Application of taguchi method in production factors of traditional spice-based ready-to-drink based on sensory responses

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Abstract. Traditional spice beverages commercial could not attract the interest of the young generation yet, primarily due to its original taste and need a process to be consumed. To meet the need of the consumers, it is important to develop the ready-to-drink wedang uwuh. Therefore, this study aims to optimize the production process of ready-to-drink wedang uwuh, by combining four factors and three levels based on sensory responses. To address this issue, a fractional factorial Taguchi design (3^3) was applied to study the sensory responses of time and temperature, as well as the composition of milk powder-sugar using the pasteurization technique. The sensory evaluation conducted involved 36 respondents who were asked to rate the color, aroma, viscosity, flavor, aftertaste, and overall of the ready-to-drink wedang uwuh on a 9-point Likert scale. The results indicated that the optimal combination of the ready-to-drink wedang uwuh was with milk powder at 2 gram and sugar at 20 gram, with the process parameter set at 85°C for 20 minutes of pasteurization. This produced the highest sensory liking score of viscosity, flavor, aftertaste, and overall, at 6.56, 7.25, 6.42, and 7.17, respectively. The development enhances the production of modern-authentic beverages with greater liking by the young consumer.

1 Introduction

Wedang uwuh is an ethnic traditional drink from Yogyakarta, Java, Indonesia [1]. This drink is unique in terms of name, history, culture, properties, color, and taste. Wedang Uwuh compromise of a mixture of spices, from cloves, nutmeg leaves, sappan, cinnamon, ginger, cardamom, and rock sugar, as well as can be a functional drink due to its natural antioxidant content [2]. This beverage has a distinctive flavor of spices, a bit of slight bitterness, and reddish color. Wedang uwuh were consumed by Indonesians for over a decade and has been identified to have a beneficial effect on health [3]. Furthermore, study analysts have shown keen interest in studying the antioxidant and phenolic content of this

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beverage [4]. As a result, the health benefits associated with these bioactive compounds have made wedang uwuh increasingly popular.

Wedang uwuh has been diversified into different product forms, such as in concoction, instant, syrup, klisikan, and dip bag forms [5]. The ready-to-drink wedang uwuh has been developed with a high level of antioxidants and can withstand storage conditions of 8-10ºC [6]. Efforts to improve the sensory properties and analyze the presence of antioxidants and phenols in the products have been conducted [4], [7]. According to a study conducted by BBC (Business Communications Company) Research, the global market for functional beverages witnessed growth between 2011 to 2016 in Europe, America, and Japan [8]. Therefore, wedang uwuh from Indonesia can be developed into functional food. The development of ready-to-drink beverages offers advantages in meeting consumer demand, such as in distribution and storage.

The addition of milk powder and sugar to wedang uwuh beverage products aims to improve taste and flavor. This is in line with the preference of the young generation who tend to prefer milk-based drinks [9]. The development of these beverage products was conducted using the Taguchi method, with the main objective of testing several production parameters based on respondents to obtain high product sensory liking. Sensory test is crucial because consumers primarily choose functional beverages based on their sensory preferences, even when they are aware of potential health benefits [10]. The present approach may be employed to optimize factors in the domains of food science and engineering [11]. Moreover, in Taguchi methodology, the regulatory effect of response value and noise factor is accomplished by a solitary Signal to Noise ratio term. This term represents the reciprocal of the coefficient of variation and possesses a unitless value. The application of the log transformation method results in an impartial quantification of dispersion [12]. The signal-to-noise (SN) ratio is a metric that evaluates the influence of extraneous factors on performance metrics and quantifies the extent of variation.

Several studies on the development of wedang uwuh have been reported, including the uses of rosella for functional beverages [7], and the production of ready-to-drink wedang uwuh [6]. However, the development of the ready-to-drink wedang uwuh that is milk-based has not been implemented in practice. Therefore, this study aims to get the best production parameters of the ready-to-drink wedang uwuh milk based using the Taguchi method. The results from this study may provide an optimized product that is suitable for the preference of the young consumer.

2 Material and methods

2.1 Materials

The material used in the preparation of the ready-to-drink wedang uwuh were ginger, sappanwood, clove leaf, nutmeg leaf, cinnamon leaf, sugar, and milk powder, which were bought from the local market in Yogyakarta, Indonesia. The product was leveled up by adding milk powder and sugar following young consumer need and want.

2.2 Sample preparation

The simplisia was washed with clean water and rinsed. It was weighed on an analog weighing balance, peeled, and reweighed. Subsequently, the simplicia was extracted using 200 mL of water through a boiling method. The spices extract was filtered with tea siever, bottled, and kept for formulation and pasteurization.

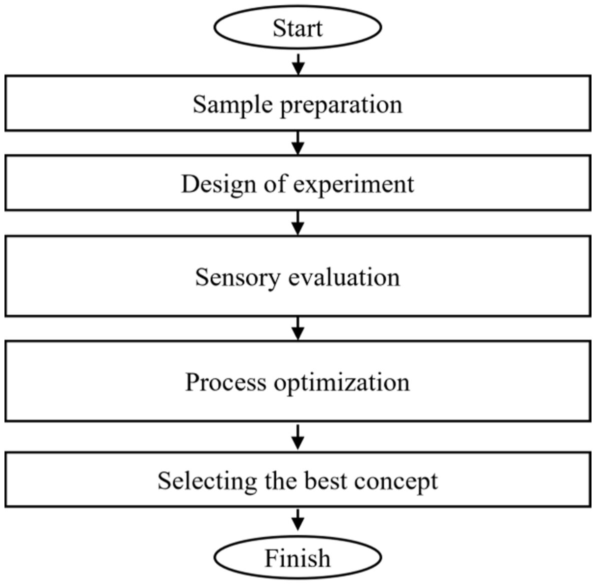

Fig. 1. Flow diagram of research

2.3 Design of experiment

The ready-to-drink wedang uwuh were processed and formulated based on a 9-run orthogonal array experimental design for four factors at three levels using MINITAB 21 (Minitab Inc, Pennsylvania), as shown in Table 1. The four factors used in this experiment were pasteurization temperature (A), pasteurization time (B), milk powder composition (C), and sugar composition (D). Table 2 presents the L9 orthogonal array. Finally, the level of each factor was modified from [13]–[15].

Table 1. Factors and Treatment Levels

Parameter	Unit	Level 1	Level 2	Level 3
Pasteurization temperature (A)	ºC	65	75	85
Pasteurization time (B)	minutes	10	20	30
Milk powder (C)	gram	2	6	10
Sugar (D)	gram	10	14	20

Table 2. Design of experiment

Sample product	Parameter			
	A	B	C	D
I	1	1	1	1
II	1	2	2	2
III	1	3	3	3
IV	2	1	2	3
V	2	2	3	1
VI	2	3	1	2
VII	3	1	3	2
VIII	3	2	1	3
IX	3	3	2	1

2.4 Sensory evaluation

The tests were conducted using an individual sensory testing booth to measure sensory liking, and 9 concept products were served with a 30 mL souffle cup. The procedure was described to each participant before the test which was conducted using a hedonic scale of 36 panelists to evaluate the taste perception of the product, including color, aroma, viscosity, flavor, aftertaste, and overall on a 9-point Likert scale [16]. Additionally, the sensory protocol used in this study was approved by the Ethical Clearance of the Universitas Gadjah Mada (No: KE/UGM/021/EC/2023).

2.6 Participants

A total of 36 healthy participants were selected as respondents for this study. They were required to have previous experience consuming spice drink products and reported having no known food allergies, intolerance, or clinical histories of major disease. Additional inclusion criteria were participants aged between 18 and 41. Finally, those that completed the study received financial compensation as an appreciation for their assistance.

2.6 Data analysis

2.6.1 Sensory test

Sensory test results data were analyzed using Kruskal-Wallis test because the data did not conform to normality assumptions. The Kruskall-Wallis test using assymp. sig 0.05 where if it is less than 0.05 then there is a significant difference between samples. If there was a significant difference, then continued with the Mann Whitney test, and these all calculation were used IBM SPSS Statistics 25 (Chicago, USA).

2.6.2 Process optimization

The mean response for level 1 was determined through the computation of the arithmetic mean of the response values obtained from the different treatments. Similarly, the mean signal-to-noise ratio (SNR) was derived for all levels of each factor. A higher sensory score denoted a more favorable reception of the product. The computation of the signal-to-noise ratio of sensory attributes was carried out utilizing the "Larger the Better" equation (equation 1).

$$S/N_{LTB} = -10\, log_{10} \left[\frac{\Sigma \left({}^{1}/_{y^2} \right)}{n} \right] \tag{1}$$

In the context of this study, it can be inferred that the dependent variable, denoted by 'y', refers to the response, while the independent variable, denoted by 'n', represents the number of treatments under consideration [12]. The utilization of statistical analysis and their corresponding mean values serve as a means for evaluating the impact of varying factors and levels on the sensory responses. The aforementioned accomplishment was obtained through the process of charting a graphical representation of the statistical mean value, while considering the associated factors and their corresponding levels.

2.6.2 Selecting the best concept

The Taguchi method was developed to solve problems with a single response. Therefore, weighting analysis was utilized to determine the best formulation of the concept with multi-responsiveness. It simplifies the product development process in this study by converting the value or coefficient of the entire response into a single value. During weighting analysis, the response values used data that has been transformed into the S/N *Ratio.* The following are stages of data processing in weighting analysis [17]:

First step: Calculates the S/N *ratio* value of each response with initially obtained results.

Second step: The weight of each S/N *Ratio* (ηij) was determined using the following equation.

$$W_{ij} = \frac{\eta_{ij}}{\sum \eta_{ij}} \tag{2}$$

where,
W_{ij} = weight of the i-th concept in the j-th response
η_{ij} = value of S/N Ratio of the i-th concept in the j-th response
$\Sigma_{\eta j}$ = total value of S/N Ratio in the j-th response

Third step: The *Multi Response Performance Index* (MRPI) value from the S/N *Ratio* value determined by each weight was calculated using the following equation.

$$(MRPI)_i = W_1\eta_1 + W_2\eta_2 + \cdots + W_j\eta_{ij} \tag{3}$$

where,
$(MRPI)_i$ = MRPI value in the i-th concept
W_j = weight on the j-th response
η_{ij} = value of S/N *Ratio* of the *i-th* concept in the j-th response

Fourth step: After obtaining the MRPI value on each product concept, the response of each design parameter and the level that produces the highest value were determined to obtain the best combination. This was conducted by summing the MRPI values on each concept with the same level in each design parameter.

3 Result and discussion

3.1 Experimental design and its responses

The ready-to-drink wedang uwuh was prepared and packed based on the treatments on L9 (3^3) of the Taguchi orthogonal array method which compares the experiments and optimizes them with less variability. Furthermore, the response of each treatment was analyzed to confirm the optimized results. Experiment 1 (I) was observed to have a higher liking for color and aroma at 6.69 and 6.33, which might be attributed to the lower pasteurization time and temperature, as well as the formula composition. Meanwhile, using a lower level of parameter helps maintain the appearance of the product, the flavor tended to be disliked by young respondents.

Higher liking scores for viscosity, flavor, aftertaste, and overall were obtained through experiment 8 (VIII). It shows that all parameter levels strongly influence the increase the sensory responses. The addition of milk and sugar can help increase the liking score because it makes the flavor sweeter, covering the bitterness or spiciness of the original product. Therefore, this new product development was able to increase liking rate among young consumers.

Table 3. Average responses of experimental design (likert value ± standard deviation)

Experiment	Sensory Responses					
	Color	**Aroma**	**Viscosity**	**flavor**	**Aftertaste**	**Overall**
I	6.69±2.03[ad]	6.33±1.55[a]	6.42±1.5[a]	5.61±1.59[ac]	5.44±2.03[afh]	5.67±1.82[acf]
II	6.5±1.66[ac]	6.11±1.39[a]	6.20±1.53[a]	5.08±1.51[ab]	4.67±1.82[bcde]	5.38±1.34[adg]
III	5.03±1.86[b]	5.92±1.76[a]	6±1.67[a]	5.19±1.90[ad]	4.78±1.84[cfig]	5.11±1.77[ag]
IV	6.056±1.90[aef]	6.06±1.67[a]	6.25±1.59[a]	6.19±2.08[c]	5.81±2.21[a]	6.28±1.88[ce]
V	5.53±1.92[be]	6.19±1.39[a]	6.19±1.35[a]	5.08±1.82[ae]	4.47±1.87[bi]	5±1.77[a]
VI	6.33±1.69[ae]	5.67±1.71[a]	6.56±1.38[a]	5.92±2.04[cdefg]	5.44±2.16[adg]	5.86±1.97[efg]
VII	5.94±1.51[cef]	5.86±1.71[a]	6.25±1.63[a]	5.08±2.06[af]	4.61±1.92[dfi]	5.17±1.83[af]
VIII	6.31±1.83[de]	6.11±1.72[a]	6.56±1.50[a]	7.25±1.48[b]	6.42±1.87[ae]	7.17±1.40[bd]
IX	5.47±1.89[bf]	6.19±1.51[a]	6.36±1.40[a]	5.11±1.97[ag]	4.31±2.01[bi]	5.11±1.85[af]

Means with different lowercase superscripts within a column are significantly different at $p \leq 0.05$.

3.2 Optimization of the process factor

The outcomes of the interventions were assessed via a graphical approach, wherein the mean average and signal-to-noise ratio (SNR) average of the sensory parameters were illustrated in Figures 2 and 3, respectively. The higher the value of sensory hedonic liking, the more acceptable the product [18]. According to the results of the analysis and the graph below, the design parameters with a dominant influence of color from the highest to the lowest sequentially were the composition of milk powder at level 1, pasteurization time at level 1, sugar composition at level 2, and pasteurization temperature at level 1. The parameters of powdered milk composition have the highest influence on sensory liking because the addition of milk at various concentrations can affect the color and taste attributes of the drink [19]. This finding aligns with Rashidinejad et al. [20], according to the information available in the literature, the sensory characteristics of coffee can be improved by adding milk as well.

Concerning the aroma attribute, the design parameters that have a dominant effect, were pasteurization time at level 2, sugar composition at level 1, milk powder composition at level 2, and pasteurization temperature at level 3. Pasteurization temperature has the highest effect on beverage aroma attributes.

The viscosity attributes were significantly affected by certain design parameters, namely the composition of milk powder at level 1, pasteurization temperature at level 3, sugar composition at level 2, and pasteurization time at level 2. Among these, milk powder composition had the highest influence on the viscosity sensory attributes of the drink. According to Liputo [21] the viscosity will increase with the higher concentration of added sucrose and skim milk. The greater the dissolved component in a solution will increase the viscosity. The dominant dissolved solid component is sucrose in addition to pigments, organic acids and proteins.

The flavor attribute was strongly influenced by some design parameters, namely the composition of milk powder at level 1, sugar composition at level 3, pasteurization temperature at level 2, and pasteurization time at level 1. Among these, the composition of milk powder had the highest influence on the flavor attributes of the drink.

The aftertaste attribute was predominantly influenced by certain design parameters, namely the composition of milk powder at level 1, sugar composition at level 3, pasteurization time at level 1, and pasteurization temperature at level 2. Among these, the composition of milk powder had the highest influence on the aftertaste attributes of the drink.

The overall liking attribute is an important factor in the development of any food product, as it reflects consumer satisfaction with the product. Its higher indicates a greater willingness to pay for the product [22]. According to the Figure below, the factors influenced the overall liking of the product. Furthermore, the composition of milk powder at level 1, sugar composition at level 3, pasteurization time at level 1, and pasteurization temperature at level 2 were discovered to have good overall responses for the ready-to-drink wedang uwuh milk-based product.

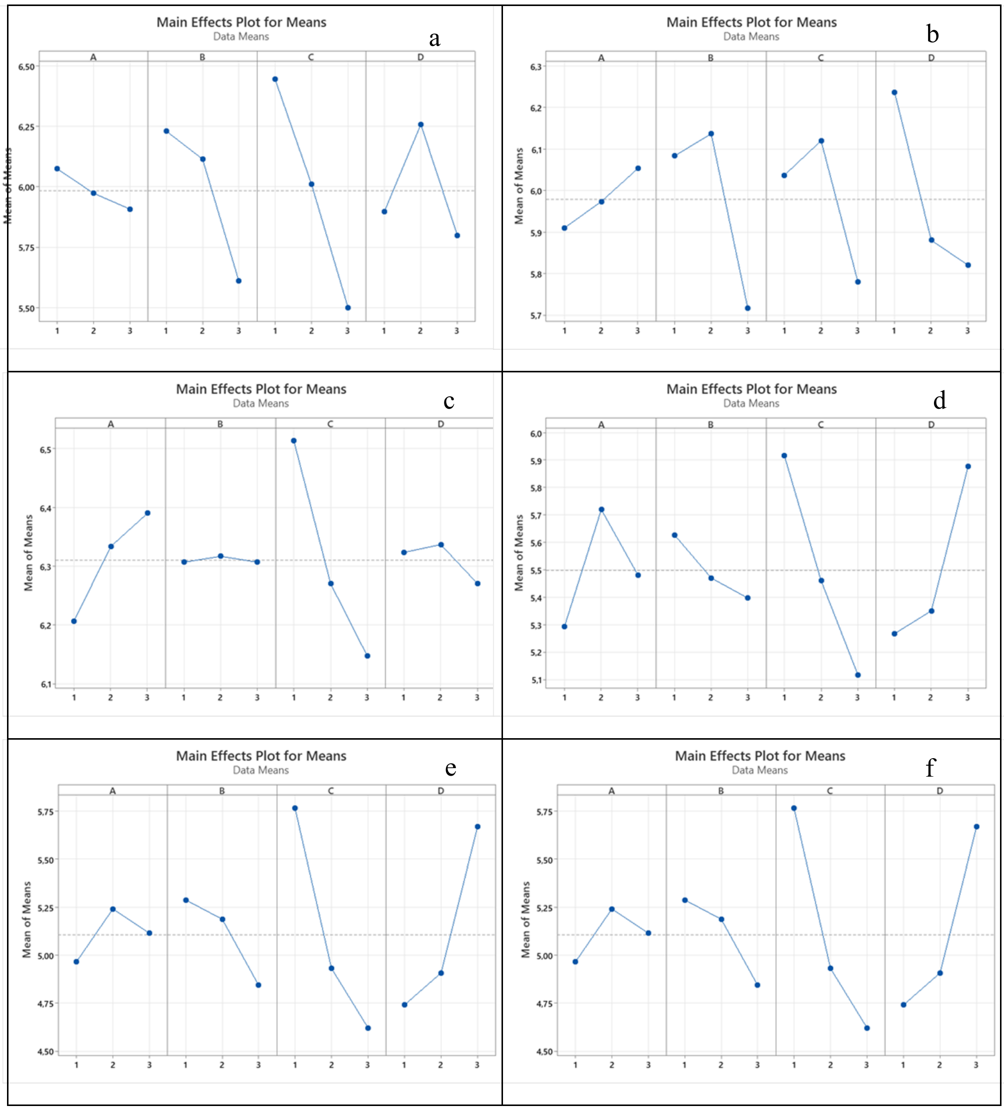

Fig. 2. Main effects plot for means of (a) color (b) aroma (c) viscosity (d) taste (e) aftertaste (f) overall

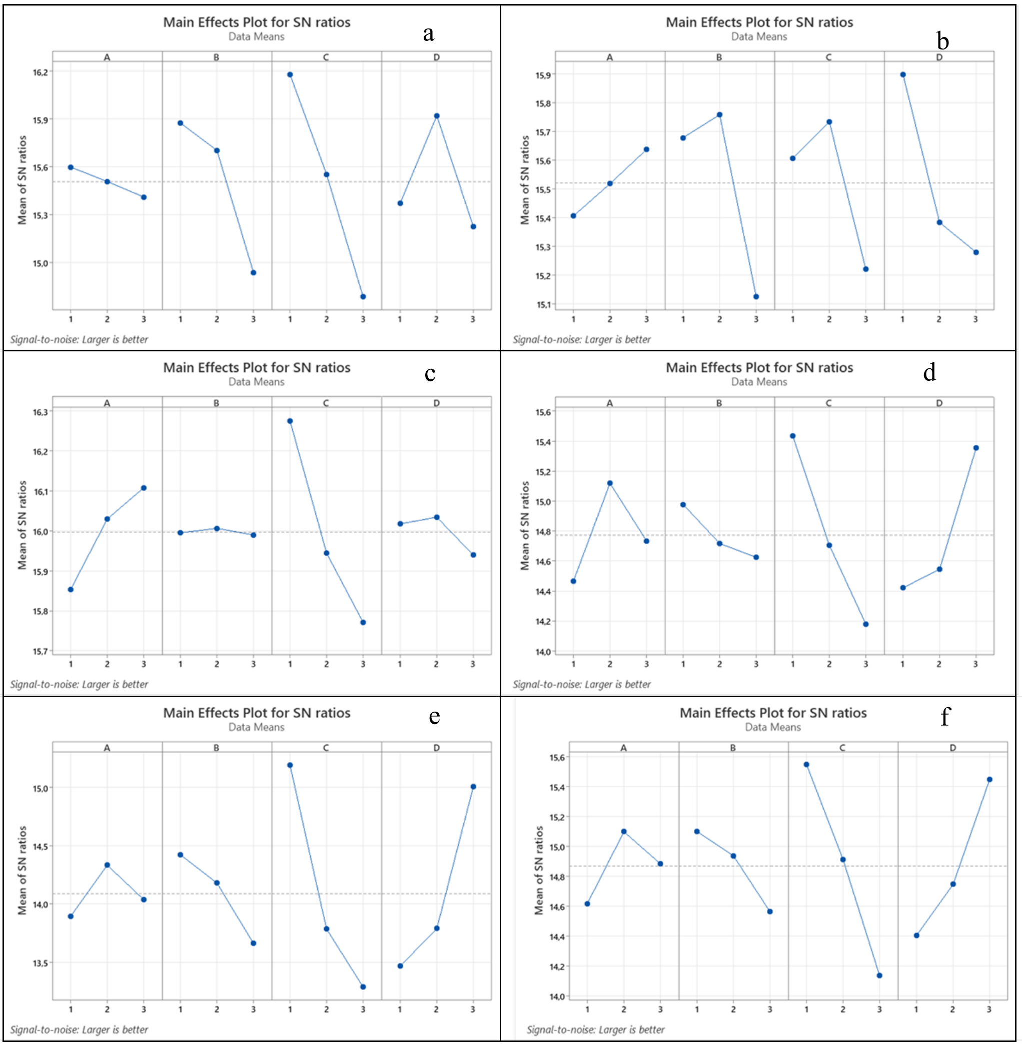

Fig. 3. Main effects plot for SN ratio of (a) color (b) aroma (c) viscosity (d) taste (e) aftertaste (f) overall

3.4 Best concept selected

Table 4. MRPI Weight Calculation and Conversion Results

Experiment	Sensory Responses						MRPI
	Color	Aroma	Viscosity	Flavor	Aftertaste	Overall	
I	0.121	0.119	0.113	0.123	0.096	0.095	9.013
II	0.126	0.115	0.110	0.117	0.107	0.125	9.789
III	0.091	0.096	0.103	0.104	0.106	0.101	7.160
IV	0.113	0.113	0.110	0.109	0.127	0.128	9.703
V	0.087	0.118	0.112	0.101	0.102	0.099	7.749
VI	0.121	0.106	0.116	0.109	0.104	0.105	8.779
VII	0.117	0.106	0.108	0.091	0.112	0.101	8.090
VIII	0.118	0.111	0.115	0.152	0.153	0.148	12.546
IX	0.105	0.115	0.113	0.094	0.092	0.099	7.777

The S/N *Ratio* value of each response was used to determine the weight of each factor in this study, which was subsequently converted into *the Multi Response Performance Index* (MRPI). **Table 4** presents the results of the weight and the MRPI conversion.

Following the determination of MRPI as a single response from the development of wedang uwuh-milk added, an analysis of the value was conducted. Since the MRPI represents a weighted score for each concept, it is important to analyze the level of each design parameter to identify those with the highest value, thereby obtaining the best product concept that meets the needs of the consumers identified during the information stage. Table 5 presents the results of the MRPI values analysis at the parameter level.

Table 5. MRPI Value Analysis Results for Each Level

	Pasteurization temperature	**Pasteurization time**	**Milk powder**	**Sugar**
Level 1	25,970	26,806	30,338	24,539
Level 2	26,231	30,092	27,277	26,667
Level 3	28,413	23,716	23,00	19,706

According to Table 5, level 3, level 2, level 1, and level 2 were selected as the optimal level for the pasteurization temperature, pasteurization time, milk powder, and sugar composition, respectively. Therefore, the product concept with this combination was identified as the 8th experiment, which involved pasteurization at 85°C for 20 minutes, 2 gram milk powder composition, and 20 gram sugar composition. According to Table 4, the 8th experiment also exhibited the highest sensory liking score for viscosity 6.56, flavor 7.25, aftertaste 6.42, and overall 7.17.

4 Conclusion

The production of wedang uwuh-milk was optimized with a combination of pasteurization temperature of 85°C (A3), pasteurization time of 20 minutes (B2), 2 gram milk powder composition (C1), and 20 gram sugar composition (D2). This combination has the highest sensory liking score of viscosity, flavor, aftertaste, and overall, at 6.56, 7.25, 6.42, and 7.17, respectively. The development of this wedang uwuh-milk added ready-to-drink enables food producers to offer a modern-authentic beverage with more young consumer sensory responses. As a result, traditional Indonesian beverages such as wedang uwuh can have a more prominent presence in the market alongside other commercial products.

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