum Arabic contributed to a decrease in the viability of LAB. This can be attributed to the thickening effect of gum Arabic, which enhances the viscosity of the encapsulating matrix. A denser, more viscous environment can physically restrict the movement of LAB cells, limiting their access to nutrients and reducing their metabolic activity.

Consequently, this hinders bacterial growth and survival during processing and storage [15], [30]. Although freeze drying generally helps preserve LAB viability, the encapsulating properties of higher gum Arabic concentrations may limit the bacteria's ability to withstand drying stress. These results suggest that formulations with higher maltodextrin content better preserve LAB viability, which is critical for maintaining the probiotic functionality of the product.

3.2. Sensory Evaluation of Probiotic Milk

The sensory evaluation (Table 2) of the probiotic milk product yielded positive results across all organoleptic attributes, highlighting the importance of formulation in influencing consumer acceptance. Including gum Arabic significantly enhanced the brightness of the product's yellowish-white color, which positively influenced quality perception and consumer preference [31]. The visual appeal of color is a crucial factor in food products, as it acts as an initial quality indicator and influences purchasing decisions.

Table 2. Sensory evaluation of probiotic milk.

MD:GA Ratio	Aroma	Texture	Flavor	Color
A (100%:0%)	3.64 ± 1.11	3.56 ± 0.67	3.56 ± 1.12	4.04 ± 0.53
B (80%:20%)	3.08 ± 1.11	3.20 ± 0.95	3.20 ± 1.11	3.96 ± 0.53
C (70%:30%)	3.60 ± 0.91	3.88 ± 0.80	3.88 ± 0.92	4.16 ± 0.62
D (60%:40%)	3.56 ± 0.96	3.44 ± 0.63	3.40 ± 0.86	4.16 ± 0.62
E (50%:50%)	3.64 ± 0.99	3.40 ± 0.99	3.40 ± 0.86	4.00 ± 0.57

Although not significantly affected by variations in maltodextrin (MD) and gum Arabic (GA) ratios, aroma plays a key role in enhancing the overall sensory experience. The aroma of the reconstituted probiotic instant milk was reported to be similar to that of traditional *dadih*, characterized by a mild sourness with subtle buttery and creamy notes, which are typical of fermented buffalo milk products. The pleasant aroma likely originates from volatile compounds generated during the production process, contributing to the product's acceptance [32]. Although the impact of ingredient ratios on aroma is limited, maintaining aromatic quality remains crucial for ensuring consumer satisfaction.

Texture, evaluated in terms of softness and chewiness, demonstrated that the combination of 70% MD and 30% GA provided the best result, delivering a smoother and more palatable product. Softness in this context refers to the soft and light mouthfeel of the reconstituted product, indicating ease of dissolution and the absence of graininess or clumping. Chewiness, although minimal in liquid-based products, was assessed to detect any residual particulates or thickness that might affect mouthfeel. These parameters were chosen because they are key indicators of consumer acceptance for reconstituted dairy powders, particularly in terms of comfort and ease of consumption. This balance likely stems from the combined effects of MD's low viscosity and GA's emulsification properties, optimizing the final texture [33]. Texture has a direct influence on consumer satisfaction and the likelihood of repeat purchases, underscoring its critical importance in product development.

Flavor, a primary driver of consumer acceptance, was also well-received, particularly in formulations with 70% MD and 30% GA. The interaction between these encapsulants contributes to a balanced flavor profile, enhancing the overall sensory experience [34]. Flavor consistency is vital for encouraging repeat purchases and reinforcing brand loyalty. Color and flavor emerged as the most influential sensory attributes, with texture playing a complementary role. Further studies are recommended to refine the interaction between MD and GA, optimizing sensory appeal and meeting consumer expectations in the functional food market.

4. CONCLUSION

In conclusion, this study demonstrated that encapsulating probiotic *dadih* with maltodextrin (MD) and gum Arabic (GA) significantly influenced the physicochemical and sensory properties of probiotic instant milk. Higher GA content increased moisture and ash levels, while MD enhanced protein and fat retention. LAB viability peaked in the 100% MD formulation, emphasizing the need for a balanced encapsulant ratio to ensure probiotic stability. Sensory evaluation identified the 70% MD and 30% GA combination (Formulation C) as the most preferred, with the highest hedonic scores for aroma (3.60 ± 0.91), texture (3.88 ± 0.80), flavor (3.88 ± 0.92), and color (4.16 ± 0.62). These results highlight that optimizing the MD–GA ratio is essential for developing a stable, nutritious, and consumer-accepted probiotic instant milk, supporting its potential in the functional food market.

AUTHOR CONTRIBUTION

All authors contributed equally to the main contributor to this paper. All authors read and approved the final paper. **Novelina**: writing of the original draft, conceptualization, methodology, resources, formal analysis, investigation, and data curation. **Daimon Syukri**: writing the review and editing, validation, data curation, formal analysis, conceptualization, supervision, and funding acquisition. **Mahfuzatul Khairani**: conceptualization, supervision, data curation, and writing the review and editing.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest to declare.

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