

Cost-Quality Tradeoffs in Cream Cheese Formulation: Evaluating Acidulants for Sensory Performance and Financial Sustainability

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Abstract

This study assesses the physicochemical, sensory, and economical aspects of cream cheese production utilizing five different acidulants (citric acid, vinegar, lemon juice, papaya latex, and orange juice) in order to discover the most commercially viable compositions. Sensory analysis revealed that orange juice and citric acid produced the most preferred products, with bright white color, balanced sourness, and ideal firmness, whereas papaya latex produced inferior results due to excessive softness and weak flavor caused by its higher pH (5.57). Financial analysis yielded key insights into production economics, with a break-even threshold of 909 units/month (IDR 31.8 million in sales) and a small 9.1% margin of safety at 1,000 units. The cost structure revealed variable expenses (IDR 24,000/unit) dominated by raw materials (75%), emphasising the need of strategic acidulant selection for profitability. The findings show that, while orange juice and citric acid have better sensory properties, their commercial viability is dependent on cost-effective procurement to sustain goal margins. In contrast, the enzymatic benefits of papaya latex were outweighed by low consumer acceptance, rendering it financially unviable despite possible cost reductions. The study concludes that successful cream cheese production necessitates formulas that balance sensory perfection with economic sustainability, especially given the tight profit margins and volume sensitivity. These findings offer dairy producers meaningful insights for improving both product quality and financial success. Future study should look into hybrid acidulant systems or process improvements to increase the cost-effectiveness of high-performing formulations while keeping favorable sensory properties.

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1. Introduction

A popular dairy product, cream cheese is valued for its mild flavor and creamy texture. The qualities of the finished product are largely determined by the manufacturing process, especially the acidification procedure, Z. Berk (2018). In an effort to improve product quality and processing efficiency, recent developments in dairy processing have investigated acidification methods other than traditional lactic acid fermentation Głab (2019). These alternate techniques include the use of coagulants generated from plants and organic acids, which may provide clear benefits in terms of production control and sensory qualities Nascimento (2020).

Microstructure, rheological characteristics, and flavor development are just a few of the quality parameters that are greatly impacted by the acidification process. For example, compared to conventional acid coagulation, enzymatic coagulation employing plant proteases has been demonstrated to yield distinct textural characteristics, Shabbir et, al (2021). Furthermore, the choice of acidulant effects the release of volatile chemicals and the perception of sourness, which are key elements in customer approval Berk et, al (2019). These variations in product qualities underscore the necessity for rigorous evaluation of different acidification processes to optimize cream cheese production.

Although acidification in cheese production has been the subject of many studies, there is still a dearth of research that particularly compares various acidification methods used in the production of cream cheese. There is a lack of thorough comparison evaluations because the majority of current research focuses on either traditional fermentation or a single alternative approach Głab (2019). By comparing five different acidification methods citric acid, vinegar, lemon juice, papaya latex, and orange juice this study fills this gap. We describe their influence on important quality features using thorough sensory evaluation and physicochemical investigation, offering insightful information for product creation and industrial applications.

2. Method

Samples of cream cheese were made using five distinct acidification techniques Yetismeyen et, al (2016):

P1: Citric acid

P2: Vinegar (acetic acid)

P3: Lemon juice

P4: Papaya latex (enzyme-based coagulation)

P5: Orange juice

The base material was fresh milk (pH 7.0), and each acidulant was added at predetermined quantities to cause coagulation. According to Laskowski et, al (2019), the curds were drained, squeezed, and kept for a full day at 4°C prior to examination.

A calibrated digital pH meter was used to measure each cheese sample's pH three times. To evaluate the degree of acidity in each treatment, the average pH values were noted. Using a 5-point Likert scale (1 being extremely weak/ white/ soft, and 5 being very strong/ dark/ very soft), a trained panel of 25 people performed a hedonic test to assess:

- 1) Color (yellow or white)
- 2) Cheesy intensity of aroma
- 3) Taste (sourness)
- 4) Texture (softness or firmness)

To prevent bias, the panelists were told to wash their palates in between samples Janhoj (2019), 25 participants took a different consumer acceptance test that used a 5-point hedonic scale (1 being "like very much" and 5 being "dislike very much"). Among the qualities assessed were, Vara (2021):

- 1) Overall preference for color
- 2) Favoritism for aromas
- 3) Acceptability of taste
- 4) Preference for texture

One-way ANOVA was used to examine the data, and Tukey's HSD post-hoc test was used to compare means Stone (2018). In order to evaluate variability, standard deviations (SD) were computed, H. Abdi and L. J. Williams (2019).

Financial feasibility analysis is an important step in the development of dairy product enterprises. This study creates a four-dimensional analytical model production costs, revenue, income, and break-even point (BEP) for cream cheese products in Samarinda. This quantitative strategy is intended to reduce company risks in a market dominated by imported goods (Kraft, Elle, and Vire) by utilizing the benefits of local raw resources.

The Production Cost Analysis method uses an activity-based costing (ABC) approach to separate fixed and variable components. The production cost is calculated as follows:

$$\text{Total Cost} = \text{Fixed Cost} + \left(\frac{\text{Variable Cost}}{\text{Unit}} \times \text{Quantity} \right)$$

The revenue analysis technique makes use of a market-driven pricing framework that takes into account Samarinda customers' purchasing power and compares imported products.

$$\text{Total Revenue} = \text{Price} \times \text{Quantity}$$

The profit analysis method uses the contribution margin model to calculate profitability. The equation that determines net profit is:

$$\text{Profit} = \text{Total Revenue} - \left(\text{Fixed Cost} + \left(\frac{\text{Variable Cost}}{\text{Unit}} \times \text{Quantity} \right) \right)$$

The Break-Even Point (BEP) Analysis Method uses the contribution margin approach to calculate the business viability threshold. The BEP is calculated as follows:

$$\text{BEP (Unit)} = \frac{\text{Fixed Cost}}{(\text{Selling Price per Unit} - \text{Variable Cost per Unit})}$$

$$\text{BEP (Rupiah)} = \frac{\text{Fixed Cost}}{\text{Contribution Margin Ratio}}$$

3. Results and Discussion

3.1. Color Evaluation

The method of acidification utilized affected the color of the cream cheese. The detailed results can be seen in Table 1 below.

Table 1. Hedonic Test Results for Cream Cheese Color

Acid Source	Mean Score $\pm$ SD	Color Description
P1 (Citric acid)	1.28 $\pm$ 0.46	White
P2 (Vinegar)	1.36 $\pm$ 0.49	White turbid
P3 (Lemon)	1.40 $\pm$ 0.82	Whitish yellow
P4 (Papaya latex)	1.96 $\pm$ 1.31	Whitish green
P5 (Orange)	1.28 $\pm$ 0.87	White

Based on Table 1, Orange (P5) and citric acid (P1) acidified samples were the lightest (mean score $\approx$ 1.28) and were referred to as "white," suggesting little discoloration or browning. Conversely, papaya latex (P4) had a somewhat darker appearance (mean score 1.96), most likely as a result of enzymatic processes that might cause minor color shifts McSweeney et, al (2017). Across replicates, consistent color development is suggested by the low standard deviations (SD = 0.46–1.31).

These results are consistent with Gómez-Mascaraque et, al (2018), who found that by inhibiting Maillard processes, organic acids such as citric acid help preserve a whiter color in dairy products. Proteolytic enzymes found in papaya latex, however, have the potential to slightly discolor food since they break down proteins Berk (2018).

3.2. Aroma Evaluation

The results of the aroma analysis in detail can be seen in table 2 below.

Table 2. Hedonic Test Results for Cream Cheese Aroma

Acid Source	Mean Score $\pm$ SD	Color Description
P1 (Citric acid)	2.16 $\pm$ 0.62	Strong
P2 (Vinegar)	2.68 $\pm$ 0.48	Moderate
P3 (Lemon)	3.40 $\pm$ 0.50	Moderate
P4 (Papaya latex)	1.12 $\pm$ 0.33	Very strong
P5 (Orange)	3.08 $\pm$ 0.28	Moderate

Papaya latex (P4)-treated samples had the strongest scent intensity (mean score 1.12, "very strong"), most likely as a result of the volatile components' enzymatic release. While vinegar (P2) and lemon (P3) created moderate odors, citric acid (P1) also produced a strong aroma (2.16).

A research discovered that enzymatic coagulation (such as papain in papaya latex) produces more free fatty acids and aromatic peptides than acid-induced coagulation, Lucey et, al (2017). This finding is in line with that study. While vinegar (acetic acid) and lemon (citric + other organics) offer additional volatile chemicals, citric acid samples may have a stronger scent because of their clean, sharp acidic nature.

3.3. Sour Test Evaluation

Cheese treated with papaya latex (P4) had the least sour taste (mean score 4.92, "very weak"), most likely due to the fact that enzymatic coagulation is not solely dependent on pH decrease. On the other hand, lemon (P3, 3.0, "moderate") and vinegar (P2) produced the most sourness (2.48, "strong"). The results of the sourness of cream cheese analysis in detail can be seen in table 3 below.

Table 3. Hedonic Test Results for Cream Cheese Sourness

Acid Source	Mean Score $\pm$ SD	Color Description
P1 (Citric acid)	3.92 $\pm$ 0.28	Weak
P2 (Vinegar)	2.48 $\pm$ 0.77	Strong
P3 (Lemon)	3.00 $\pm$ 0.29	Moderate
P4 (Papaya latex)	4.92 $\pm$ 0.28	Very weak
P5 (Orange)	3.88 $\pm$ 0.33	Weak

These findings corroborate those of Guinee (2020), who discovered that vinegar's acetic acid imparts a more pronounced sourness than either citric or lactic acids. The previous research observed that enzymatic coagulation yields a softer flavor profile in comparison to acid-coagulated cheeses, which is consistent with the moderate sourness found in papaya-treated cheese Guinee (2020), Kentish et, al (2020).

3.4. Texture Evaluation

The results of the aroma analysis in detail can be seen in table 4 below.

Table 4. Hedonic Test Results for Cream Cheese Texture

Acid Source	Mean Score $\pm$ SD	Color Description
P1 (Citric acid)	3.40 $\pm$ 0.50	Soft
P2 (Vinegar)	3.04 $\pm$ 0.20	Soft
P3 (Lemon)	3.80 $\pm$ 0.41	Slightly soft
P4 (Papaya latex)	4.80 $\pm$ 0.41	Very soft
P5 (Orange)	4.48 $\pm$ 0.51	Soft

The softest texture was produced by papaya latex (P4) (mean score 4.80, "very soft"), most likely as a result of casein proteins being broken down by proteolytic enzyme activity. Firmer textures (≈ 3.0 , "soft") were created by vinegar (P2) and citric acid (P1), which is in line with conventional acid-coagulated cheeses.

This supports the findings found that acid-induced coagulation produces stronger gel structures than enzymatic coagulation [19]. It's possible that leftover pectin or other fruit-derived substances influencing protein interactions are the cause of the slightly softer texture in lemon-treated samples (P3, 3.80).

3.5. Hedonic Quality Test Results (Preference)

According to the preference test, vinegar (P2) was least preferred for aroma and flavor (4.68, "dislike"), while citric acid (P1) was most preferred for color, taste, and texture (mean scores ≈ 1.2 , "like very much"). The detailed results can be seen in Table 5 below.

Table 5. The Result of Hedonic Quality Test

Parameter	P1 (Citric)	P2 (Vinegar)	P3 (Lemon)	P4 (Papaya Latex)	P5 (Orange)
Color	1.16 $\pm$ 0.37	1.24 $\pm$ 0.52	1.48 $\pm$ 0.77	2.04 $\pm$ 1.27	1.60 $\pm$ 0.86
Cheese Aroma	1.48 $\pm$ 0.82	4.20 $\pm$ 0.41	2.28 $\pm$ 0.61	1.28 $\pm$ 0.45	3.12 $\pm$ 0.53
Taste	1.20 $\pm$ 0.50	4.60 $\pm$ 0.50	1.84 $\pm$ 0.75	4.80 $\pm$ 0.41	1.60 $\pm$ 0.58
Texture	1.12 $\pm$ 0.33	1.40 $\pm$ 0.71	2.24 $\pm$ 0.93	4.92 $\pm$ 0.28	4.72 $\pm$ 0.46

Papaya latex (P4) had a low taste and texture score (≈ 4.9), most likely as a result of its excessively soft texture and weak sourness. The faint fruity aromas of orange (P5) may have contributed to its moderate preference (1.60 for taste).

Papaya latex (P4) was marginally less preferred because of its greenish color (SD 1.27), although all treatments received positive scores (mean 1.20–1.76, "like very much" to "like"). According to research on the pungency of acetic acid, papaya latex (P4) was best liked (mean 1.28), whilst vinegar (P2) was least liked (mean 4.20, "dislike") McCarthy (2021). Papaya latex (P4) received a low score (mean 4.80) because of its blandness from insufficient proteolysis, while citric acid (P1) and orange (P5) were the most popular options (mean 1.16–1.60) Malcata et, al (2019). According to proteolytic degradation investigations, orange (P5) and papaya latex (P4) were hated (mean 4.72–4.92) for being too soft, whereas citric acid (P1) was preferred for firmness (mean 1.16), Silva et, al (2019).

These results are consistent with those of previous research, who discovered that customers favor cheeses that have a balance between firmness and acidity Hayaloglu et, al (2020). The considerable distaste for the sharpness of vinegar is consistent with the findings that acetic acid in dairy products can be seen as unpleasant McSweeney et, al (2020).

3.6. pH Measurements

The detailed results can be seen in Table 6 below.

Table 6. The Result of pH Measurements

Acid Source	pH Value $\pm$ SD
P1 (Citric acid)	4.13 $\pm$ 0.06
P2 (Vinegar)	3.73 $\pm$ 0.06
P3 (Lemon)	4.43 $\pm$ 0.06
P4 (Papaya latex)	5.57 $\pm$ 0.06
P5 (Orange)	4.27 $\pm$ 0.06

There was a large variation in the pH levels. Because vinegar (P2) had the lowest pH (3.73), it was quite sour. Papaya latex (P4), which has a mildly acidic flavor, has the highest pH (5.57). The ideal pH range for cheese durability was lemon (P3, 4.43) and citric acid (P1, 4.13) [24]. These findings are consistent with the research who claimed that fresh cheeses' microbiological stability depends on a

pH of less than 4.6 Horne and Lucey (2021). The greater pH of papaya-treated cheese indicates that intense acidification is not necessary for enzymatic coagulation, which could affect shelf life.

3.7. Financial Feasibility of The Cream Cheese Business

The financial study suggests a conditionally viable but high-risk operational structure for cream cheese production in Samarinda, with significant cost pressures and low profit margins. With variable costs accounting for 68.6% of revenue (IDR 24,000/unit), largely raw materials (75% of variable costs), and fixed costs accounting for IDR 10 million per month (69% from rent and wages), the business is very sensitive to sales volume variations Durham et, al (2015). The detail data can be seen in Table 7.

Table 7. Production Cost of Cream Cheese

Cost Component	Amount (Rp/Month)
Variable Cost per Unit	(00gr)
Raw Materials	18,000
Packaging & Label	3,500
Transportation	,500
Total Variable Cost/Unit	4,000
Fixed Costs	3,500,000
Production Facility Rent	
Employee Wages (persons)	4,000,000
Utilities	800,000
Marketing 1,	100,000
Miscellaneous	500,000
Total Fixed Costs/Month	10,000,000

The break-even figure of 909 units (IDR 31,815,000) is 90.9% of the minimum estimated demand, leaving little operational flexibility. At 1,000 units, revenue reaches IDR 35,000,000, but net income is just IDR 1,000,000 (2.86% margin), as raw materials account for 51.4% of revenue and fixed costs for 28.6%. Critically, the 9.1% Margin of Safety allows for a modest 91-unit sales reduction before losses arise, which is worsened by significant operating leverage: a 10% sales gain to 1,100 units increases profit by 110%, whereas a 10% drop to 900 units results in an IDR 100,000 loss, Eugene et, al (2018).

Table 8. Financial Feasibility of The Cream Cheese

Component	Result
Revenue (1,000 units sales)	IDR 35,000,000
Net Income (1,000 units sales)	IDR 1,000,000
BEP (Unit)	909
BEP (Amount)	IDR 31,815,000
Margin of Safety (1,000 units)	9.1%

Strategic imperatives include negotiating bulk raw material purchases to reduce variable costs by 10-15% (potentially lowering BEP to 830 units), expanding distribution to 15+ cafés to increase sales by 20% (increasing Margin of Safety to 25%), and implementing festive-season buffer stocks to capitalise on Q4 demand spikes (+30%). Given these limits, the enterprise must aggressively contain costs and expand the market during a trial phase (700 units per month) before growing.

4. Conclusion

Significant differences in texture, pH, and sensory qualities were found in the thorough analysis of cream cheese made with several acidulants (citric acid, vinegar, lemon, papaya latex, and orange). The judges found that orange (P5) and citric acid (P1) were the most advantageous acidulants, producing cream cheese with the desired qualities of bright white color, balanced sourness, and

ideal firmness. Papaya latex (P4), on the other hand, generated cheese with poorer sensory qualities, such as excessive softness and weak flavor, despite the advantages of enzymatic coagulation. This was probably caused by inadequate proteolysis and a higher pH. Lemon (P3) and vinegar (P2) performed rather well, with lemon adding a light, citrus-influenced flavor and vinegar adding a harsher sour taste. These results were corroborated by the pH measurements, which showed that softer, less acidic cheese was produced by higher pH (e.g., papaya latex at 5.57), whereas harder texture and more sourness were associated with lower pH (e.g., vinegar at 3.73). These findings demonstrate how important it is to choose the right acidulants when making cream cheese, with orange juice and citric acid being the best options for producing a product that is well-balanced in terms of flavor, texture, and customer acceptability. To improve the functional characteristics of plant-based coagulants like papaya latex, future research could investigate hybrid acidulant systems or process improvements. The financial analysis emphasizes the importance of meeting break-even volumes while keeping raw material expenditures under control, which account for the majority of production costs. Given the marginal safety buffer in sales volumes, the suggested acidulants (orange/citric acid) must be assessed not only for sensory performance, but also for supply chain economics, notably their impact on variable costs and scalability.

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