Optimization of Quality Parameters in a Herbal Turmeric and Tamarind Beverage through Crystallization and Oven Drying Techniques

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Abstract. Indonesia is rich in spices such as turmeric (Curcuma longa) and tamarind (Tamarindus indica), both valued for their health-promoting properties. Turmeric contains curcumin, a compound with antioxidant and anti-inflammatory effects, while tamarind aids digestion and enhances immunity. These spices have long been integral to traditional herbal beverages (jamu). However, their processing methods critically influence the final product's nutritional quality and sensory appeal. This study evaluates the efficacy of crystallization and oven drying techniques in preserving the organoleptic attributes and antioxidant activity of instant turmeric and tamarind beverages. An experimental design compared three formulations with varying tamarind concentrations: 5 g (CM1/ODM1), 7 g (CM2/ODM2), and 10 g (CM3/ODM3), combined with 125 g of turmeric and 75 g of sugar. Organoleptic analysis assessed sensory parameters—color, aroma, taste, and texture—using a 1–5 hedonic scale. Statistical evaluation employed the Kruskal-Wallis test, supplemented by post-hoc Mann-Whitney comparisons. The top-performing formulation from each method underwent proximate composition analysis and antioxidant activity testing via the 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay. Results indicated that crystallization marginally surpassed oven drying in enhancing sensory acceptance and retaining antioxidant activity. This aligns with the hypothesis that controlled crystallization better preserves heat-sensitive bioactive compounds. Consequently, crystallization is recommended as the superior method for optimizing quality parameters in instant turmeric and tamarind beverages.

Keywords: Antioxidants, Crystallization, Instant Turmeric-Tamarind, Organoleptic, Oven-Drying.

1 Introduction

Indonesia is renowned for its rich biodiversity and diverse array of spices, many of which are integral to health-promoting practices. These spices are deeply embedded in daily practices, often consumed as traditional herbal beverages (jamu) [1]. Turmeric (Curcuma longa) and tamarind (Tamarindus indica) are two prominent ingredients in

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such formulations. Turmeric, a perennial herb of the Zingiberaceae family, is prized for its curcumin content—a potent antioxidant that mitigates oxidative damage by neutralizing free radicals [2]. Extensive research underscores curcumin's therapeutic potential in preventing oxidative stress-linked pathologies, including cardiovascular diseases, neurodegenerative disorders, and cancer [3]. Tamarind, conversely, is distinguished by its sweet and sour flavor profile, derived from high tartaric acid and reducing sugar content, and is characterized by a unique aroma. While it contains modest levels of vitamin C and carotene, tamarind is a notable source of vitamin B and bioactive compounds with demonstrated antimicrobial, antidiabetic, antihyperlipidemic, analgesic, anti-obesity, and antioxidant properties [4].

Turmeric and tamarind herbal beverage (jamu), a traditional formulation, synergistically combines the bioactive benefits of both ingredients. Turmeric (Curcuma longa) is rich in curcuminoids, compounds renowned for their antioxidant, anti-inflammatory, and anticancer properties. Tamarind (Tamarindus indica), conversely, contains bioactive agents with antihyperglycemic, antihyperlipidemic, and antioxidant effects. When combined, these extracts exhibit enhanced antioxidant activity, as demonstrated by their synergistic free radical scavenging capacity [5]. Notably, turmeric-tamarind jamu has also been shown to alleviate menstrual discomfort in adolescent populations [6]. The rising demand for convenient, health-focused products positions instant turmeric-tamarind jamu as a promising functional beverage. However, the selection of processing methods critically impacts the retention of bioactive compounds. High-temperature drying risks degrading thermolabile antioxidants, whereas crystallization techniques may better preserve polyphenols and flavonoids [7]. Comparative studies confirm significant differences in antioxidant levels and sensory acceptability between drying and crystallization methods for instant turmeric-tamarind products, underscoring the need for method optimization [6,7].

Crystallization is a phase transition process wherein solid particles form from a homogeneous solution under controlled supersaturation conditions, typically induced by cooling or solvent evaporation [8]. This method promotes solute precipitation by exceeding the solution's solubility limits. In contrast, oven drying employs controlled thermal energy to remove moisture, offering practical advantages such as reduced material volume, extended shelf stability, and simplified logistics for packaging, storage, and distribution [9]. Developing instant turmeric and tamarind jamu through these methods enhances commercial viability by improving shelf life, marketability, and portability while retaining therapeutic efficacy. However, the impact of processing techniques on bioactive retention and sensory quality remains underexplored. This study specifically investigates how crystallization and oven drying influence antioxidant content and overall quality parameters in instant turmeric and tamarind jamu, addressing critical gaps in optimizing functional herbal beverage production.

2 Method

2.1 Design, Location, and Duration of the Study

This experimental study evaluated the effects of processing methods on antioxidant content and sensory properties of instant turmeric and tamarind products. Two techniques, oven drying and crystallization, were used to convert turmeric (Curcuma longa) and tamarind (Tamarindus indica) into an instant powder. The research involved three phases: product formulation, powder production, and organoleptic testing. The study was conducted over three months, from 13 November 2023 to 13 February 2024, in the Culinary Nutrition and Dietetics Laboratory at Binawan University.

2.2 Materials and Equipment

The primary ingredients utilized in this study were turmeric (Curcuma longa), tamarind (Tamarindus indica), and palm sugar. Two processing techniques were implemented: oven drying and crystallization. The equipment required for preparation included measurement tools (digital kitchen scales, tablespoons), heating apparatus (stove, frying pan), and processing instruments (power blender, baking trays, and spatula).

2.3 Research Procedures

The research process commenced with ingredient preparation, wherein raw turmeric (*Curcuma longa*) and tamarind (*Tamarindus indica*) were meticulously cleaned, cut into uniform pieces, and homogenized. These prepared materials were subsequently processed using two distinct techniques: oven drying and crystallization. Sensory evaluations were then conducted to analyze aroma, taste, texture, and color, with 30 trained panelists participating in the organoleptic assessment using a standardized hedonic scale. The highest-rated formulation from each method was selected based on panelist feedback. Following method optimization, proximate analysis was performed to quantify macronutrient composition (e.g., protein, carbohydrates, ash). Finally, serving size standardization was executed to align with dietary guidelines and consumer practicality. This systematic approach aimed to develop a functional beverage optimized for sensory appeal, nutritional integrity, and market viability.

Crystallization Method (CM)

The turmeric (Curcuma longa) underwent initial processing involving washing, weighing, and homogenization with 375 mL of water to extract its juice. The mixture was allowed to settle for 30 minutes to facilitate liquid-solid separation. The clarified turmeric juice was then blended with a tamarind (Tamarindus indica) solution and palm sugar in a frying pan. This blend was heated at a medium temperature range (100 to 110°C) for approximately 15 minutes to partially reduce moisture content. Granulated sugar and a minimal quantity of salt were incrementally incorporated, followed by continuous stirring for five minutes as the temperature was reduced to 80°C. Crystallization was initiated upon observable increases in viscosity and decreased free water, at which point heating ceased. The mixture was agitated until a crystalline powder formed, after which residual aggregates were mechanically pulverized using a blender and sieved through an 80 mesh sieve to achieve a homogeneous, fine powder.

Oven Drying Method (ODM)

The turmeric (Curcuma longa) was thoroughly rinsed under running water, manually peeled, and sectioned into uniform slices (3 mm thick). These slices were dehydrated in an oven at 50°C for 60 minutes. The dried turmeric was then homogenized with palm sugar using a mechanical blender to produce a shelf-stable powdered formulation.

2.4 Formulation

Tabel 1. Formulation of Turmeric and Tamarind Jamu Using Crystallization and Oven Drying Methods

Ingredients	CM1/ODM1	CM2/ODM2	CM3/ODM3
Turmeric (gram)	125	125	125
Tamrind (gram)	5	7	10
Brown sugar (gram)	75	75	75

Note: CM refers to the crystallization method, and ODM refers to the oven-drying method.

2.5 Data Processing and Analysis

The study encompassed two primary datasets: organoleptic evaluations and antioxidant activity metrics. Organoleptic assessments employed hedonic and hedonic quality testing to evaluate color, aroma, taste, and texture. Statistical analysis began with the Kolmogorov-Smirnov (K-S) test to determine data normality. As the results deviated from a normal distribution, nonparametric alternatives were applied, specifically the Kruskal-Wallis test, supplemented by post-hoc Mann-Whitney tests for pairwise comparisons. Antioxidant activity data, derived from the DPPH radical scavenging assay, were analyzed descriptively and reported as mean ± standard deviation.

2.6 Research Ethics

This study obtained ethical approval from the Ethics Committee of Binawan University with approval number 002/KEPK-UBN/I/2024.

3. Results and Discussion

3.1 Organoleptic Test Results of Instant Turmeric Tamarind

This study conducted a sensory evaluation of instant turmeric and tamarind beverages using a 5-point hedonic scale (1 = strongly dislike; 5 = strongly like) to quantify panelists' preferences across product variations. Two processing methods—crystallization and oven drying—were evaluated, each with three formulations differing in tamarind concentration. The analysis focused on determining the impact of these methods on sensory attributes, including aroma, color, texture, taste, and overall acceptability. Table 2 summarizes the hedonic test outcomes for the instant turmeric and tamarind formulations.

Table 2 Hedonic Test Results for Instant Turmeric and Tamarind Formulations

Treatment	Attribute				
	Aroma	Color	Texture	Taste	Whole
	$3{,}40 \pm 1{,}003^{abc}$	$3{,}57 \pm 0{,}971^{c}$	$3{,}77 \pm 0{,}728^{b}$	$3{,}63 \pm 1{,}033^{b}$	$3{,}63 \pm 1{,}033^{c}$
CM2	$3{,}77 \pm 0{,}728^{abc}$	$3{,}73 \pm 1{,}081^{c}$	$3{,}80 \pm 0{,}847^{b}$	$3{,}40 \pm 1{,}102^{b}$	$3{,}60 \pm 1{,}192^{c}$
	$3{,}47 \pm 1{,}074^{bc}$	$3{,}37 \pm 0{,}999^{c}$	$3{,}43 \pm 0{,}935^{b}$	$3{,}27 \pm 1{,}172^{b}$	$3{,}63 \pm 1{,}066^{c}$
ODM1	$2{,}63 \pm 1{,}189^{bc}$	$2{,}73 \pm 1{,}015^{b}$	$2{,}50 \pm 1{,}106^{a}$	$1{,}90 \pm 0{,}960^{a}$	$2{,}20 \pm 1{,}095^{b}$
ODM2	$2{,}53 \pm 1{,}042^{bc}$	$2{,}50 \pm 1{,}106^{b}$	$2{,}37 \pm 1{,}159^{a}$	$1{,}97 \pm 1{,}098^{a}$	$2{,}07 \pm 0{,}785^{ab}$
ODM3	$1{,}87 + 0{,}937^{a}$	$1{,}83 + 1{,}206^{a}$	$2{,}00 + 1{,}050^{a}$	$1{,}47 + 0{,}819^{a}$	$1{,}60 + 0{,}770^{a}$

Note: The attribute scale ranges from 1 = strongly dislike to 5 = strongly like. Different letters in the same column indicate significant differences (Kruskal-Wallis test followed by Mann-Whitney test, significant at p<0.05). CM: crystallization method, ODM: oven-drying method.

Table 2 summarizes the sensory evaluation outcomes of instant turmeric and tamarind formulations processed via crystallization (CM) and oven drying (ODM) methods. Sensory attributes—aroma, color, texture, taste, and overall acceptability—were rated on a 5-point hedonic scale (1 = strongly dislike; 5 = strongly like). Three formulations per method were tested, differing in tamarind concentration (5 g, 7 g, 10 g) against fixed quantities of turmeric (125 g) and sugar (75 g). Results demonstrate that CM formulations achieved consistently higher ratings across all sensory parameters compared to ODM counterparts, indicating stronger consumer preference for crystallization-processed products. Notably, increasing tamarind content inversely correlated with overall acceptability scores in both methods. This trend was statistically significant ($p < 0.05$) in ODM products, particularly for aroma, color, and overall acceptability, which declined markedly at higher tamarind concentrations.

This study demonstrated that the crystallization method exhibited superior efficacy in preserving and enhancing key sensory attributes, particularly aroma and taste. This superiority likely stems from precise control over dissolution and crystallization kinetics, which stabilize thermolabile bioactive compounds (e.g., curcuminoids in turmeric and tartaric acid in tamarind) under moderate processing conditions [10]. However, increasing tamarind concentration from 5 g to 10 g inversely affected preference scores, attributed to elevated acidity imparting excessive sourness and disrupting flavor balance, thereby reducing hedonic appeal [10]. Conversely, oven drying induced volatilization of aromatic compounds in turmeric, diminishing its characteristic aroma and flavor intensity [11]. Prolonged exposure to higher temperatures also degraded heat-sensitive phytochemicals, exacerbating undesirable textural changes (e.g., grittiness) and bitter aftertastes—effects amplified in formulations with incremental tamarind content [12].

Crystallization, as a moderate processing technique, demonstrated enhanced capacity to retain desirable sensory attributes compared to oven drying. Notably, formulations produced via crystallization exhibited greater resilience to tamarind concentration increments, mitigating the adverse sensory effects observed in oven-dried counterparts. These findings underscore the necessity of method optimization in turmeric and tamarind product development, where preserving bioactive integrity and flavor equilibrium directly correlates with consumer acceptability. Empirical evidence from this study advocates for crystallization as the preferred method, as it minimizes critical compound degradation while maintaining organoleptic balance—a decisive factor for commercial viability.

Table 3 The Result of Hedonic Quality Testing of Instant Turmeric Tamarind

Treatment	Attribute			
	Aroma	Color	Texture	Taste
CM1	2,73 ± 0,868	2,67 ± 0,711	2,73 ± 0,907	2,90 ± 1,062
CM2	2,87 ± 1,074	2,93 ± 0,907	2,80 ± 0,961	2,87 ± 1,106
CM3	3,00 ± 1,017	3,87 ± 1,306	3,20 ± 1,031	3,53 ± 1,167
ODM1	3,23 ± 1,278	2,53 ± 0,819	2,70 ± 1,055	2,23 ± 1,251
ODM2	2,83 ± 1,315	2,73 ± 1,172	2,50 ± 0,974	2,17 ± 1,053
ODM3	3,07 + 1,701	2,87 + 1,525	2,43 + 1,305	1,97 + 1,189

Note: The attribute scale includes the following: **Aroma:** 1 = Not pungent at all; 2 = Not pungent; 3 = Neutral; 4 = Pungent; 5 = Very pungent. **Color:** 1 = Bright yellow (yellow); 2 = Turmeric yellow (fire); 3 =

Honey yellow (honey); 4 = Golden yellow (gold); 5 = Brownish yellow (dijon). **Texture:** 1 = Not thick at all; 2 = Not thick; 3 = Slightly thick; 4 = Thick; 5 = Very thick. **Taste:** 1 = Not sour at all; 2 = Not sour; 3 = Slightly sour; 4 = Sour; 5 = Very sour.
Different letters in the same column indicate significant differences (Kruskal-Wallis test followed by Mann-Whitney test, significant at $p<0.05$). **CM** refers to the crystallization method, and **ODM** refers to the oven-drying method.

Table 3 presents the results of the hedonic quality test for instant turmeric-tamarind products processed using two methods: the Crystallization Method (CM) and the Oven- Drying Method (ODM). The evaluation focused on four sensory attributes: aroma, color, texture, and taste. Aroma was rated on a scale from 1 (not pungent at all) to 5 (very pungent), color from 1 (bright yellow) to 5 (brownish yellow), texture from 1 (not thick at all) to 5 (very thick), and taste from 1 (not sour at all) to 5 (very sour).

Formulations processed via crystallization (CM) consistently achieved superior sensory scores, particularly in taste and aroma, with Formulation CM3 (10 g tamarind) exhibiting the highest performance. This preference correlates with its balanced acidity and enhanced aromatic retention, suggesting that crystallization effectively preserves volatile organic compounds while stabilizing pH levels—critical factors for optimizing flavor profiles in turmeric and tamarind beverages. Mechanistically, crystallization minimizes moisture-mediated degradation through controlled supersaturation, which promotes the formation of sugar crystalline matrices that encapsulate bioactive particles. This encapsulation mitigates oxidative damage to heat-sensitive phytochemicals (e.g., curcuminoids) and volatile aroma constituents, thereby preserving sensory integrity [13,14,15].

In contrast, the ODM method resulted in lower scores for taste and aroma, with significant declines noted in ODM3. This could be attributed to the intensive heating during drying, which may have damaged or evaporated volatile compounds essential for aroma and taste [16]. The high-temperature drying also led to a darker, less desirable color (brownish yellow). Rapid moisture loss in this method might have negatively affected texture and caused color fading due to accelerated oxidation [17]. As a result, the oven drying process may not be as effective at retaining the desired sensory attributes of turmeric and tamarind products.

Increasing tamarind concentration from CM1 to CM3 and ODM1 to ODM3 was hypothesized to elevate acidity and improve attributes such as color and texture. However, these effects were more pronounced in crystallization relative to oven drying. Turmeric and tamarind compounds exhibit differential reactivity under processing conditions, with crystallization better preserving equilibrium between acidity, viscosity, and aromatic retention compared to high-temperature drying. Tamarind, abundant in organic acids (e.g., citric, tartaric acid), imparts pronounced sourness and serves as a natural antioxidant, thereby stabilizing the product's flavor profile [18]. In CM3, elevated tamarind content enhanced flavor complexity, aligning with panelists' preferences.

In contrast, the oven drying method struggled to maintain the desired flavor profile with higher tamarind concentrations, as observed in ODM2 and ODM3. This may result from thermal interactions between acidic components and the drying process, which promote undesirable chemical alterations. Previous studies corroborate that low temperature processing methods or those with precise moisture control, such as crystallization, better preserve sensory and nutritional qualities in food products [19]. Additional research confirms that high temperature drying significantly reduces the concentration and activity of aroma and flavor compounds in natural ingredients [20]. Another study on tamarind juice reported that formulations with higher acidity (pH 2.5) received lower consumer acceptance compared to moderately acidic formulations (pH 3.5). Crystallization, however, appears to modulate acidity perception, likely via sugar crystallization, which improves flavor balance and overall palatability [21]. These findings highlight the critical role of selecting optimal processing methods to retain sensory and nutritional integrity in developing products like instant turmeric and tamarind.

Tabel 4. Proximate Analysis Results and Antioxidant Activity of Instant Turmeric Tamarind

Component	**Crystalization method** (CM) per 100 gram	**Oven Drying Method** (ODM) per 100 gram	***P-value***
Moisture content (%)	3,56	2,28	0,000
Ash content (%)	1,09	1,27	0,014
Fat content (%)	0,52	0,34	0,002
Protein content (%)	0,67	0,83	0,010
Antioxidant activity (µg/mL)	549.49 µg/mL	633.77 µg/mL	

Note : *Independent sample t-test* : significant at $p<0,05$.

Table 4 indicates that the crystallization method (CM) yields a higher moisture content (3.56%) compared to the oven drying method (ODM), which exhibits 2.28% moisture. Crystallization retains moisture through controlled cooling and crystal formation, which entraps water molecules. Conversely, oven drying employs intensive heat, accelerating water evaporation. ODM demonstrates higher ash content (1.27%) than CM (1.09%), likely due to water removal concentrating non-volatile minerals during drying, resulting in a higher ash concentration.

The fat content is lower in ODM (0.34%) than in CM (0.52%), likely due to oxidative degradation of lipids under high heat during oven drying. Conversely, protein content is higher in ODM (0.83%) compared to CM (0.67%), potentially due to reduced sample volume concentrating protein mass per unit weight. Antioxidant activity was significantly elevated in oven dried samples (ODM: 633.77 µg/mL) relative to crystallized samples (CM: 549.49 µg/mL). This disparity may result from thermal processing enhancing phenolic compound bioavailability or structural modifications that augment free radical scavenging capacity [22]. However, antioxidant activity declined over time in both methods, likely due to oxidative degradation of vitamin C.

Tumpa et al. observed similar trends, reporting a decrease in tamarind drink vitamin C content from 8.96 mg/100g to 5.45 mg/100g over 50 days, underscoring the inevitability of vitamin C loss in tamarind based beverages [23]. Their findings stress the necessity of stabilization strategies and optimized storage to mitigate nutrient degradation. Heat exposure also alters component volatility and stability, affecting not only moisture but also lipid and protein retention, which collectively influence antioxidant dynamics.

4 Conclusion

The crystallization method demonstrates superior retention of antioxidant content and sensory characteristics compared to oven drying in instant turmeric and tamarind beverages. This method effectively preserves volatile compounds critical to flavor and aroma profiles while maintaining higher antioxidant levels. Consequently, crystallization is recommended as the optimal processing technique for herbal beverages prioritizing nutritional stability and quality. The choice of processing method is pivotal in maximizing nutrient retention, ensuring optimal sensory quality, and enhancing potential health benefits for consumers.

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6 Conflict Of Interest

This study declares no conflict of interest. All researchers participated in this work solely for scientific purposes, focusing on evaluating how processing methods affect the organoleptic qualities and antioxidant levels of instant turmeric-tamarind. There were no financial or commercial interests involved that could have influenced the research outcomes.

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