PRINCIPAL COMPONENT ANALYSIS (PCA) OF THE PHYSICOCHEMISTRY OF TRADITIONAL SOUTH SUMATERAN CAKES

ANALISIS *PRINCIPAL COMPONENT ANALYSIS* (PCA) TERHADAP FISIKOKIMIA KUE TRADISIONAL SUMATERA SELATAN

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ABSTRACT

The physicochemical characteristics of traditional South Sumatran cakes may vary due to differences in raw materials, formulations, and processing methods among producers; however, scientific information regarding such variation remains limited. This study aimed to characterize the physicochemical properties of traditional South Sumatran cakes obtained from producers in Palembang, Indonesia. The samples comprised three types of cakes—maksuba, engkak ketan, and delapan jam—collected from three different producers. Texture, moisture, ash, fat, protein, and carbohydrate content were analyzed using principal component analysis (PCA) in Minitab 22. PCA differentiated the samples according to their dominant physicochemical attributes. The first two principal components (PC1 and PC2) explained a substantial proportion of the total variance, indicating that the analyzed parameters contributed strongly to sample differentiation. The PCA score plot revealed three distinct clusters, suggesting that each cake type had a relatively consistent chemical and textural profile within its group while remaining distinguishable from the other groups. These findings demonstrate the potential of PCA as a useful tool for characterizing traditional food products, supporting quality standardization, and informing the development of new formulations. Nevertheless, owing to the relatively limited number of observations, the PCA findings should be considered exploratory and interpreted cautiously rather than generalized to all traditional South Sumatran cakes.

Keywords: *physicochemical characteristics; product quality; traditional foods; producers; standardization*

ABSTRAK

Karakteristik fisikokimia kue tradisional Sumatera Selatan dipengaruhi oleh perbedaan bahan baku, formulasi, dan proses pengolahan antarprodusen yang menyebabkan keragaman, tetapi informasi ilmiah mengenai variasi tersebut masih terbatas. Oleh karena itu, penelitian ini bertujuan untuk menganalisis kualitas fisikokimia dari kue tradisional Sumatera Selatan yang diperoleh dari beberapa produsen di kota Palembang. Metode yang digunakan dalam penelitian ini adalah Principal Component Analysis (PCA) untuk menganalisis hubungan antarvariabel fisikokimia yang memengaruhi kualitas produk. Sampel yang digunakan terdiri dari tiga jenis kue (maksuba, engkak ketan, dan delapan jam) dari tiga produsen yang berbeda di kota Palembang. Data yang diperoleh berupa hasil analisis tekstur, kadar air, abu, lemak, protein, dan karbohidrat antara jenis kue dan produsen dianalisis menggunakan PCA dengan aplikasi

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Minitab 22. Penggunaan PCA mampu mengelompokkan sampel berdasarkan atribut fisikokimia yang dominan. Dua komponen utama yang diperoleh (PC1 dan PC2) mampu menjelaskan proporsi besar dari variabilitas total data, menunjukkan bahwa parameter yang dianalisis memiliki kontribusi kuat dalam membedakan sampel. Pola pemisahan sampel pada plot PCA memperlihatkan tiga klaster yang jelas, mengindikasikan bahwa masing-masing jenis kue memiliki profil kimia dan tekstural yang konsisten dalam kelompoknya, namun terpisah antarkelompok. Temuan ini menunjukkan bahwa PCA menjadi alat yang efektif dalam karakterisasi dan standardisasi mutu produk pangan tradisional, serta dapat digunakan untuk mengembangkan formulasi baru. Namun demikian, jumlah observasi yang relatif terbatas dapat membatasi ketangguhan dan generalisasi hasil PCA, oleh karena itu, pola pengelompokan yang teramati beserta interpretasinya perlu disikapi dengan hati-hati.

Kata kunci : fisikokimia; kualitas produk; pangan tradisional**;** produsen; standardisasi

INTRODUCTION

Traditional Indonesian foods fulfill a dual function: they satisfy basic physiological needs and convey cultural values and local wisdom that have been transmitted across successive generations. The physical characteristics and flavors of the traditional foods of each region in Indonesia reflect the local cultural identity. These unique characteristics originate from ingredients available locally, serving as cultural markers of the region (Wargadalem et al., 2023). Cultural considerations aside, traditional foods also play a significant role in the local economy. Indeed, traditional food products have the potential to drive economic growth through the food industry, tourism, and small and medium enterprises (SMEs), thereby creating job opportunities (Aini et al., 2024)

Market evidence suggests sustained and increasing demand for traditional Sumatran cakes in Palembang during 2022–2024. Traditional South Sumatran cakes continue to show substantial seasonal demand, particularly during Ramadan and Eid al-Fitr. In 2022, a local producer reportedly received orders for more than 2,000 trays of traditional cakes prior to Eid al-Fitr (Syaiful, 2022). Similar consumer interest was reported in subsequent years, including increasing orders for maksuba as Eid approached in 2023 (Assajidin, 2023) and strong demand for traditional cakes from both within and outside South Sumatra in 2024 (DetikSumbagsel, 2024). Among the most popular types of cakes are delapan jam cake, maksuba cake, and engkak ketan cake (Marlina, 2021). Despite its significance as a cultural heritage, the quality of products produced by various manufacturers in Palembang exhibits considerable variation with respect to taste, texture, aroma, color, and appearance. In the contemporary consumer landscape, there is a growing concern for food quality, which, in turn, necessitates that producers ensure consistency and adhere to stringent quality standards. However, discrepancies in production methods, raw materials, and quality standards among producers frequently result in inconsistencies in the quality of the resulting products. These inconsistencies have the potential to influence consumer perception and tarnish the image of traditional cuisine (Ana et al., 2017).

The evaluation of the quality of cakes is frequently conducted on a subjective basis; consequently, there is a necessity for a more objective and measurable analytical methodology. The quality of traditional foods can be evaluated based on various sensory and physical parameters, including but not limited to taste, texture, aroma, color, and other physicochemical properties. Given the complexity of the relationships between these parameters, multivariate statistical approaches, such as Principal Component Analysis (PCA), are required to identify the structure of interrelated and complex data (Watizega et al., 2024). PCA has the capacity to reduce data dimensions into key

components that facilitate interpretation, whilst identifying key factors that affect product quality (Jolliffe, 2002). Therefore, the utilization of PCA in research on the quality of South Sumatra's traditional cakes is imperative for standardizing quality and developing more consistent products. PCA's primary strengths lie in its ability to explore the relationship between variables and to group data based on similar characteristics without the loss of pertinent information. In the domain of food quality analysis, this method can be utilized to identify the dominant attributes that influence product quality perception and to compare quality performance between producers in an objective and measurable manner (Pratama et al., 2012).

PCA has also been demonstrated to facilitate the reduction of data complexity, the elucidation of relationships between physicochemical variables, and the provision of more intuitive profile mapping (Komalasari et al., 2025). The present study endeavors to undertake a comprehensive analysis of the physicochemical attributes of traditional cakes produced by various manufacturers in Palembang. This analysis employs the Principal Component Analysis (PCA) method, with the objective of providing an objective description of the attributes that underpin the quality of these products. The outcomes of this PCA analysis are expected to function as a foundational reference in endeavors to enhance the quality and differentiation of traditional South Sumatra cakes, thereby ensuring their enhanced competitiveness within the market.

This study aims to analyze the multivariate relationship patterns of physicochemical characteristics of various types of traditional cakes in South Sumatra using Principal Component Analysis (PCA), and to identify the dominant parameters that contribute to product differentiation. These findings could indicate that multivariate analysis is an effective tool in characterizing and standardizing the quality of traditional food products and can be used to develop new formulations.

METHODS

Materials and Instruments

This study employed a selection of traditional South Sumatran cakes, in addition to 400 mL of 4% boric acid, 500 mL of 0.01N hydrochloric acid (HCl), 200 mL of sulfuric acid, and 20 L of distilled water. The following reagents are required for this experiment: 50 mL of methyl red indicator, 100 g of potassium sulfate, 500 mL of 30% sodium hydroxide (NaOH), 5 L of n-hexane, and 1 g of selenium. The instruments utilized in this study included an alu and mortar, a Kjeldahl apparatus, a Soxhlet apparatus, a burette, aluminum cups, and porcelain cups. The following equipment was used for the experiment: a desiccator, Erlenmeyer flasks, beakers, a hot plate, clamps, a muffle furnace, an oven, tweezers, dropper pipettes, measuring pipettes, stands, a texture analyzer (Brookfield LFRA Texture Analyzer), an analytical balance (Kenko KK-Lab, Japan), and a vortex.

This study investigated three traditional South Sumatran cakes: Maksuba, Delapan Jam, and Engkak Ketan. These cakes were selected because they are well-recognized traditional foods of South Sumatra and constitute an important part of the region’s culinary heritage and cultural identity. Samples were obtained from three local producers in Palembang, South Sumatra, Indonesia. The producers were selected using purposive sampling, with a production capacity of more than 50 trays per day as the inclusion criterion. This criterion was used to select established producers with regular commercial production of the traditional cakes investigated in this study.

A total of nine sample groups were collected, consisting of three cake types from each of the three producers. The samples were coded according to cake type and producer: MB1, MB2, and MB3 for Maksuba; 8J1, 8J2, and 8J3 for Delapan Jam; and EK1, EK2, and EK3 for Engkak Ketan, corresponding to Producers 1, 2, and 3, respectively. Following collection, the samples were

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immediately transported to the laboratory and analyzed on the same day to minimize changes in their physicochemical and textural characteristics. Prior to physicochemical analysis, each sample was homogenized to obtain a uniform and representative test portion. The samples were analyzed for moisture, ash, protein, fat, carbohydrate, and texture. All analytical determinations were performed in triplicate on the same homogenized sample as analytical replicates to improve measurement precision and minimize analytical error. The mean values obtained from the analytical replicates were subsequently used for Principal Component Analysis (PCA).

Research Design

The sampling structure consisted of nine sample groups representing combinations of three traditional cake types (Maksuba, Delapan Jam, and Engkak Ketan) and three producers (Producer 1–3). The samples were coded as MB1, MB2, and MB3 for Maksuba; 8J1, 8J2, and 8J3 for Delapan Jam; and EK1, EK2, and EK3 for Engkak Ketan, corresponding to Producers 1–3, respectively. Samples from each cake type and producer were homogenized prior to physicochemical analysis. All physicochemical determinations were performed in triplicate on the homogenized samples as analytical replicates. The physicochemical dataset was standardized prior to Principal Component Analysis (PCA). PCA was applied as an exploratory multivariate technique to examine relationships among physicochemical variables and to characterize patterns of differentiation and clustering among the nine sample groups. No ANOVA or post-hoc multiple comparison tests were performed.

Research Implementation

The research process entailed the meticulous preparation of raw materials and the judicious selection of samples of traditional cakes. Samples were methodically chosen from cake shops exhibiting a production capacity that exceeded 50 trays per day, ensuring a broad representation of medium to large-scale production entities. Subsequently, samples of maksuba cake, eight-hour cake, and sticky rice cake were procured from a range of producers, thereby facilitating a comprehensive representation of the diverse production landscape. Following the acquisition of the cakes, they were subjected to immediate testing and analysis at the Agricultural Product Processing and Sensory Laboratory of Sriwijaya University.

The sample in this study was determined using purposive sampling, considering the sample's suitability to the research objectives. This technique was chosen because traditional South Sumatran cakes have specific characteristics, including raw materials, traditional processing methods, and cultural values. Therefore, not all cakes on the market could be used as research objects.

The sample selection criteria included: (1) cakes traditionally known as typical South Sumatran cakes; (2) produced by actively operating businesses with consistent production processes, producing more than 50 trays per day; and (3) regularly available during the sampling period. Based on these criteria, 3 types of cakes from 4 producers were selected as research samples.

The sample units in this study were selected using purposive sampling based on predefined criteria, namely cake producers with daily production exceeding 50 trays, which reflects active production scale and process consistency. This criterion-based approach is consistent with the principle of purposive sampling that prioritizes information-rich units capable of providing relevant and in-depth data aligned with the research objectives (Palinkas *et al*., 2015). Selecting producers with high production capacity enables the collection of stable and representative product characteristic data of typical South Sumatran cake processing practices. Furthermore, purposive

sampling grounded in quantitative criteria such as production volume has been recognized as appropriate in applied quantitative research, particularly for studies focusing on pattern identification, product characterization, and multivariate analysis rather than population-wide statistical generalization (Memon *et al*., 2025). In line with this, Etikan *et al*. (2015) stated that purposive sampling is suitable for heterogeneous populations where only certain units meet key research criteria. Therefore, the selection of four high-production cake producers was considered sufficient and relevant to support characteristic analysis and multivariate mapping using Principal Component Analysis (PCA).

Research Variables

Moisture Content

Moisture content was determined using a gravimetric oven-drying procedure following AOAC (2006). Porcelain crucibles were first conditioned by heating in an oven for 30 min, then cooled in a desiccator at room temperature for 15 min and weighed repeatedly until a constant mass was achieved. Approximately 2 g of sample was placed into the pre-weighed crucible and dried at 105°C until the weight became constant, defined as a difference of no more than 0.02 mg between successive weighings. Moisture content was calculated from the mass loss during drying relative to the initial sample mass.

Ash Content

Ash content was determined using method of AOAC (2006).The porcelain crucible was first weighed repeatedly until a constant mass was obtained, and approximately ±5 g of sample was then weighed. The sample was placed into the pre-weighed crucible and ashed in a muffle furnace at 550°C until a pale gray/whitish ash residue was produced. After ashing, the crucible was removed using tongs and transferred to a desiccator to cool to room temperature. Ash content was determined from the remaining inorganic residue after the organic matter was volatilized/combusted during incineration. The ash percentage was subsequently calculated using the standard formula.

Fat Content

Lipid content was determined using a Soxhlet extraction procedure in accordance with AOAC (2006). Briefly, about 5 g of a homogenized sample was placed in a paper thimble lined with cotton. The loaded thimble was pre-dried in an oven (≤80°C) for approximately 1 h, reweighed, and then positioned in the Soxhlet apparatus. Extraction was performed with 100 mL of n-hexane for 8 h at a temperature close to the solvent's boiling point (~69°C). After extraction, the solvent was removed by distillation and the flask containing the extracted oil was dried at 105°C. The flask was then cooled in a desiccator for 15 min and weighed repeatedly until a constant mass was obtained. Fat content was calculated from the increase in flask mass (flask + extracted fat minus empty flask) relative to the initial sample mass. For the formulated mayonnaise, total fat content was adjusted to the final product basis by accounting for the fat obtained from the 5 g premix together with the added palm oil (2.5 g), then expressing the value as a percentage of the total mayonnaise yield

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(11.5 g).

Protein Content

Protein content was determined using the Kjeldahl method (AOAC, 2006). Briefly, 2 g of homogenized sample was placed in a Kjeldahl flask, followed by the addition of 1.94 g of catalyst and 10 mL of concentrated sulfuric acid (H_2SO_4). The mixture was heated for approximately 20 min until the digest became clear, indicating complete breakdown of organic matter, and then allowed to cool. The digest was diluted with distilled water to 200 mL and three drops of phenolphthalein (PP) were added. The solution was neutralized with sodium hydroxide (NaOH) until a purple coloration appeared while the flask was cooled under running water. The mixture was subsequently distilled, and the liberated ammonia was captured in an Erlenmeyer flask containing 20 mL of boric acid (H_3BO_3), with the condenser tip kept submerged in the receiving solution to ensure efficient absorption. After collecting 100 mL of distillate, three drops of bromocresol green (BCG) indicator were added, and the absorbed ammonia was quantified by titration using standardized 0.02 N hydrochloric acid (HCl) to the endpoint, as indicated by the final color change.

Carbohydrate

Carbohydrate content was calculated by difference by subtracting the sum of moisture, ash, protein, and fat contents from 100%, as follows:

$$\text{Carbohydrate (\%)} = 100 - [\text{moisture (\%)} + \text{ash (\%)} + \text{protein (\%)} + \text{fat (\%)}].$$

All components were expressed on a wet-weight basis.

Texture Analysis

Texture was measured using a Texture Analyzer (Brookfield CT3, Ametek inc, USA). Measurements were performed at room temperature at three positions on each cake sample (top, middle, and bottom). The sample was placed beneath the probe, and the force required for the probe to penetrate the cake was recorded. Hardness was expressed in Newtons (N). The sample was centrally positioned on a flat surface directly beneath the probe to ensure perpendicular compression at the center of the sample. A cylindrical probe with a diameter of 10 mm was used. The measurement was conducted in compression mode with a test speed of 1 mm/s, a trigger force of 4 g, and a compression distance of 10 mm.

Data Analysis

The data obtained from the study were then subjected to averaging. Each sample was analyzed in triplicate, and the results were expressed as the mean ± standard deviation (SD) of the three analytical replicates. Moreover, an investigation into the relationship between variables and the identification of patterns or similarities between treatments was conducted through the analysis of data using Principal Component Analysis (PCA) via Microsoft Excel and Minitab 22 software. Was the observation repeated? If yes, fill in the standard deviation calculation!

RESULTS AND DISCUSSION

Physicochemical Analysis of Cake Samples

Table 1. Mean Physicochemical Values Used for PCA Analysis

Sample	Moisture Content (%)	Ash Content (%)	Fat Content (%)	Texture (N)	Carbohydrate (%)	Protein (%)
MB1	37.01±0.010	0.85±0.126	23.53±0.004	407.67±58.451	12.91±0.005	25.70±0.001
MB2	47.03±0.021	1.03±0.038	25.00±0.000	279.53±30.774	9.76±0.020	17.19±0.002
MB3	39.22±0.007	1.17±0.012	22.16±0.006	334.67±11.349	16.96±0.010	20.50±0.003
8J1	44.14±0.013	0.58±0.125	21.66±0.006	184.53±27.871	25.48±0.015	11.02±0.010
8J2	36.63±0.027	0.80±0.061	24.31±0.002	231.60±18.252	29.44±0.025	9.96±0.007
8J3	39.68±0.004	0.18±0.007	19.71±0.002	210.73±40.428	28.17±0.014	12.26±0.009
EK1	31.66±0.003	0.49±0.020	20.42±0.008	203.53±21.151	47.59±0.010	8.55±0.002
EK2	40.98±0.014	0.84±0.029	23.81±0.019	438.40±11.226	57.16±0.008	7.86±0.008
EK3	29.84±0.007	0.31±0.013	13.86±0.017	266.93±19.802	48.13±0.017	7.86±0.005

Note: MB1= Maksuba Producer 1; MB2= Maksuba Producer 2; MB3= Maksuba Producer 3; 8J1= 8 Jam Producer 1; 8J2= 8 Jam Producer 2; 8J3= 8 Jam Producer 3; EK1= Engkak Ketan Producer 1; EK2= Engkak Ketan Producer 2; EK3= Engkak Ketan Producer 3

As presented in Table 1, considerable variation was observed in the physicochemical composition of the three traditional cake types obtained from different producers. These differences may be associated with variations in product formulation and processing conditions, which can influence water retention in the cake matrix. The moisture content ranged from 29.84 ± 0.007% to 47.03 ± 0.021%, with Maksuba from Producer 2 exhibiting the highest moisture content and Engkak Ketan from Producer 3 showing the lowest value. Moisture content is an important quality attribute because it can influence the softness, textural characteristics, and storage stability of cake products. Cakes with higher moisture content may exhibit a softer and more moist texture; however, higher moisture availability may also contribute to greater susceptibility to quality deterioration during storage. Conversely, lower moisture content may contribute to a firmer or drier product characteristic. Therefore, the observed variation in moisture content may contribute to differences in the overall quality characteristics of the traditional cakes investigated in this study.

The disparity in water content is intimately associated with the chemical composition of the raw materials and the thermal process employed. Raw materials that are abundant in starch, hydrocolloids, or coconut-based components tend to exhibit a heightened water-binding capacity attributable to the presence of hydrophilic functional groups, such as hydroxyl groups, which facilitate hydrogen bonding with water molecules. The elevated water content observed in the maksuba cake samples from Producer 2 suggests the utilization of raw materials characterized by high water absorption or the employment of a more delicate cooking method, such as steaming, which aims to minimize water loss. For instance, in a study of steamed apem cakes, the water content ranged from 34.73±0.01 to 37.80±0.013 %, depending on the ratio of rice flour to banana flour. This indicates that the raw materials significantly impact water retention (Pratiwi et al., 2023)

In contrast, engkak ketan samples exhibited the lowest water content, potentially attributable to factors such as higher fat content, lower starch hydration capacity, or the application of high-temperature cooking techniques that expedite water evaporation. From a food chemistry perspective,

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the water content of a foodstuff has the potential to exert a considerable influence on its texture attributes, microbiological stability, and shelf-life behavior. Products with elevated water content typically exhibit a softer texture; however, they are also more prone to spoilage and enzymatic degradation. These findings underscore the substantial role that variations in formulation and processing play in determining the final water retention characteristics of traditional cakes. Furthermore, adding sugar can bind air, thereby increasing the hardness of the food (Shaskara et al., 2024).

As illustrated in Table 1, variations in total mineral composition were observed. The ash content ranged from 0.18% to 1.17%, with the highest mineral content being exhibited by maksuba cake producer 3 and the lowest being exhibited by delapan jam cake producer 3. The mineral content in traditional cakes is influenced by the composition of raw materials, including the use of coconut products, brown sugar, salt, or mineral-rich fortified flour. The higher ash content in the producer 3 maksuba cake sample illustrates the presence of raw materials with higher natural mineral levels or the effect of concentration due to specific heating conditions and the composition of the raw materials. For instance, research on klenyem cakes demonstrates that the substitution of coconut pulp flour, which is rich in minerals, results in an increase in the ash content to 1.15–2.73% ($p < 0.01$), thus indicating the contribution of minerals from raw materials to inorganic residues (Septiana et al., 2021). Augmented thermal processing has been shown to enhance the detection of inorganic residues following the decomposition of organic matrices, particularly in products with solid structural characteristics.

The considerable discrepancy in protein content among the three producers of Maksuba signifies variations in the formulation, particularly concerning the utilization of duck eggs as the primary ingredient (Lestari dan Winata, 2021). Eggs have been demonstrated to enhance the protein content of the subject product, in addition to facilitating the formation of its distinctive layered structure. A positive correlation exists between the quantity of eggs utilised and the resulting protein content, thereby elucidating the notable disparities observed among the maksuba from the three producers.

The protein content of delapan jam cake is moderate and exhibits minimal variability among manufacturers. The consistency of this composition indicates that the delapan jam recipe is reliably uniform among manufacturers, particularly with regard to the proportion of eggs and milk. This phenomenon may be attributed to the fact that 8 Jam is a traditional cake with a relatively standard recipe, thereby resulting in less variation in the formulation than is observed in maksuba cake. Regarding fat content, distinct patterns emerge among the three types of cake when examined between manufacturers, with maksuba cake consistently exhibiting the highest levels. This finding signifies that maksuba is a cake with an exceptionally high fat content, which is believed to be attributable to the incorporation of substantial amounts of butter, margarine, and egg yolks during its preparation (Lestari dan Winata, 2021).

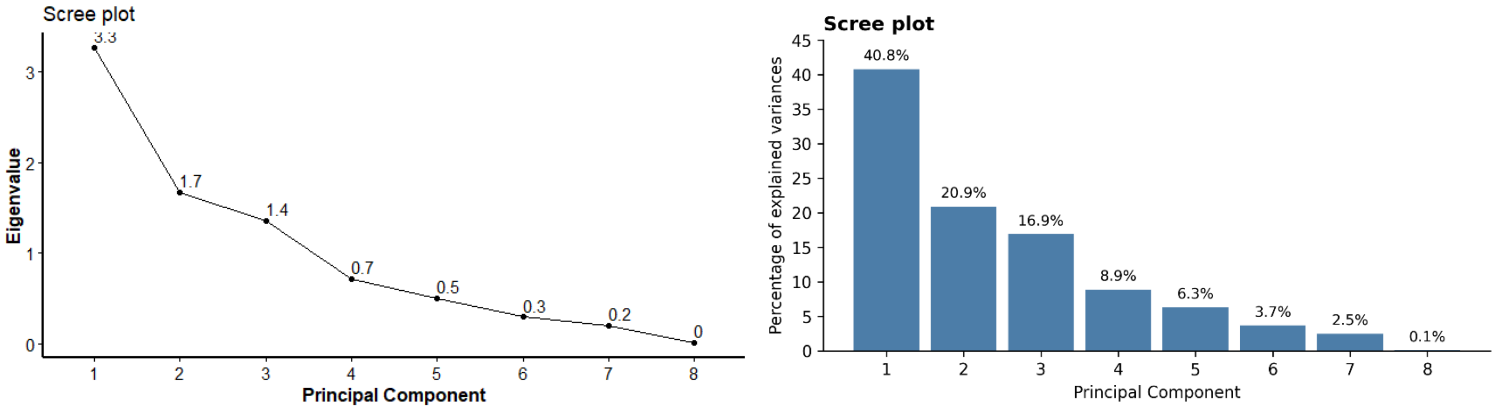
The difference in carbohydrate content among various cakes exerts a substantial influence on the texture and physical properties of the product. Carbohydrates, particularly sugar and starch, play a pivotal role in the processes of caramelization and Maillard reactions, which can expedite the darkening of the product. It has been observed that samples with higher carbohydrate content tend to exhibit greater density and darker coloration than samples with lower carbohydrate content. This pattern is of particular significance in light of the role of carbohydrates, especially starch and reducing sugars, as not only a source of energy but also in the modulation of texture through starch gelatinization and retrogradation, and in the development of color through browning reactions. According to Tamanna and Mahmood (2015), the Maillard reaction, which occurs between sugar and

amino acids, is significantly influenced by the carbohydrate content of the product. This reaction has the potential to cause color changes and an increase in product hardness.

A Principal Component Analysis (PCA) of Cake Samples

(a) (b)

Figure 1. (a) Eigenvalue of Principal Component; (b) Percentage of explained variances



Principal component analysis (PCA) was performed to reduce the dimensionality of the dataset and identify the principal sources of variation among the eight variables examined. According to the scree plot (Figure 1.a), the first three principal components (PCs) exhibited eigenvalues greater than 1 (3.3, 1.7, and 1.4 for PC1, PC2, and PC3, respectively), satisfying the Kaiser criterion (Ramos and Sepúlveda, 2025), whereas the remaining components (PC4–PC8) displayed eigenvalues below 1 (0.7, 0.5, 0.3, 0.2, and 0.0, respectively) and were therefore considered to contribute negligibly to the overall variance structure.

The corresponding percentage of explained (Figure 1.b) variance further supported this pattern, with PC1, PC2, and PC3 accounting for 40.8%, 20.9%, and 16.9% of the total variance, respectively, and collectively explaining 78.6% of the cumulative variance. A pronounced decline in eigenvalues was observed between PC1 and PC2, followed by a more gradual decrease thereafter, indicating that the majority of the variability in the dataset could be attributed to the first two or three components. For the purpose of this study, only the first two principal components (PC1 and PC2) were retained for subsequent interpretation and visualization, cumulatively accounting for 61.7% of the total variance (Figure 2). Although this proportion falls slightly below the commonly recommended threshold of 70–80% for comprehensive variance representation, the two-dimensional PC1–PC2 configuration was considered sufficient to reveal the dominant patterns of sample discrimination and variable association, consistent with similar approaches reported in food chemistry and metabolomics studies employing PCA for exploratory data analysis (Ramos and Sepúlveda, 2025).

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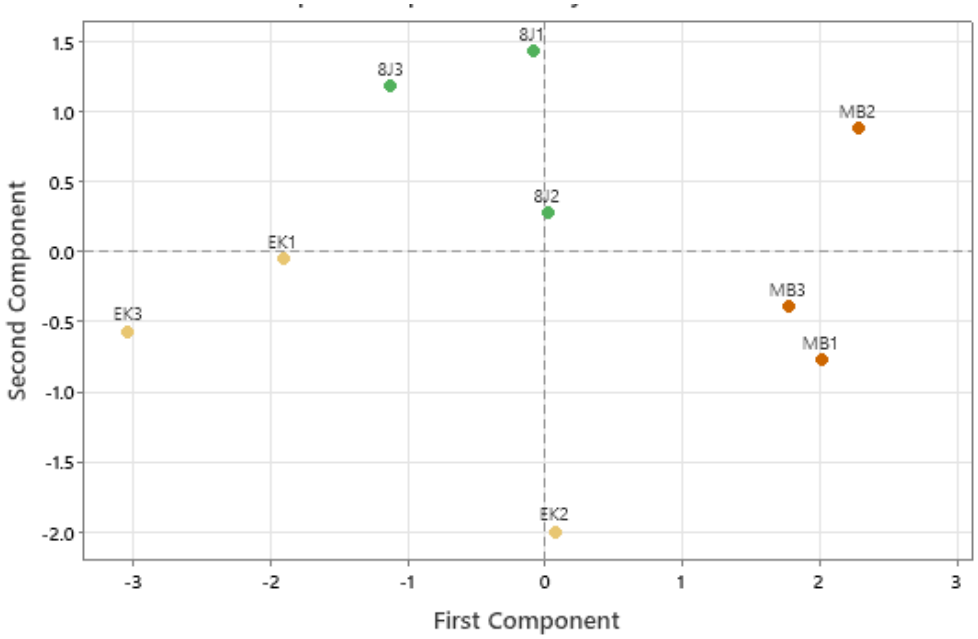


Figure 2*:* Scoreplot Principal Component Analysis of Cake Samples

Note: (MB1= Maksuba Producer 1; MB2= Maksuba Producer 2; MB3= Maksuba Producer 3; 8J1= 8 Jam Producer 1; 8J2= 8 Jam Producer 2; 8J3= 8 Jam Producer 3; EK1= Engkak Ketan Producer; EK2= Engkak Ketan Producer 2; EK3= Engkak Ketan Producer 3

Table 2. Loading value principal component of all parameters

Parameters	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
moisture content	0.793969	0.164318	-0.25705	0.424715	-0.02299	0.044376	0.305968	0.006471
ash content	0.62962	-0.46157	0.259581	-0.01753	0.541251	-0.17238	0.007098	-0.01108
protein	0.748485	-0.25558	0.490104	-0.28853	-0.21434	0.019581	0.033909	0.059338
fat content	0.742033	0.37478	0.183962	0.42549	0.00678	0.091439	-0.29257	0.006056
carbohydrate	-0.91567	0.130031	0.018427	0.279494	0.239265	-0.06625	0.012407	0.066216
texture	-0.41921	-0.68615	0.40714	0.242245	0.01202	0.356862	0.036887	-0.01243

The loading values (Table 2) indicated that PC1 was primarily driven by strong positive contributions from moisture content (0.794), protein (0.748), and fat content (0.742), together with a strong negative contribution from carbohydrate (–0.916), reflecting a moisture–protein–fat versus carbohydrate contrast. PC2, on the other hand, was mainly characterized by a negative loading from texture (–0.686) and a moderate positive loading from fat content (0.375), representing a texture-related dimension. These loading patterns indicate that PC1 primarily differentiates samples based on proximate composition (moisture, protein, fat, and ash versus carbohydrate), whereas PC2 further distinguishes samples according to textural characteristics, providing the basis for the sample clustering observed in the subsequent score plot.

The PCA scoreplot in Figure 2 illustrates the mapping of 9 samples (EK, 8J, and MB) onto

two principal components (PC1 and PC2), which cumulatively account for the greatest proportion of the total data variation. Multivariate approaches such as PCA are widely employed in food research to discern product groups based on chemical profiles, texture, and other quality parameters (Wold et al., 1987; Zbikowska et al., 2017). The first component (PC1) demonstrates a distribution of values ranging from −3.0 to 2.5. Samples of EK3 and EK1 are situated on the negative axis of PC1, signifying that their physicochemical characteristics diverge substantially from those of the MB1 and MB3, which is positioned on the positive axis of PC1. The observed separation pattern suggests that PC1 is predominantly impacted by texture and moisture content parameters. Maksuba samples exhibit a tendency to possess a denser texture or elevated soluble solids content, whereas sticky rice samples demonstrate heightened water absorption and a comparatively loose matrix structure. These findings are consistent with prior reports that water content and starch composition exert a predominant influence on the differentiation of *bakery* and traditional cake product categories in PCA (Sahin and Sumnu, 2006; Renzetti and van der Sman, 2022).

The second component (PC2), ranging from −2.0 to 1.5, contributes to the separation based on variations in texture and composition, such as fat, sugar, or organoleptic parameters such as chewiness and softness. Delapan jam cake producer 1 and delapan jam cake producer 3 demonstrate comparatively elevated PC2 values, suggesting distinctive characteristics that differentiate them from the remaining groups. The engkak ketan cake sample from producer 2, which is positioned at the lowest point along PC2, exhibits characteristics that are distinctly divergent from the other groups. Differences in formulation and processing conditions among producers may contribute to variations in the physicochemical characteristics of the cake matrix. Previous studies have shown that compositional and structural characteristics of food matrices can influence their physical properties. (Cayot, 2007). However, the specific formulation-related factors responsible for the observed sample separation were not directly evaluated in the present study.

PCA mapping demonstrated a clear clustering pattern, in which each of the three cake groups (EK, BJ, and MB) formed a predominantly distinct cluster. This result supports the hypothesis that the evaluated physicochemical parameters are capable of effectively discriminating among samples. The clear separation observed in the score plot reflects both the consistency of formulations within each product category and the pronounced variability between categories. These results indicate that principal component analysis (PCA) is an appropriate and robust method for the characterization of traditional and modern food product quality. Moreover, PCA may be applied for quality standardization, product authentication, and the development of new formulations (Zbikowska et al., 2017).

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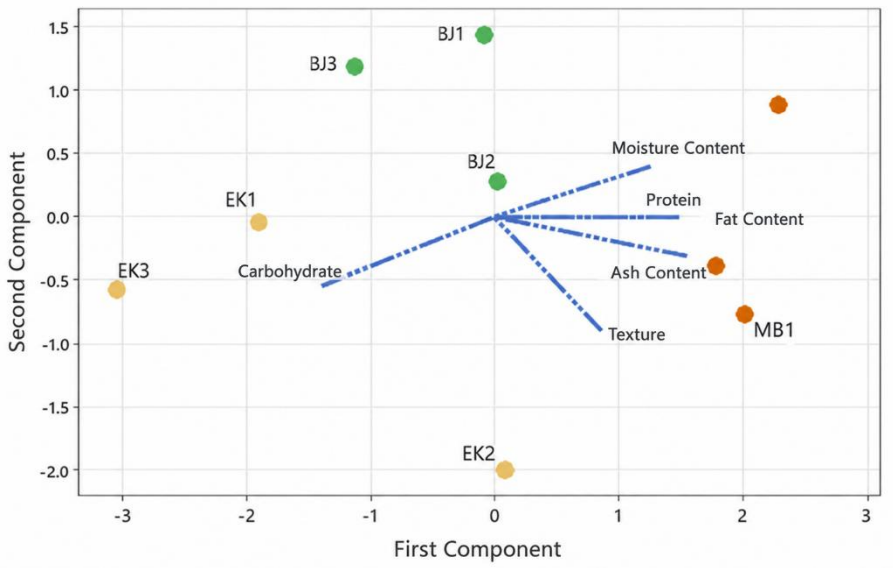


Figure 3. Biplot Principal Component Analysis of Cake Samples

Note: MB1= Maksuba Producer 1; MB2= Maksuba Producer 2; MB3= Maksuba Producer 3; 8J1= 8 Jam Producer 1; 8J2= 8 Jam Producer 2; 8J3= 8 Jam Producer 3; EK1= Engkak Ketan Producer; EK2= Engkak Ketan Producer 2; EK3= Engkak Ketan Producer 3

The PCA biplot illustrated in Figure 3 demonstrates the direction and actual contribution of the variables moisture content, ash content, protein, fat, carbohydrates, and texture to the distribution of cake samples. The length and orientation of the vectors indicate the strength of the data contribution to the principal components, while the angles between variables reflect the degree of correlation (Wold et al., 1987; Zbikowska et al., 2017). It is generally acknowledged that nutritional variables and physical properties form two groups of patterns, thereby indicating a functional relationship in the structure of starch-based food matrices.

The moisture content vector shows a strong orientation toward the upper-right quadrant, indicating a substantial contribution to both PC1 and PC2. Samples positioned in the same direction as this vector tend to exhibit higher moisture levels and a softer texture. This relationship is consistent with the characteristics of starch gelatinization–based products, in which water plays a critical role in gel formation and the development of a soft crumb structure (Sahin and Sumnu, 2006). In addition, the positive correlation with protein content indicates the involvement of starch–protein matrix interactions in enhancing water retention capacity (Tuta Şimşek, 2020).

Protein and moisture content were positively associated in the PCA space, as their loading vectors pointed in similar directions. This suggests that samples with higher protein levels tend to exhibit increased moisture content, which may be related to the hydration capacity of proteins and their contribution to product viscoelasticity. This variable also contributed to separating in distinguishing sample groups with more elastic and stable structural characteristics.

The fat vector is positioned close to the protein and moisture content vectors, although it is slightly oriented toward the negative side of PC2. This phenomenon signifies the contribution of the fat variable to the formation of the product's structure and its perceived mouthfeel. Nevertheless, it is important to note that this contribution manifests through a distinct functional direction when compared to the protein-water interaction. The presence of fat tends to enhance softness and impart a buttery character, which is attributed to its lubricating mechanism within the gluten structure or starch matrix (Scott and Awika, 2023). This relationship is also commonly observed in the context of

pastry or cake products that incorporate coconut milk or margarine.

The ash content variable displays a diagonal orientation toward the lower right quadrant, indicating that mineral content contributes to sample discrimination along PC1, while showing an inverse relationship with the texture variable. This suggests that specific formulations such as those containing brown rice flour, palm sugar, or fermented ingredients may yield higher mineral levels without exhibiting a positive association with texture firmness (Cayot, 2007).

The texture vector is oriented toward the lower right quadrant, indicating a strong contribution to PC1 and a negative association with PC2. This orientation suggests that texture attributes, particularly hardness, are inversely related to moisture and protein contents. Consequently, samples with firmer textures tend to exhibit lower moisture levels. This observation is consistent with well-documented processes such as starch retrogradation and moisture loss during storage, which contribute to structural hardening (Scott and Awika, 2023).

Based on the orientation of the carbohydrate vector, samples dominated by carbohydrate content exhibit clear structural differences compared with those characterized by higher moisture, protein, or fat levels, reflecting a strong contribution to the negative side of PC1. This variable shows a pronounced association with starch-based components (e.g., maltodextrin, starch, and simple sugars), which are known to significantly affect gel particle structure, dough viscosity, and gluten extensibility (Renzetti and van der Sman, 2022). The large angular separation from the moisture content vector further indicates that elevated carbohydrate levels in certain samples do not necessarily result in increased hygroscopicity or the development of a softer texture.

CONCLUSION

Conclusion

Analysis of PCA has been effectively applied to visualize differences in physicochemical characteristics among various categories of cakes (engkak ketan, delapan jam, and maksuba) produced by different manufacturers, based on proximate composition and texture-related variables. The first two principal components (PC1 and PC2) accounted for a substantial proportion of the total variance, demonstrating that the analyzed parameters played a significant role in discriminating among samples. The PCA score plot revealed three distinct clusters, indicating that each cake type exhibited a consistent chemical and textural profile within its group, alongside pronounced differences between groups.

Suggestion

The present study provides an exploratory characterization of the physicochemical variability of traditional South Sumatran cakes from different producers. Future studies should incorporate sensory evaluation to investigate the relationships between physicochemical characteristics and sensory attributes, such as appearance, texture, aroma, taste, and overall acceptability. Integrating physicochemical and sensory data through multivariate analysis may provide a more comprehensive understanding of the quality characteristics of these traditional products.

In addition, future research should focus on a single type of traditional cake obtained from a larger number of producers and independent production batches. This approach would enable a more detailed assessment of variability among producers and help identify the key physicochemical and sensory attributes associated with product quality and consistency. Such information could provide a

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stronger scientific basis for future quality standardization while preserving the distinctive characteristics of traditional South Sumatran cakes.

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