Daygurt: A functional drink combining dadih and yoghurt from cow's milk using response surface methodology

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Abstract. Response Surface Methodology (RSM) was employed to optimize the formulation of Daygurt, a functional drink combining dadih and yogurt made from cow's milk. The independent variables included the percentages of dadih, yogurt, and skimmed milk, while the optimized responses encompassed sensory profile, viscosity, pH, and protein content. Statistical analysis revealed significant effects of the variables on aroma and texture. The optimal formulation was determined to consist of 1% dadih, 4.89% yogurt, and 9.1% skimmed milk. The experimental values closely aligned with the predicted values, showing a 95% Confidence Interval (CI), confirming the model's accuracy. Quality and safety assessment confirmed that Daygurt complied with the standards established by the Indonesian Food and Drug Authority.

1 Introduction

Dadih remains an underexplored functional health drink, primarily due to its less favourable characteristics, such as rancid aroma and high acidity taste. The sensory characteristics of dadih are less favourable than yoghurt [1]. In addition, dadih production is limited due to the low production of buffalo milk. Dadih is only produced when buffaloes lactate their calves, making continuous production unfeasible [2].

There is potential for developing a novel functional beverage called 'daygurt', which combines the properties of dadih and yogurt. This combination is expected to yield a product more favourable than traditional products. Generally, dadih is fermented using *L.plantarum* and yeast, while yoghurt utilizes *L.bulgaricus* and *S.thermophillus* [3]. This combination will result in a more diverse microorganism profile [4]. Besides, incorporating cow's milk can support the sustainability of production.

Previous research has shown that cow milk dadih products were successfully prepared using a 3% starter combination of the probiotics *Lactobacillus plantarum*, *Lactobacillus acidophilus*, and *Bifidobacterium bifidum* [5]. Additional research has explored the use of additives and packaging to enhance the quality of cow's milk dadih. These efforts include incorporating skim milk to improve texture, increase protein content, reduce syneresis, and enhance the total lactic acid bacteria in cow's milk dadih. Skim milk has been added at concentrations of 6% and 9% to achieve these improvements [5]. These efforts successfully

produce dadih with desirable qualities. Developing daygurt by combining yogurt and dadih starter, along with additional ingredients such as skim milk, is expected to improve product quality. Therefore, this study aims to develop 'daygurt' under acceptable and optimum conditions, focusing on sensory profile, viscosity, pH, and protein content using Response Surface Methodology (RSM).

2 Materials and methods

2.1. Raw materials

Fresh cow's milk was sourced from Padang Panjang City, West Sumatera, Indonesia for daygurt preparation. Dadih starter cultures containing *Lactobacillus plantarum* and *Streptococcus thermophilus* were collected from Payakumbuh City. Additional ingredients, including Greek-style yogurt, Fontera-brand skim milk, Orafti-produced inulin fiber, and Gulaku sugar were procured from local supermarkets, reflecting commonly accessible branded items in the regional consumer market.

2.2. Response surface methodology for optimization

Formula optimization using RSM was conducted with Design Expert software version 13. The optimized formula, derived from a review of previous research, comprises specific percentages of dadih, yogurt, and skim milk [6–8]. The limits in determining the formula were set as follows: dadih (X1) 1-5%, yoghurt (X2) 1-5%, and skimmed milk (X3) 5-10%. The formula is shown in Table 1. The response variables included sensory attributes: Y1 = taste, Y2 = odor, Y3 = color, Y4 = texture, Y5 = pH, Y5 = Viscosity and Y6 = Protein content.

The formulation criteria are as follows: X1 (minimum), X2 (in range), X3 (in range), Y1 (maximum), Y2 (maximum), Y3 (maximum), Y4 (maximum), Y5 (in range), Y6 (maximum), Y7 (within range). The optimum formula was selected based on the highest desirability (D) value, corresponding to the expected response. Following the selection of the best formula, a confirmation test was conducted to compare the formula with the expected response. The verification response was deemed successful if the Confidence Index (CI) was 95%. The best optimized product was tested for quality and food safety in compliance with Indonesian Food and Drug Authority (FDA) standards, including assessments of nutritional content, microbiological contamination (Salmonella), and heavy metals.

2.3. Daygurt production

The Daygurt production process began with pasteurizing cow's milk at 80°C for 5 minutes. Sugar, skimmed milk, and inulin fiber were then added. Once fully dissolved, the mixture was cooled to 40-45°C. In this temperature range, dadih and yogurt starters were incorporated and stirred until completely dissolved. The Daygurt was then bottled and fermented for 24 hours at 35-40°C [9]. After fermentation, Daygurt was stored in a chiller.

2.4. Sensory analysis

Sensory analysis was conducted using a hedonic test to evaluate taste, aroma, color, and texture, with products rated on a scale from 1 to 5 based on the level of liking.

2.5. Chemical analysis

Chemical analysis was performed to determine the nutritional content using the proximate test following the AOAC method [10].

2.6. Microbiological analysis

Microbiological analysis was carried out to assess the presence of lactic acid bacteria and salmonella using the Total Plate Count method.

2.7. Physical analysis

Physical testing was conducted by measuring the viscosity of the product using a Brookfield viscometer.

2.8. Statistical analysis

Statistical analysis for RSM optimization using Design-Expert involved experimental design, fitting data to mathematical models (e.g., quadratic models), and validating these models through ANOVA. A p-value < 0.05 indicates statistical significance, while R^2 values greater than 0.90 demonstrated model reliability. Diagnostic plots, including residual and response surface plots, were used to verify model assumptions and visualize factor interactions. Optimization was performed to achieve a high desirability score (> 0.95), and the model's accuracy was confirmed through validation experiments comparing predicted and observed results.

3 Results and discussion

3.1 Formula optimization

Table 1 shows the results of the response optimization. The daygurt characteristics analyzed include taste (Y1), aroma (Y2), color (Y3), texture (Y4), viscosity (Y5), protein content (Y6), and pH (Y7). The response (Y) is a function of the independent variables (X), as shown in equation 1.

$$Y = f(X1, X2, X3, X4 \ldots\ldots\ldots\ldots Xn) \quad (1)$$

The quadratic polynomial model for each response is presented in equation 2.

$$Y = \beta_0 + \sum_{i=1}^{3} \beta_1 X_1 + \sum_{i=1}^{3} \beta_{ii} {X_{ii}}^2 + \sum_{i=1}^{2} \sum_{j=i+1}^{3} \beta_{ij} X_i X_j \quad (2)$$

Where, 0, i, ii, and ij are the regression coefficients, and Xi and Xj are the code levels of independent variables i and j, respectively. The equation can include linear, quadratic, and interaction terms of independent variables.

It was found that the combination of dadih, yoghurt and skimmed milk had a significant effect on aroma, and texture (p-value <0.05). Increasing the amount of dadih reduced the preference for the aroma characteristics. This could be attributed to the volatile compounds, fatty acids, and ketones found in buffalo milk, which are key constituents of dadih [11].

The texture of daygurt was influenced by the amount of skimmed milk added. However, the addition of 5-10% skimmed milk remains acceptable [6]. Casein micelles are specialized particles found in milk, stabilized by a layer of κ-casein, which prevents them from clumping. These micelles are important for producing dairy products, such as yoghurt, with smooth texture and stability, and they play a key role in their overall structure and function [12]. In

the future, the use of Trans-glutaminase and Protein-Glutaminase to improve stability holds potential [13].

Consumer satisfaction with yogurt is influenced by several physical characteristics, including the absence of syneresis, perceived viscosity, acidity, aroma, and textural properties. These factors are crucial for determining the overall quality and sensory performance of the product [14]. The addition of skim milk can increase the protein content of yoghurt. The viscosity of fermented milk is affected by the rise in total milk solids resulting from the increased protein content. Additionally, the production of total acid increases with the amount of milk solids [15].

The addition of skim milk affected the pH. The pH value of daygurt ranged from 4.57 to 4.99, which is within the acceptable range. The standard pH of yoghurt is between 3.8 and 5.0, and the addition of skim milk can reduce the pH of yoghurt due to its high lactose content, resulting in higher lactic acid production. During fermentation, lactic acid bacteria utilize the milk's energy, which is metabolized into lactic acid [16].

Based on the product testing results, four formulas were developed using RSM, with the combination of 1% dadih, 4.89% yogurt, and 9.1% skimmed milk achieving the highest desirability score of 0.94. Figure 1 presents the 3D surface response results.

Table 1. Formula design and response using RSM

Run	Dadih (%)	Yoghurt (%)	Skimmed Milk(%)	Response						
				Taste	Odour	Color	Texture	Viscosity	Protein content	pH
1	3.2	3.1	8.7	4.91	5.62	6.45	6.49	8503	4.35	4.59
2	1.0	4.9	9.1	5.37	6.12	6.62	6.75	3759	4.6	4.89
3	4.6	1.0	9.4	4.12	5.28	6.16	4.79	3399	4.55	4.78
4	2.3	2.7	10.0	6.08	5.95	6.58	6.37	16230	4.38	4.84
5	3.4	1.6	10.0	5.25	5.66	6.16	5.25	21825	4.27	4.99
6	3.2	3.1	8.7	6.33	5.79	6.91	6.83	5384	4.30	4.85
7	5.0	2.4	7.6	4.63	4.99	5.99	4.78	5384	4.70	4.85
8	2.6	4.9	7.5	5.46	5.70	6.32	6.40	1719	4.47	4.60
9	3.2	3.1	8.7	4.74	5.66	5.70	4.91	3491	4.43	4.57
10	3.7	3.8	7.5	4.12	4.67	5.45	4.24	2291	4.48	4.68
Model				Linear	Linear	Linear	Linear	Linear	Linear	Quadratic
Anova p-value				0.07	0.00	0.14	0.03	0.06	0.20	0.06
R^2				0.52	0.98	0.42	0.61	0.54	0.99	0.92

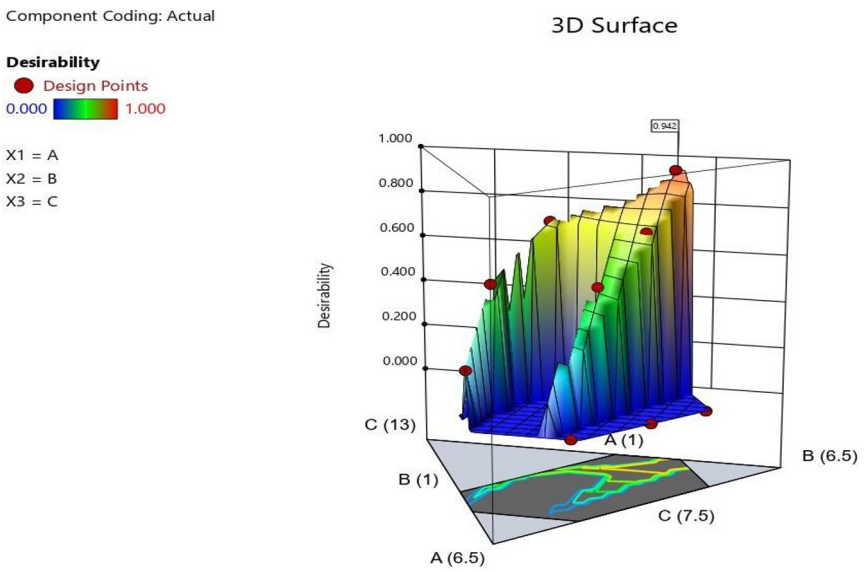

Fig 1. Response surface of best formula

Table 2 presents the confirmation results of the developed formula. The confirmation process involved comparing the Daygurt produced with the optimized formula to the predicted values. The verification response is considered satisfactory if it meets the 95% Confidence Index (CI) [17]. To calculate the Confidence Interval (CI) Low and High values in RSM optimization, the standard error of the predicted response was determined. The corresponding t-value for the desired confidence level was then used to apply the formulas: CI Low = predicted response - (t-value × standard error) and CI High = predicted response + (t-value × standard error), based on the model.

Table 2. Confirmation result of the best daygurt

Attribute	95% CI low	95% CI High	Confirmation results of response
Taste	4.69	6.04	5.95
Odour	5.76	6.12	6.06
Color	5.81	6.69	6.65
Texture	5.48	7.05	6.85
Viscosity	4286.3	7420.1	7324
Protein content	4.20	4.83	4.73
pH	4.35	4.58	4.55

3.2 Product quality and safety test

The testing of Daygurt products included both quality and safety assessments. Quality was evaluated based on nutritional composition, while safety was ensured through compliance with food safety regulations established by the Food and Drug Administration. The following tables (Table 3 and 4) outline the results of the yogurt product testing, which were conducted at the SIG Analytical Laboratory.

Table 3.Product quality test results by SIG Analytical Laboratory

Parameters	Unit	Mean	SD
Total Energy	Kcal/100 g	116.34	0.52
Energy From Fat	Kcal/100 g	36.14	0.45
Ash Content	%	1.21	0.01
Water Content	%	74.73	0.21
Carbohydrate (By Difference)	%	15.32	0.33
Total Fat Content	%	4.02	0.05
Protein Content	%	4.74	0.09
Lactic Acid Bacteria	colony / g	$3.8x10^8$	-

Table 4. Daygurt product safety test results by SIG Analytical Laboratory

Parameter	Unit	Hasil	Limit Of Detection
Salmonella sp.	/ 25 g	Negative	-
Arsen (As)	mg / kg	Not Detected	0.0003
Cadmium (Cd)	mg / kg	Not Detected	0.0001
Mercurry (Hg)	mg / kg	Not Detected	0.0003
Lead (Pb)	mg / kg	Not Detected	0.0018
Tin (Sn)	mg / kg	Not Detected	0.0016
Aflatoksin M1	mcg / kg	Not Detected	0.0080

The test results indicated that Daygurt met the quality and food safety requirements established by the FDA, confirming the product's safety for public consumption. As a combination of dadih starter and cow's milk-based yogurt, Daygurt is considered a promising functional beverage and a source of probiotics. The product contains a diverse range of lactic acid bacteria, including Lactobacillus plantarum, Lactobacillus bulgaricus, Streptococcus thermophilus, and Bifidobacterium. Additionally, the inclusion of inulin as a source of prebiotic fiber enhances the product's functional benefits. Daygurt is viewed as an effective alternative for improving digestive health and boosting body metabolism [18,19].

4 Conclusion

Optimization through RSM successfully produces daygurt with the optimal attribute response. The formulation was maximally optimized with 1% dadih, 4.89% yogurt, and 9.1% skimmed milk. The experimental values closely aligned with the predicted values, within a 95% Confidence Index (CI), confirmin its suitability. The results of the daygurt quality and safety testing confirm compliance with the quality and safety standards established by the Indonesian Food and Drug Authority.

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