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Formulasi of Pastry with Salak Flour as a Source of Phenolic Compounds and Antioxidant Activity Analysis

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Abstract: Snake fruit (Salacca zalacca) is a potential source of dietary fiber and bioactive compounds, particularly phenolic compounds, and can be developed as a flour substitute in pastry products; however, its application as flour in puff pastry remains limited. This study aimed to develop a puff pastry formulation incorporating salak flour as a functional food ingredient and evaluate the effects of soaking treatments on its physicochemical characteristics. The research consisted of two stages: preparation of salak flour using different soaking solutions and formulation of puff pastry with varying levels of salak flour substitution for wheat flour (0–100%). The analyzed parameters for the flour included yield, color (Hue), bulk density, moisture content, ash content, and mold resistance; while for the puff pastry, the analyses covered proximate composition (moisture, protein, fat, carbohydrate), antioxidant activity (DPPH, IC_{50}), total phenolics, and hedonic evaluation. The results showed that soaking type and concentration significantly affected several flour characteristics. The highest yield was obtained with the 1% lime-water treatment (13.93%), while the lowest observed with 2% lactic acid (8.24%). Salak flour substitution altered the chemical composition and increased phenolic content and antioxidant activity, while carbohydrate content was not significantly affected ($p>0.05$). Based on chemical quality, antioxidant activity and sensory acceptance, 25% substitution was recommended as the optimal formulation. Further research should evaluate storage stability, starch profiling, industrial-scale feasibility, and economic analysis for the commercialization of salak flour.

Keywords: Antioxidant activity; DPPH; Phenolic compounds; Puff pastry; Salak flour; Soaking treatment

Introduction

The food industry is one of the strategic sectors in supporting national economic growth, especially in relation to the tourism industry and the lifestyle of modern society. Based on data from the Ministry of Industry, the food and beverage industry contributes 6.66% to Indonesia's Gross Domestic Product (GDP) (Banjarbaru Center for Standardization and Industrial Services, 2021). As public awareness of the importance of a healthy lifestyle increases, food consumption trends are shifting, not only focusing on taste and energy fulfillment but also on nutritional content and bioactive components (Batubara et al., 2020).

These changes in consumption patterns have led to increased attention toward foods containing bioactive components, one of which is phenolic compounds (Suryawati et al., 2021). Phenolic compounds are a group of secondary metabolites commonly found in plant-based foods and are known to have high antioxidant activity (Mu'nisa, 2023). These compounds play a role in neutralizing free radicals thru the mechanism of electron or hydrogen atom donation, thereby potentially reducing oxidative stress (Ulma'nun et al., 2023). Therefore, the development of food products containing phenolic compounds has become one of the important approaches in enhancing the functional added value of food (Kusumayanti et al., 2016).

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On the other hand, pastry products such as puff pastry, croissants, and pies are bakery products favored by the public, but they are generally still dominated by the use of wheat flour as the main raw material. Wheat flour contributes to the formation of dough structure thru its gluten content (Biesiekierski, 2017), but wheat-based products generally have relatively low fiber and bioactive component content (Eugene et al., 2022). This condition opens up opportunities for the development of pastry products by adding alternative raw materials that not only function technologically but also contribute to the increase in bioactive compound content (Sutardi, 2017).

One of the local ingredients with great potential as a substitute for wheat flour is the salak fruit (Salacca zalacca). Salacca zalacca is a tropical fruit widely cultivated in Indonesia, particularly in the regions of North Sumatra, Java, and Bali. This fruit is known for its sweet taste even when still young, its relatively high water content, and its ability to bear fruit throughout the year (Hidayatun et al., 2018). Salacca contains dietary fiber, complex carbohydrates, vitamin C, calcium, phosphorus, and antioxidant compounds such as phenols and flavonoids (Mandei et al., 2021; Saleh et al., 2018). Interestingly, its protein content is low and it almost does not contain gluten, making it suitable as a raw material for gluten-free flour (Sinaga et al., 2024).

To make salacca flour-based pastries a functional food suitable for consumption, it is necessary to evaluate their physical characteristics (moisture content, protein, fat, and carbohydrates), as well as the content of bioactive components such as total phenols and antioxidant activity (Rahmah et al., 2024). Research on the substitution of salacca flour in pastry making includes: The study by Anggara et al. (2022) which sought the best salacca flour substitution in cake making, with the best characteristics including color, aroma, texture, and taste being a 40% salacca flour substitution. The study by Poiana et al. (2023) found that a 25% substitution of grape pomace in bakery products could increase total phenols by up to 8 times and significantly enhance antioxidant activity. Meanwhile, Mahmoud et al. (2021) reported that the fermentation of wheat bran with Saccharomyces cerevisiae increased the phenolic content in puff pastry products. On the other hand, Aditami et al. (2024) sought the best substitution of salacca flour in cookie making, with the best results including color, aroma, taste, texture, and nutritional content being a 50% substitution of salacca flour. Therefore, this study aims to examine the effect of salacca flour substitution on the physical quality and bioactive components of puff pastry products, thereby contributing to the development of healthy, innovative, and economically valuable local functional foods.

Method

The research will be divided into two stages according to the sample preparation to be conducted, the first stage being the production of salacca flour and the second stage the production off pastry. Salacca Flour Research Equipment and Materials I Some of the equipment used in this first stage of research includes; analytical balance, digital scale, stainless steel knife, plastic cutting board, stainless steel spoon, basin, plastic strainer, filter cloth, tissue, aluminum baking sheet, food dehydrator, oven, blender, Tyler mesh 80 sieve, stopwatch, freezer, nitrile gloves, zip lock plastic, colorimeter, petri dish, spatula, lint-free cloth, measuring cup, spoon, porcelain dish, desiccator, tweezers, laboratory oven (100–105°C), furnace, room temperature storage cabinet, camera, beaker glass, running water, filter paper, small sieve. The materials used in this first phase of research are: Sidempuan Putih (Nabontar) variety salak fruit at physiological maturity of 5 months, food-grade lactic acid, citric acid, food-grade slaked lime ($Ca(OH)_2$), clean water/aquades, 70% ethanol, label paper, silica gel.

Method and Research Design Model

The method used in this research is a Completely Randomized Design (CRD) consisting of two factors with 3 treatments for soaking salacca, namely: Factor I: Type of Soaking (P), which are: P1 = Lactic acid solution (C3H6O3) P2 = Citric acid solution (C6H8O7) P3 = Slaked lime solution (Ca(OH)2) Factor II: Concentration Treatment (K) with a duration of 30 minutes, namely: K1 = 1% K2 = 1.5% K3 = 2% Thus, the Treatment Combination (Tc) is 3 x 3 = 9 and the minimum number of replications (n) is as follows: Tc (n-1) ≥ 15 9 (n-1) ≥ 15 n-1 ≥ 15/9 = 1.67 n ≥ 2.67 For accuracy in this analysis, 3 replications are performed, resulting in a total of 27 samples.

The Research Design Model is conducted using a two-factor completely randomized design (CRD) model as follows:

$$\hat{Y}ijk = \mu + \alpha i + \beta j + (\alpha\beta)ij + \varepsilon ijk \quad (1)$$

Explanation:
$\hat{Y}ijk$: The test result of factor P at level i and factor K at level j in the k-th replication.
μ : The effect of the mean value αi : The effect of factor P at level i.
βj : The effect of factor K at level j.

(αβ)ij : The interaction effect of factor P at level i and factor K at level j.
εijk : The error effect of factor P at level i and factor K at level j in the k-th replication.

If significantly different or very significantly different results are obtained, the test is continued with a mean difference test, using Tukey's test for further testing of the ANOVA test. Making Salacca Flour Here is the method for making Salacca Flour (Ifmalinda et al., 2019).

Slicing and Soaking the salacca fruit is first cleaned and then thinly sliced. Next, the slices are weighed and evenly divided according to the treatment type. The samples are soaked for 30 minutes in lactic acid solution, citric acid solution, and lime solution according to the treatments K1= 1%, K2 = 1.5%, and K3 = 2%. After soaking, the materials are not rinsed again before drying, with the aim of preserving the antioxidant effects and natural antimicrobial properties of the soaking solution, but they are drained on clean tissue/cloth to avoid being too wet from the solution. Drying After soaking, transfer the salak to a baking tray and then place it in the oven at 60°C for a drying time of 12 hours.

Blender

The process of reducing particle size is done mechanically using a blender.

Sieving

Sieving is the process of separating materials based on the size of the wire mesh holes in the sieve. Materials smaller than the mesh size will pass thru, while larger materials will be retained on the surface of the sieve wire. Mesh is the number of holes in a one square inch area of the screen/net that can be passed thru by solid material. If expressed in millimeters, the indicated number represents the size of the material being sieved. The sieve used in this study is a Tyler mesh 60 sieve (Ayu et al., 2022).

Research Parameters for Salak Flour

The analysis to be conducted includes physical and chemical analysis. Determination of Yield The yield of flour referred to is the flour that passes thru a 60 mesh sieve. The yield is calculated using the formula:

$$\text{Yield } \% = \frac{\text{Final product weight}}{\text{Initial product weight}} x\ 100\% \quad (2)$$

Moisture Content Test (AOAC 2005)

The cup is first dried in an oven at 100–105°C until its weight is constant, then cooled in a desiccator and weighed as the empty cup (Galera et al., 2023). A 3 g sample of flour is weighed and placed in the dried cup. The weighing result is recorded as the weight of the cup + sample. The cup containing the sample is placed back in the oven at a temperature of 100–105°C for 6 hours until its weight is constant. After the drying process, the dish is cooled in a desiccator and then weighed again (weight of the dish + dry sample). Moisture content (%) is calculated using the formula:

Moisture content % = (Initial weight - Final weight - Cup weight) /(Initial weight) × 100% (3)

Ash Content Test (AOAC, 2005)

Porcelain dishes are first dried in an oven at 100–105°C until their weight is constant, then cooled in a desiccator and weighed (weight A). A 3 g flour sample is weighed and placed into the dish (weight B). The dish with the sample is then burned in a furnace at 550°C for 4 hours until all organic material is burned off, leaving only ash. After ashing, the dish is cooled in a desiccator and weighed again (weight C). Ash content is calculated using the formula:

Ash content % = (((Weight of ash + Weight of cup) - Weight of cup)) / (Weight of sample)) × 100% (4)

Puff Pastry

The best salak flour from stage I is used in the formulation of puff pastry in stage II as a substitute for wheat flour. Substitution was carried out in five treatment levels to determine its effect on the chemical characteristics and bioactive compounds of the final product.

Research Equipment and Materials II

The tools used in the second phase of the research are: digital scale, mixing bowl, stand mixer, rolling pin, rubber spatula, plastic scrapper, clear plastic, plastic wrapping, Tyler sieve 60 mesh, kitchen tissue, chiller, baking oven, oven tray, silicone brush, porcelain cup, drying oven (100-105°C), desiccator, hot plate, Kjeldahl flask, Kjeldahl distillation system, electric heater, 550°C furnace, Soxhlet extractor, fat sleeve, fat flask, measuring cup, beaker glass, Erlenmeyer flask, glass funnel, tweezers, reflux flask, condenser, filter paper, UV-Vis spectrophotometer, cuvettes, dropper pipette, volumetric pipette, vortex mixer, water bath, shaker, measuring flask, reaction tube, centrifuge, Whatman filter paper no. 1, dark bottle, flat plate, mineral water glass, hedonic assessment sheet, stationery. The materials used in stage II are; the best quality salacca flour from stage I, high-protein wheat flour, salt, white butter, shortening, cold water, distilled

water, 0.02 N HCl solution, petroleum ether, concentrated sulfuric acid (H_2SO_4), potassium sulfate (K_2SO_4), 30% NaOH solution, boric acid solution (H_3BO_3). mixed indicators (methyl red + bromocresol green), DPPH (2,2-diphenyl-1-picrylhydrazyl), methanol, ascorbic acid, Folin–Ciocalteu reagent, sodium carbonate (Na_2CO_3), gallic acid.

Method and Research Design Model

The method used in this research is a Completely Randomized Design (CRD) with the treatment of substituting wheat flour with salacca flour, conducted with 5 treatment levels and 3 replications. The comparison of the mixture of salacca flour and wheat flour is as follows: T1 = 0% : 100% T2 = 25% : 75% T3 = 50% : 50% T4 = 75% : 25% T5 = 100%: 0%.

For accuracy in this analysis, 3 replications were conducted, resulting in a total of 15 experimental units. The research design model was conducted using a completely randomized design (CRD) one-factorial model as follows:

$$Yij = \mu + \tau i + \varepsilon ij \quad (5)$$

Explanation:
Yij = The observed value in treatment T for the i-th and j-th replication
μ = The overall mean effect
τi = The effect of treatment T with the third substitution of salacca flour
εij = The error effect of treatment T at the i-th level in the j-th replication

Data were analyzed using Analysis of Variance (ANOVA) to see the differences between treatments. If there are significant differences, it will be followed by Tukey's post-hoc test to determine the significant differences between treatment.

Research Parameters

The testing methods used include the analysis of chemical properties in puff pastry with substitution formulas according to treatments, namely moisture content analysis, fat content analysis, protein content, carbohydrate content, DPPH, and total phenols.

Moisture Content

The determination of moisture content is carried out based on the drying oven method. The dish is first dried in an oven at a temperature of 100–105°C until a constant weight is achieved, then cooled in a desiccator and weighed as the initial weight of the empty dish. A 3-gram sample of puff pastry is weighed and placed into the dish. The cup is then placed in the oven at the same temperature for 6 hours until its weight stabilizes. After drying, the dish is cooled in a desiccator and reweighed as the final weight (dish + dry sample). Moisture content is calculated based on the mass loss during the drying process using the following formula:

$$\%\text{Moisture content} = ((A-B))/A \times 100 \quad (6)$$

Explanation:
A = Weight of the cup + sample before drying (g)
B = Weight of the cup + sample after drying (g)

Protein Content Test

The determination of protein content is carried out using the Kjeldahl method according to AOAC (2005), which consists of three main stages: digestion, distillation, and titration. In the digestion stage, approximately ±0.5 g of the sample is weighed and placed into a Kjeldahl flask, then 10 mL of concentrated sulfuric acid (H_2SO_4) and a mixture of potassium sulfate (K_2SO_4) and copper sulfate ($CuSO_4$) catalyst are added. The mixture is heated until the solution becomes clear, indicating that the organic nitrogen has been oxidized into ammonium ions (NH_4^+). The resulting digest solution is then cooled and diluted with distilled water. The next step is distillation. The digested solution is added to a 40% NaOH solution to convert NH_4^+ ions into ammonia gas (NH_3). The NH_3 gas is then distilled and captured by a 4% (w/v) boric acid solution that has been mixed with a methyl red-bromocresol green indicator. The capture of NH_3 by boric acid forms a borate-ammonium complex, which is subsequently analyzed thru titration. The distillation-titration process was carried out on both the sample and the blank (without the sample) using the same reagents and procedures. The blank titration aims to correct the volume of HCl used due to the reagents and trapping solution, thus obtaining the value of Vb (blank HCl volume). Thus, the volume of HCl that actually reacts with the nitrogen sample is obtained from the difference Vs – Vb. The distillate is then titrated using 0.1 N HCl until the indicator changes color to the endpoint of the titration. The volume of HCl required for the titration reflects the amount of nitrogen in the sample. This nitrogen value is converted into protein using the Kjeldahl conversion factor (Fk). The calculation of protein content is determined by the following equation: %"Protein"=((V_s-V_b)×N×14.007×F_k)/(m x 1000)×100% Explanation: Vs = Volume of HCl for the sample (mL) Vb = Volume of HCl for the blank (mL) N = Normality of HCl (0.1 N) 14.007 = Atomic weight of nitrogen (mg) Fk = Conversion factor from nitrogen to protein (6.25) This formula is based on the concept that (Vs – Vb) × N produces milliequivalents of HCl that react with the nitrogen from the sample. After being multiplied by the nitrogen equivalent weight (14.007 mg/meq), the

nitrogen mass (mg) is obtained, which is then converted into protein using a factor of 6.25 and expressed as a percentage of the sample mass.

Fat Content Test

The sample is weighed 3 g, then placed into a fat sleeve, inserted into a pre-weighed fat flask, and connected to a Soxhlet tube. The fat sleeve is placed into the Soxhlet extractor and heated at 40 ˚C using a hot plate for 6 hours. The solvent in the fat flask is distilled until all the solvent is removed, then the fat flask is dried in an oven at 150 ˚C, the flask is cooled in a desiccator, and weighed until a constant weight is achieved. The fat content is calculated using the formula:

$$\%Fat = (W2 - W1) / m \times 100 \quad (7)$$

Explanation:
W1 = Weight of the empty flask (g)
W2 = Weight of the flask + fat extract (g)
m = Weight of the sample (g)

Antioxidant Activity Test
Sample Preparation

The puff pastry samples were dried in a low-temperature oven (50°C) for approximately 24 hours to reduce moisture content, then ground using a blender until powdered. As much as 10 grams of puff pastry powder was extracted using 100 mL of 70% ethanol with the maceration method using a shaker for 2 hours at room temperature. The obtained extract was filtered using Whatman No. 1 filter paper, and the filtrate was used as the stock solution (Singleton et al., 1999).

Preparation of DPPH Solution

10 mg of DPPH powder (2,2-diphenyl-1-picrylhydrazyl) was weighed and dissolved in 100 mL of 70% ethanol, resulting in a DPPH stock solution with a concentration of 100 µg/mL. This solution was then diluted to obtain a working concentration of 40 µg/mL, which was used in the antioxidant activity test. The DPPH solution is prepared fresh before use and stored in dark bottles to avoid degradation due to light (Molyneux, 2004).

Determination of Maximum Wavelength (λmax)

The absorbance of a 40 µg/mL DPPH solution was measured using a UV-Visible spectrophotometer in the wavelength range of 400–800 nm. The wavelength value with the highest absorbance is designated as the maximum wavelength (λmax). The measurement results show that λmax is at 516 nm, consistent with visual observations and literature references (Molyneux, 2004).

Determination of Optimum Incubation Time

To determine the optimum reaction time, a 40 µg/mL DPPH solution was measured for absorbance every 1 minute for 60 minutes at a wavelength of 516 nm. The time when the absorbance value began to stabilize was set as the optimum incubation time. Based on the measurements, the absorbance stabilized at the 20th minute, so the incubation time used in the antioxidant activity test was 20 minutes (Molyneux, 2004).

Determination of DPPH Radical Scavenging Percentage

The antioxidant activity of puff pastry extract is assessed based on its ability to scavenge DPPH free radicals. The scavenging is calculated using the following formula (Brand-Williams et al., 1995):

$$\%Inhibition = ((Ao - As)) / Ao \times 100 \quad (8)$$

Explanation:
A0 = Absorbance of the DPPH solution without the sample (control)
AS = Absorbance of the DPPH solution + sample

Preparation of the Scavenging Percentage Calibration Curve

1 mL of 100 µg/mL DPPH solution is pipetted into five 5 mL volumetric flasks. Each is supplemented with 0 mL, 0.25 mL, 0.5 mL, 0.75 mL, and 1 mL of sample solution, then diluted with 70% ethanol to a volume of 5 mL. The solution is homogenized and incubated in the dark for 20 minutes at room temperature. The absorbance of each solution was measured at a wavelength of 516 nm with three repetitions. The measurement results are used to calculate the percentage inhibition, which is then plotted against the concentration of the sample solution to form a linear regression curve (Molyneux, 2004).

Determination of IC_{50} Value

The IC_{50} value is the concentration of the extract that can quench 50% of DPPH free radicals. This value is obtained from the linear regression equation of the calibration curve between the extract concentration (X) and the percentage inhibition (Y), by substituting the value Y = 50 into the equation:

$$Y=aX+b \quad (9)$$

Explanation:
Y = Percentage inhibition of DPPH
X = Concentration of the sample solution (µg/mL) IC50

Total Phenol Analysis

The total phenol content is determined using the Folin–Ciocalteu (FC) method based on the procedure

modified from Singleton et al. (1999). The principle of this method is a redox reaction between phenolic compounds and the Folin–Ciocalteu reagent (a complex mixture of phosphomolybdate-phosphotungstate) that produces a blue-colored complex. The intensity of the blue color formed is measured spectrophotometrically and is proportional to the total phenol concentration in the sample.

Preparation of the Calibration Curve

Gallic acid standard solutions will be prepared in various concentrations, namely 0, 20, 40, 60, 80, and 100 mg/L. Each solution of 1 mL will be reacted with 1 mL of 10% Folin–Ciocalteu reagent, then incubated for 5 minutes at room temperature. Next, 3 mL of 7% Na_2CO_3 solution will be added, and the mixture will be incubated for 90 minutes in the dark at room temperature. The absorbance of the solution will be measured at a wavelength of 725 nm using a spectrophotometer. The absorbance measurements of the gallic acid standard solution are plotted against the concentration (mg/L) to produce a linear calibration curve. This relationship is then formulated in the form of the following linear regression equation:

$$Y=aX+b \quad (10)$$

Explanation:
Y = Absorbance measured at a wavelength of 725 nm
X = Gallic acid concentration (mg/L)
a = Slope (gradient of the regression line), indicating the change in absorbance with increasing concentration
b = Intercept (Y-intercept), which is the absorbance value when the concentration (X) = 0.

This equation will be used to calculate the total phenol concentration in the sample. The value of X (in mg/L) can be obtained from the sample absorbance Y using the formula:

$$X=(Y-b)/a \quad (11)$$

This value of X is then expressed as the phenol concentration (C) used in the calculation of total phenol content.

Sample Preparation

1 gram of puff pastry sample was weighed and extracted using 10 mL of 70% ethanol. The mixture was sonicated for 30 minutes to maximize the release of phenolic compounds, then centrifuged at 3000 rpm for 15 minutes. The clear supernatant obtained is used as the phenolic extract solution.

Dilution of Extract

To ensure the absorbance value is within the linear range of the calibration curve, the extract solution is diluted tenfold using 70% ethanol. A total of 0.5 mL of this diluted extract is used for the total phenol analysis reaction.

Folin-Ciocalteu Reaction

0.5 mL of the diluted extract is reacted with 1 mL of 10% Folin–Ciocalteu reagent. After 5 minutes of incubation, 3 mL of 7% Na_2CO_3 solution is added and incubated in the dark for 90 minutes at room temperature. The absorbance of the solution was measured at a wavelength of 725 nm. The absorbance value is corrected against the reagent blank (ethanol + reagent without sample) to eliminate reagent interference in the reading results.

Calculation of Total Phenol Content

The phenol content is expressed in mg Gallic Acid Equivalent (GAE) per gram of dry material, calculated using the following formula:

$$\text{Total phenol content (mg GAE/g)} = (C \times V \times DF) / (1000 \times m) \quad (12)$$

Explanation:
C = phenol concentration from the calibration curve (mg/L)
V = total extract volume (mL) = 10 mL
DF = dilution factor = 10
m = sample mass (g) = 1 g
1000 = conversion from mL to L to obtain the unit in mg

Repetition

The entire analysis process was conducted three times (triplicate) for each treatment sample.

Hedonic Testing

Organoleptic testing on the parameters of color, aroma, texture, and overall acceptance using a hedonic test (scale 1-7) on pastries (Triandini et al., 2022). The hedonic test is used to measure the level of preference for snack bar products using a scoring sheet. The assessment of the product taken from (Wulandari et al., 2023) includes taste, aroma, color, texture, and overall. The assessment indicators for each sub-variable are very much liked (5), liked (4), somewhat liked (3), disliked (2), and very much disliked (1). The hedonic test was conducted on untrained panelists, specifically 100 students from the 2022 batch of the sports science program. The hedonic test was conducted in the physiology laboratory room at Universitas Negeri Medan. The testing was conducted from 10:00 to 11:00 AM.

The implementation procedure includes (1) at the time of testing, the number of students entering was 20 people, (2) placing the sample product on a flat plate and putting it on each panelist's table, accompanied by a glass of drinking water, (3) panelists receiving an explanation of the testing procedure and filling out the assessment sheet, (4) panelists trying the product and filling out the assessment sheet, (5) the assessment sheets being collected. The samples were tested by untrained panelists with different codes assigned to each sample. The hedonic test scale for the parameters of color, aroma, texture, and overall acceptance can be seen in Table 1.

Table 1. Hedonic Test Scale for Puff Pastry Test

Numeric Scale	Description
7	Very much like
6	Like
5	Spmewhat like
4	Neutral
3	Somewhat dislike
2	Dislike
1	Very much dislike

Result and Discussion

The research was conducted in two stages. The first stage aims to produce high-quality salacca flour thru soaking treatment using lactic acid, citric acid, and lime with a concentration of 1–2%. The second stage aims to evaluate the effect of substituting salacca flour in puff pastry on its physicochemical, functional, and sensory characteristics. Making Salacca Flour and Soaking Treatment The Sidempuan Putih variety of salak fruit is processed into flour thru peeling, slicing, soaking, drying, grinding, and sieving. The soaking treatment is carried out to inhibit enzymatic browning and maintain the quality of the flour. The acid solution works by reducing the activity of the PPO enzyme, while lime strengthens the tissue thru the formation of calcium pectate. The resulting flour is expected to have a bright color, low moisture content, and stability during storage.

Physicochemical Characteristics of Salacca Flour Moisture Content

The interaction of the type of solution and concentration has a very significant effect on the moisture content. The moisture content values range from 5.78% to 11.47%, with the lowest moisture content in the treatment with 2% lime (P3K3). All treatments meet the SNI standards because the moisture content is below 14.5%, resulting in good storage stability for the flour.

Distance	Tukey HSD 0,05	Tukey HSD 0,01	Treatment	Mean	Std. Dev	Notation 0,05	Notation 0,01
			P1K1	6,518	0,179	a	A
2	1,713	2,410	P1K2	7,783	1,356	a	A
3	1,831	2,611	P1K3	7,841	1,665	a	A
4	1,890	2,729	P2K1	6,707	1,328	a	A
5	1,932	2,800	P2K2	6,932	0,454	a	A
6	1,961	2,853	P2K3	7,748	0,944	a	A
7	1,985	2,901	P3K1	11,469	0,224	b	B
8	2,003	2,936	P3K2	7,795	0,813	a	A
9	2,020	2,966	P3K3	5,781	1,098	a	A

Figure 1. Tukey HSD test of the effect of solution type and concentration on the moisture content of salacca flour. Note: Values are presented as the mean ± standard deviation of three repetitions (n = 3). Different letter notations indicate significant differences at the 5% level (lowercase letters) and very significant differences at the 1% level (uppercase letters) in the same column

This finding is in line with Santosa et al. (2019), who reported that soaking in citric acid solution during the production of purple sweet potato flour increases the moisture content at high acid concentrations due to the formation of gel structures from pectin degradation. Amin et al. (2022) also explained that increasing acid concentration accelerates the hydrolysis of polysaccharides, making it easier for water to be absorbed into the tissue but difficult to be released during drying.

Ash Content

The type of solution, concentration, and their interaction significantly affect the ash content. The highest ash content is found in 2% lime (18.69%), while the lowest is in 2% lactic acid (0.61%). The high ash content in lime is due to the accumulation of Ca^{2+} minerals during soaking. Acid treatment, specifically P1K3, resulted in an ash content that closely resembles commercial wheat flour.

Distance	Tukey HSD 0,05	Tukey HSD 0,01	Treatment	Mean	Std. Dev	Notation 0,05	Notation 0,01
			P1K1	3,511	0,250	b	C
2	0,728	1,024	P1K2	0,901	0,201	a	AB
3	0,778	1,109	P1K3	0,610	0,230	a	A
4	0,803	1,160	P2K1	2,787	0,342	b	C
5	0,821	1,190	P2K2	2,397	0,146	b	BC
6	0,833	1,212	P2K3	2,452	0,194	b	C
7	0,843	1,232	P3K1	12,695	1,131	e	D
8	0,851	1,247	P3K2	14,585	0,289	d	E
9	0,858	1,260	P3K3	18,695	0,059	e	F

Figure 2. Tukey HSD test on the effect of solution type and concentration on the ash content value of salacca flour. Note: Values are presented as the mean ± standard deviation of three repetitions (n = 3). Different letter notations indicate significant differences at the 5% level (lowercase letters) and very significant differences at the 1% level (uppercase letters) in the same column

The treatment using a basic solution (P3: slaked lime) resulted in a very high spike in ash content compared to the acid treatments (P1 and P2). This phenomenon is strongly suspected to be related to the chemical properties of calcium hydroxide [$Ca(OH)_2$], which dissociates into Ca^{2+} ions during soaking. The calcium ions can bind with organic acids and pectin in the cell walls, forming calcium pectate compounds that are water-insoluble, thus remaining after the drying process. A similar mechanism was reported by Falade & Okafor (2015), which showed that starchy materials can absorb minerals from the soaking solution and result in a significant increase in ash content (Koc et al., 2020).

Chemical Composition of Puff Pastry

Moisture Content

The substitution of salacca flour has a very significant effect on the moisture content of puff pastry. The higher the proportion of salacca flour, the higher the moisture content due to the high ability of the fibers and starches in salacca flour to bind water. The highest value was found in T5 (100% salak flour) at 7.04%.

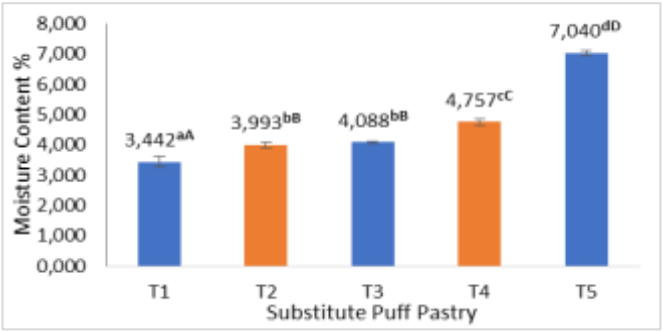


Figure 3. Moisture content. T1= 0%:100%, T2= 25%:75%, T3=50%:50%, T4= 75%:25%, T5= 100%:0%

Protein Content

The protein content increased from 7.45% at T1 to 8.00% at T5. This increase indicates that salak flour contributes to the protein content of puff pastry and helps in the formation of the product's structure.

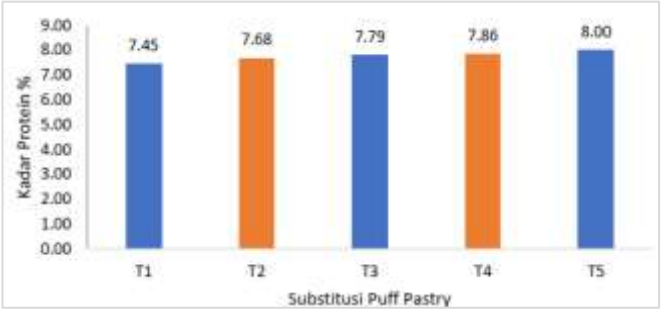


Figure 4. Protein content. T1= 0%:100%, T2= 25%:75%, T3=50%:50%, T4= 75%:25%, T5= 100%:0%

Fat Content

The substitution of salacca flour significantly reduces the fat content of puff pastry. The highest value was found in T1 (35.84%) and the lowest in T5 (29.17%). This decrease is related to the fiber content in salacca flour, which can bind some of the fat during the processing.

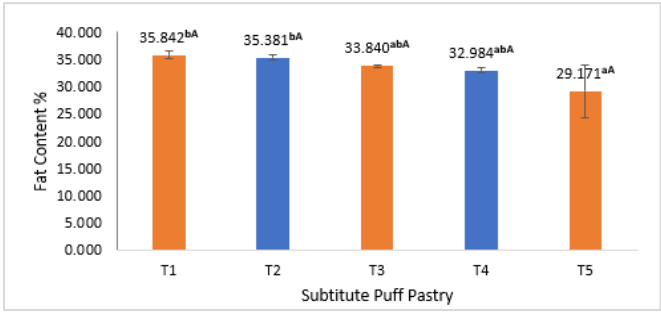


Figure 5. Fat content. T1= 0%:100%, T2= 25%:75%, T3=50%:50%, T4= 75%:25%, T5= 100%:0%

Antioxidant Activity and Total Phenol of Puff Pastry

Antioxidant Activity (IC_{50})

The substitution of salacca flour has a very significant effect on the antioxidant activity of puff pastry. The IC_{50} value decreased from 199.26 µg/mL at T1 to 93.12 µg/mL at T5, indicating an increase in antioxidant capacity as the substitution of salacca flour increased. The increase in antioxidant activity is related to the content of phenolic compounds, flavonoids, and tannins in salak flour that can capture free radicals. In addition, melanoidins formed during the Maillard reaction during roasting also contribute to the antioxidant activity of the product.

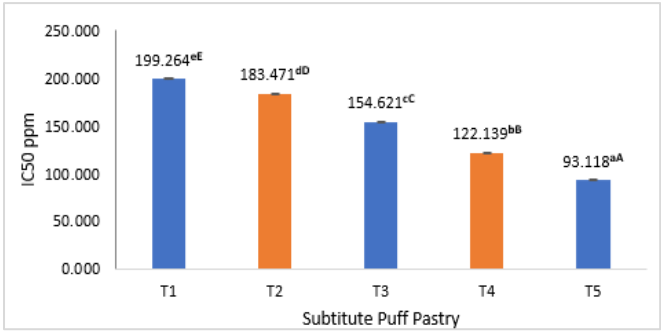


Figure 6. Antioxidant activity and total phenol of puff pastry antioxidant activity (IC_{50}). T1= 0%:100%, T2= 25%:75%, T3=50%:50%, T4= 75%:25%, T5= 100%:0%

Total Phenol

The substitution of salacca flour has a very significant effect on the total phenol content of puff pastry. The total phenol value increased from 12.46 mg GAE/g at T1 to 26.31 mg GAE/g at T5. This increase indicates that salacca flour is a potential source of phenolic compounds. The phenolic content plays an

important role in enhancing the antioxidant activity and functional value of puff pastry. The correlation between the increase in total phenols and the decrease in IC_{50} value indicates that phenolic compounds are the main contributors to the antioxidant activity of the product.

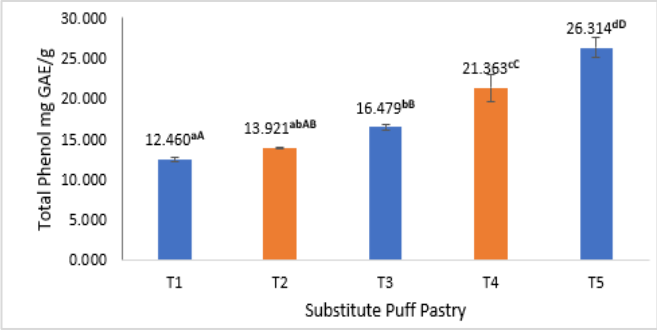


Figure 7. Total phenol. T1= 0%:100%, T2= 25%:75%, T3=50%:50%, T4= 75%:25%, T5= 100%:0%

Hedonic Test of Puff Pastry

The hedonic test was conducted on aspects of color, aroma, texture, taste, and overall acceptance to determine the panelists' level of preference for puff pastry with salak flour substitution.

Color

The substitution of salak flour has a very significant effect on the preference for the color of puff pastry. The higher the proportion of salacca flour, the darker the product color becomes due to the Maillard reaction and the phenolic content of the salacca flour. Treatments T1 and T2 had the highest levels of preference, while T4 and T5 showed a decrease in acceptance due to the color being too brown and less resembling conventional puff pastry.

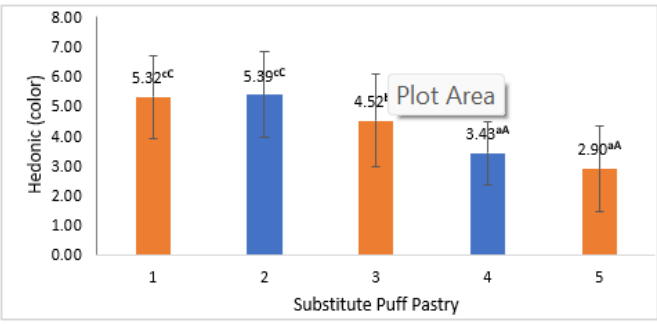


Figure 8. Color of puff pastry. T1= 0%:100%, T2= 25%:75%, T3=50%:50%, T4= 75%:25%, T5= 100%:0%

Aroma

The substitution of salacca flour does not have a significant effect on the aroma of puff pastry. The panelists' preference scores are relatively stable across all treatments because the aroma of butter, margarine, and the caramelization results during baking are more dominant than the characteristic aroma of salacca flour.

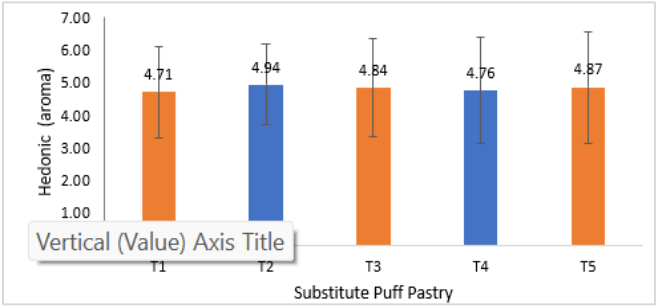


Figure 9. Aroma of puff pastry. T1= 0%:100%, T2= 25%:75%, T3=50%:50%, T4= 75%:25%, T5= 100%:0%

Texture

The substitution of salacca flour has a very significant effect on the texture of puff pastry. The higher the level of substitution, the denser, harder, and less crispy the product's texture becomes due to the decrease in gluten content and the increase in fiber content. Treatments T1 and T2 showed the most preferred texture because they were still able to maintain the characteristic layered structure of puff pastry.

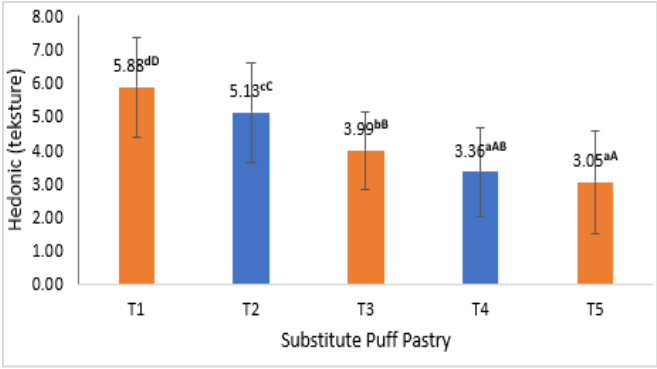


Figure 10. Texture of puff pastry. T1= 0%:100%, T2= 25%:75%, T3=50%:50%, T4= 75%:25%, T5= 100%:0%

Taste

The substitution of salak flour has a very significant impact on the taste of puff pastry. Increased substitution causes the distinctive taste of salak to become more dominant and tends to be bitter or astringent due to the presence of tannins and phenolic compounds. Treatments T1 and T2 had the highest preference levels, while T5 showed the lowest score.

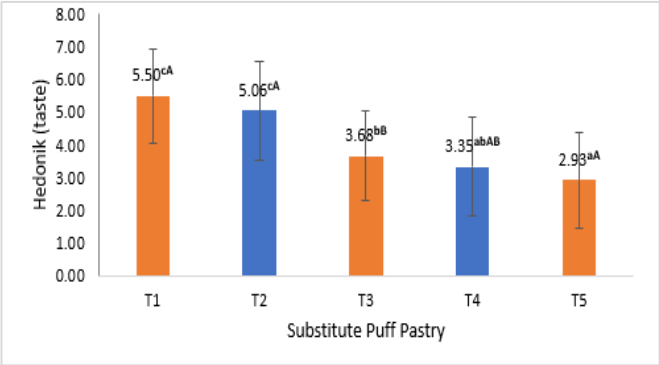


Figure 11. Taste of puff pastry T1= 0%:100%, T2= 25%:75%, T3=50%:50%, T4= 75%:25%, T5= 100%:0%

Conclusion

The type and concentration of the soaking solution significantly affect the physicochemical characteristics of salacca flour. The best treatment was obtained with 2% lactic acid soaking (P1K3), which produced flour with low moisture content, stable color, ash content in accordance with SNI, and stability against mold growth during storage. The substitution of salacca flour in puff pastry significantly affects moisture content, ash content, fat content, fiber content, total phenols, antioxidant activity, and sensory characteristics. Increasing the proportion of salacca flour can enhance total phenols and antioxidant activity, but it decreases sensory acceptance at high substitutions. The best formulation was obtained with a 25% substitution (T2) because it provided the best balance between chemical quality, antioxidant activity, and panelist acceptance.

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