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Research article

Study on the physicochemical and sensory profile of *pliek-u*: A traditional dried fermented coconut endosperm from Aceh, Indonesia

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Abstract: *Pliek-u* is dried fermented coconut endosperm that has been produced by people in Aceh Province, Indonesia for a long time. It is made by implementing a highly efficient process; thus, we want to conserve this tradition. The objective of this study was to determine the physicochemical and sensory quality of *pliek-u*. A survey was conducted in five local markets in Banda Aceh and Aceh Besar District. About 12 samples were collected and analyzed quantitatively and qualitatively. The parameters observed were moisture, ash, fat, protein, fiber and carbohydrate contents, as well as pH-value, color and volatile compounds. Three expert panelists were interviewed to document the information about the sensory quality of *pliek-u*. Results showed that the quality of *pliek-u* highly varied among the processors, as indicated by the distribution of those samples in all quadrants of the principal component analysis (PCA) biplot graph. About two principal components (PCs) were determined and two parameters were excluded i.e., fat and fiber content; PC_1 contributed to 34.111% of the variance, with pH value as the most important factor; while PC_2 contributed to 24.968% of the variance, with protein content as the most important factor. Interestingly, the volatile compounds of the three best samples selected by panelists were unique and different from the others. Therefore, the sensory quality of *pliek-u* should be supported by the physicochemical quality to guarantee the safety of consuming the product. Further studies on determining certain volatile compounds produced during fermentation are recommended.

Keywords: coconut endosperm; fermentation; physicochemical; sensory; *pliek-u*

1. Introduction

Coconut (*Cocos nucifera*) is a well-known plant used in Indian and African systems of medicine. The coconut fruit consists of the following layers: exocarp, mesocarp, endocarp, endosperm and embryo [1]. In Acehnese culture, we have an old tradition of processing coconut endosperm to produce *pliek-u* and coconut oil [2]. *Pliek-u* is dried fermented coconut endosperm. Presently, Acehnese society uses *pliek-u* as a spice in a special soup called *kuah pliek,* in a fruit salad called *rujak* for certain occasions, as well as in sauce [3]. However, the consumption rate of *pliek-u* tends to be low since the community does not know about its functional properties.

In other parts of the world, coconut oil is commonly produced through the fermentation of coconut milk [4–6], as well as by drying coconut kernels [7,8]. The tradition of processing coconut endosperm through fermentation, which is called *pliek-u* processing, only exists in Aceh. In batch processing, *pliek-u* processors can not only produce *pliek-u*, but also virgin coconut oil and crude coconut oil. Since it is made through a highly efficient process, we want to conserve the tradition of *pliek-u* processing. The conservation of this tradition can be used as a tool to improve the economy and public health [9].

There are about six species of fungi (*Microascus* sp., *Sordaria* sp., *Curvularia* sp., *Trichurus* sp., *Acremonium* sp. and *Gonytrichum* sp.) and approximately three species of gram-positive bacteria identified in *pliek-u* processing [3]. Another study has also shown nine isolates of fungi consisting of *Aspergillus sp*., *Penicillium citrinum*, *Thielaviopsis paradoxa* and *Geotrichum candidum*. *Pliek-u* contains lactic acid bacteria, and it can inhibit the growth of *Escherichia coli* and *Staphylococcus aureus* [10]. The gas chromatography–mass spectrometry (GC-MS) analysis had shown that *pliek-u* contained antimicrobial compounds as a result of fermentation [11]. Recently, the bioinformatic approach has shown the potential of the fatty acid in *pliek-u* as a component for atopic dermatitis treatment [12]. The antibacterial activity of *pliek-u* has been reported to be at a concentration of 5% [13] and at concentration of 4% against *S. aureus* [14]. The crude coconut oil also contains oleic acid, which can be used as a component for atopic dermatitis treatment [15]; and, its linoleic acid can be used against SARS-CoV-2 [16]. The use of *pliek-u* in feed had also improved the growth of African catfish significantly [17]. In contrast, the incidence of mycotoxins also degrades the quality of *pliek-u* after the infestation of *Aspergillus flavus* [18]. These findings motivate us to determine both the physicochemical and sensory quality of *pliek-u*.

Pliek-u processing consists of several steps, e.g., grating, fermentation, drying and pressing, and it takes a long time, i.e., about 13 to 16 days. The people who process *pliek-u* use traditional technologies that result in low productivity and quality. There are limited studies about improving the quality of *pliek-u*. The optimization of *pliek-u* quality has been achieved through the use of a kinetic dryer [19] and a Hohenheim solar tunnel dryer [9]. The quality of *pliek-u* could be determined by using near infrared spectroscopy [20]. The shelf life of *pliek-u* has been determined through the construction of an Arrhenius model [2], and the use of glass packaging can extend its shelf life [21] However, the standard quality of *pliek-u* has not been determined. Therefore, the objective of this study was to determine the physicochemical and sensory quality of *pliek-u* produced by random processors in Aceh. The results of this study are expected to help improve the understanding of *pliek-u* quality. Last but

not least, we hope that this information will contribute to the standardization of *pliek-u* processing and prevention of mycotoxin contamination, thereby conserving this tradition and increasing its consumption rate.

2. Materials and methods

2.1. Research procedure

A survey study was conducted in five local markets, namely, Rukoh, Ulee Kareng, Al Mahirah, Kampong Baro and Lambaro, to get random samples of *pliek-u* from various processors in Aceh, Indonesia. We conducted a survey in these local markets due to their locations in two districts i.e., Banda Aceh and Aceh Besar, as well as their large size, which made complete products available; thus, we had a high possibility of finding *pliek-u* products. A set of questionnaires built with KoboToolbox (https://kf.kobotoolbox.org/) was used to collect the samples of *pliek-u*. There were six questions that focused on the names of sellers, name of the market, origin of the *pliek-u*, price per kilogram, sample number and location of the market by coordinates. In these local markets, we looked for *pliek-u*, retrieved some information from the sellers according to the questionnaires and then bought the products to be later used as samples.

Another set of questionnaires built using KoboToolbox was also used for an organoleptic test. An organoleptic test was conducted using the hedonic scale. A hedonic score of 5 was applied, where 1 refers to extremely dislike, 2 refers to dislike, 3 refers to neither like nor dislike, 4 refers to like and 5 refers to extremely like. All collected samples were evaluated by experts on the organoleptic properties of aroma, color, texture and taste. In addition, there were 11 questions about the characteristics of *pliek-u*, recipes, *pliek-u* conservation and the consumption rate. We chose the three experts on the basis of their expertise as related to the products, i.e., their skill and experiences in the production of *pliek-u*, as well as their experience in using *pliek-u* in their recipes. To find these experts, we used snowball sampling.

2.2. Research parameters

The samples of *pliek-u* collected for the survey were stored in a plastic bag and sent to a laboratory for quality analysis. The parameters observed were the moisture, ash, fat, protein, fiber and carbohydrate contents, and the pH value and color. All parameters were analyzed by following the Indonesian National Standard (SNI) No. 01-2891-1992 in duplicate; the moisture content was analyzed by using the drying oven method at 105 ℃; the ash content was analyzed by conducting gravimetric analysis following implementation of the dry ashing method at 550 ℃; the fat content was analyzed via a direct extraction method; the protein content was analyzed by using the Kjeldahl method; and the fiber content was analyzed by using a gravimetric method. The carbohydrate content was calculated by using the pass difference method (it was by subtracting the measured water, protein, fat and ash from the total percentage) as it was used in the United States and Canada. The pH value was measured by using a pH meter (HM PH-80). The color of the *pliek-u* was determined by using a digital colorimeter (LS171) with a scale of Red (R), Green (G) and Blue (B).

For the three best samples with the highest organoleptic scores, the volatile compounds were analyzed by conducting the GC-MS method at the Laboratory of Science and Technology Faculty at

State Islamic University Ar-Raniry. It is an internationally accepted analytical comparative technique whereby the compounds are separated in the gas phase and a characteristic pattern of separate compounds is obtained [22]. PerkinElmer apparatuses were used [23]. A PerkinElmer Turbomatrix HS 40 Headspace Trap automatic sampler with trap enrichment was used to extract the volatile compounds. Volatile compounds were analyzed using a PerkinElmer Clarus 680GC with an SQ8 mass spectrometer. They were separated on a capillary column with dimensions of 30 m × 0.25 mm, with helium as the mobile phase. The initial temperature of the oven, 40 ℃, was maintained for 3 min. An increase in temperature was applied at rate of 3 ℃/min up to 115 ℃ and held for 10 min, and then at 2 ℃/min up to 140 ℃ and kept for 5 min. The injector temperature was 210 ℃, and the transfer temperature was 150 ℃. The mass spectrometer was operated in the scan mode within a range of 45–500 AMU.

2.3. Data analysis

Data were analyzed by using Microsoft Excel, including the statistical descriptives of mean value and standard deviation, and by building a map of the processor regions. Data were also analyzed by performing principal component analysis (PCA) using IBM SPSS Statistic 20.

3. Results

3.1. The distribution of pliek-u processors in Aceh

Aceh Province is located at the northwestern end of Sumatra Island, Indonesia. According to our survey, we collected 12 samples of *pliek-u* that were produced in four districts, i.e., Bireuen (eight samples), Banda Aceh (two samples), Aceh Besar (one sample) and Aceh Timur (one sample). The results showed that the central producer of *pliek-u* was the Bireuen subdistrict, which supplied about 67% of the *pliek-u* in the market. Aceh province has about 23 subdistricts; however, in other areas, a *pliek-u* processor was rarely found. Therefore, the conservation of this product should be initiated immediately.

From the survey, we also collected the information that the price of *pliek-u* in the local markets ranged from IDR 30,000 (USD 1.98) to IDR 50,000 (USD 3.3). *Pliek-u* was sold traditionally without labeling and packaging. Figure 1 shows the distribution of *pliek-u* processors in Aceh; the map was built by using Microsoft Excel.

3.2. The proximate analysis of pliek-u

Proximate analysis was conducted for all samples collected from the survey, as can be seen in Table 1. The moisture content of *pliek-u* ranged from 8% to 19%, the ash content ranged from 2% to 8%, the fat content ranged from 27% to 50%, the protein content ranged from 17% to 24%, the fiber content ranged from 2% to 5%, the carbohydrate content ranged from 13% to 29% and the pH value ranged from 3.97 to 5.04. Two samples were found to be moldy after a week of storage, i.e., sample numbers 2 and 10. High standard deviations were observed for fat content, carbohydrate content and moisture content. The variation in the physicochemical quality of the *pliek-u* was caused by the unstandardized quality of processing among the processors.

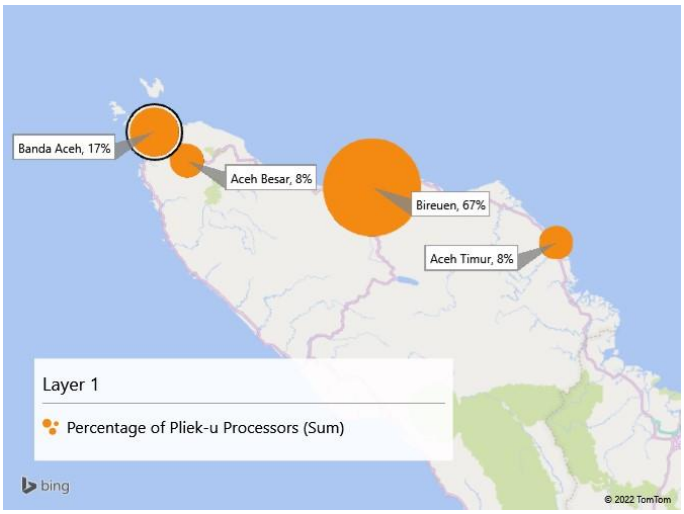

Figure 1. The distribution of *pliek-u* processors in Aceh, Sumatra Island.

3.3. Organoleptic test of pliek-u

Three experts were interviewed to evaluate the quality of *pliek-u* by using an organoleptic test. The ages of the experts were 62, 68 and 70 years; thus, each was well experienced in *pliek-u* processing. Since the sample numbers 2 and 10 were moldy, only 10 samples were evaluated. The results can be seen in Table 2.

Table 1. Results of proximate analysis of *pliek-u*.

Sample number	Origin	Moisture (%)	Ash (%)	Fat (%)	Protein (%)	Fiber (%)	Carbohydrate (%)	pH
1	Bireuen	15.46	5.71	33.28	20.01	3.26	25.54	4.05
2	Bireuen	15.84	4.37	31.81	18.24	3.48	29.74	4.85
3	Bireuen	13.34	5.19	39.92	23.59	2.73	17.97	4.27
4	Banda Aceh	18.16	5.77	38.76	19.18	2.87	18.12	4.32
5	Bireuen	15.02	7.81	27.71	20.93	2.31	28.54	3.99
6	Bireuen	12.09	5.95	35.23	18.27	4.71	28.46	3.97
7	Bireuen	13.80	4.86	49.30	17.40	4.36	14.63	4.47
8	Bireuen	16.63	6.88	34.03	18.35	2.20	24.11	4.09
9	Aceh Timur	8.30	4.66	51.44	19.98	4.69	15.63	4.29
10	Banda Aceh	19.32	5.12	29.06	20.01	2.17	26.49	5.04
11	Bireuen	17.76	2.34	34.99	20.89	3.18	24.03	4.04
12	Aceh Besar	12.38	6.28	45.99	21.76	2.35	13.59	4.25
Mean		14.84	5.41	37.63	19.88	3.19	22.24	4.30
Standard deviation		3.07	1.37	7.71	1.75	0.95	5.89	0.34

Note: Sample numbesr 2 and 10 were moldy after a week of storage

The highest total score was obtained for sample number 12, at 17.3 (from the district of Aceh Besar), followed by sample number 1, at 15.7 (from the district of Bireuen) and sample number 4, at

15 (from the district of Banda Aceh). However, about five out of 10 samples received average scores of 4 (i.e., "like"). The worst sample was obtained from the district of Bireuen for sample number 7, which had an average organoleptic score of 2 (i.e., "dislike"), as compared to the total score of 9.

Table 2. The organoleptic scores of *pliek-u* collected for the survey.

Sample number	Color	Aroma	Texture	Taste	TOTAL SCORE	AVERAGE SCORE
1	4.0 ± 1	4.0 ± 1	3.7 ± 1.2	4.0 ± 1.7	15.7	4
3	4.0 ± 1	3.0 ± 0	4.0 ± 1	3.7 ± 0.6	14.7	4
4	4.0 ± 1	3.7 ± 0.6	3.3 ± 0.6	4.0 ± 1	15.0	4
5	3.3 ± 0.6	2.7 ± 0.6	3.3 ± 0.6	4.3 ± 0.6	13.7	3
6	3.3 ± 0.6	2.3 ± 1.2	3.3 ± 0.6	3.3 ± 1.2	12.3	3
7	2.7 ± 1.5	2.3 ± 0.6	1.7 ± 0.6	2.3 ± 0.6	9.0	2
8	3.0 ± 1.7	3.3 ± 1.5	4.0 ± 1	4.0 ± 1	14.0	4
9	4.0 ± 1.7	3.0 ± 1	2.7 ± 0.6	3.0 ±1	12.7	3
11	3.0 ± 1.7	2.3 ± 0.6	2.3 ± 0.6	3.7 ± 1.5	11.3	3
12	4.3 ± 1.2	4.3 ± 1.2	4.3 ± 1.2	4.3 ± 1.2	17.3	4

Note: 1 refers to extremely dislike, 2 refers to dislike, 3 refers to neither like nor dislike, 4 refers to like and 5 refers to extremely like; sample numbers 2 and 10 were not evaluated due to their poor quality.

From the extensive interviews with the experts, some information about the sensory quality of *pliek-u* was also documented. *Pliek-u* has a certain aroma, its color is light to dark brown and its taste can be best described as acidic but not bitter or rancid. All experts agreed on the importance of preserving traditional *pliek-u* processing in the future. They were consuming *pliek-u* at a low frequency (i.e., about once in a month), but they hoped for *pliek-u* to be produced with good and uniform quality by all processors. The taste of *pliek-u* was found to be very impressive, but they did not have knowledge about the health impact of consuming *pliek-u*.

3.4. Color of pliek-u

Figure 2 shows the pictures of the *pliek-u* samples, and Figure 3 shows the color properties of *pliek-u*. The incidence of mold can be identified by a white color, and the color of moldy *pliek-u* appears darker (as can be seen on samples 2 and 10). According to Figure 3, it can be seen that the color properties of *pliek-u* are varied. The red (R) properties have average of 100 and deviation of 9. The reddest color is sample number 9 with highest R-value of 119. However, the green (G) and blue (B) values are more uniform indicated by lower deviation at 3.5 and 2.1, respectively. Overall, it can be said that the color of these samples was uniform as the deviation of each color properties was lower than its average.

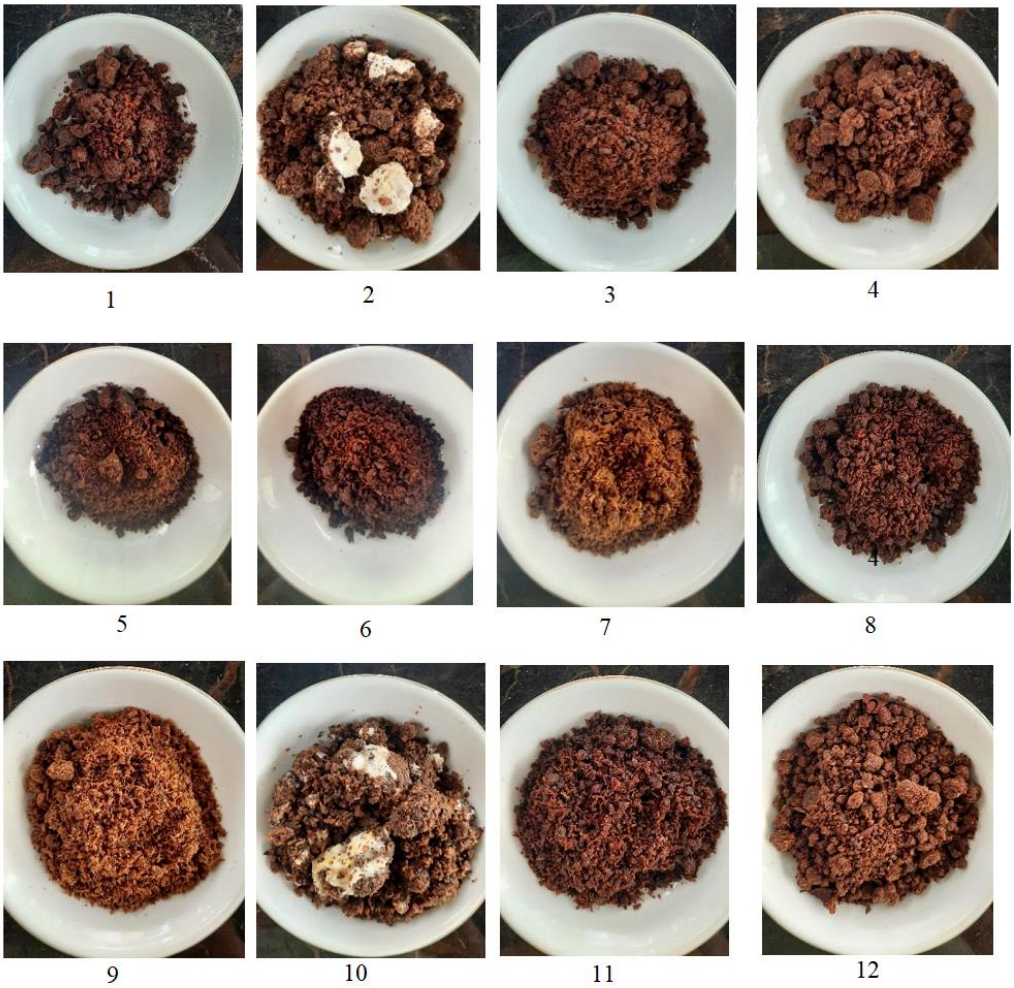

Figure 2. The samples of *pliek-u*.

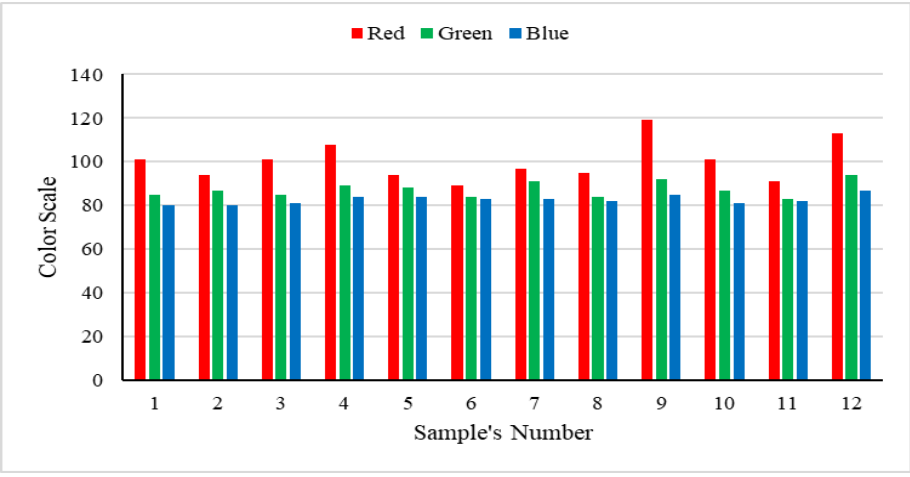

Figure 3. The color properties of *pliek-u*.

3.5. The volatile compounds of pliek-u

The volatile compounds of the three best samples were analyzed, i.e., sample numbers 1, 4 and 12, as chosen because of their highest total scores for the organoleptic tests (Table 2). It can be seen in Figure 4 that *pliek-u* contained different volatile compounds. The volatile compounds that were found in all samples were 3-methylbutanal, [ethanol, 2-nitro, propionate (ester)] and (2R,3R)-butanediol. The volatile compounds found only in sample number 1 were urea (14.59%), azulene (6.72%), cyclic octasulfur (4.75%) and [2-amino-4,5-dimethoxybenzonitrile, N-] (4.72%).

The volatile compounds identified only in sample number 4 were octanoic acid (8.4%) and [2-thiazolamine,4-(3,4-dimethoxyphenyl)-5-] (5.9%). The volatile compound found only in sample number 12 was [nitrous acid, ethyl ester] (5.29%). The most volatile compounds were observed in sample number 12. It contained [butanal, 3-methyl] at about 15.496%, methyl formate at 15.013%, silver octanoate at 10.421%, 2-amino-1-pentanol at 6.719% and [2-amino-4,5-dimethoxybenzonitrile, N-] at about 6.307%. Sample numbers 4 and 12 had the same six volatile components, but sample number 12 had fewer volatile compounds compared to sample numbers 1 and 4.

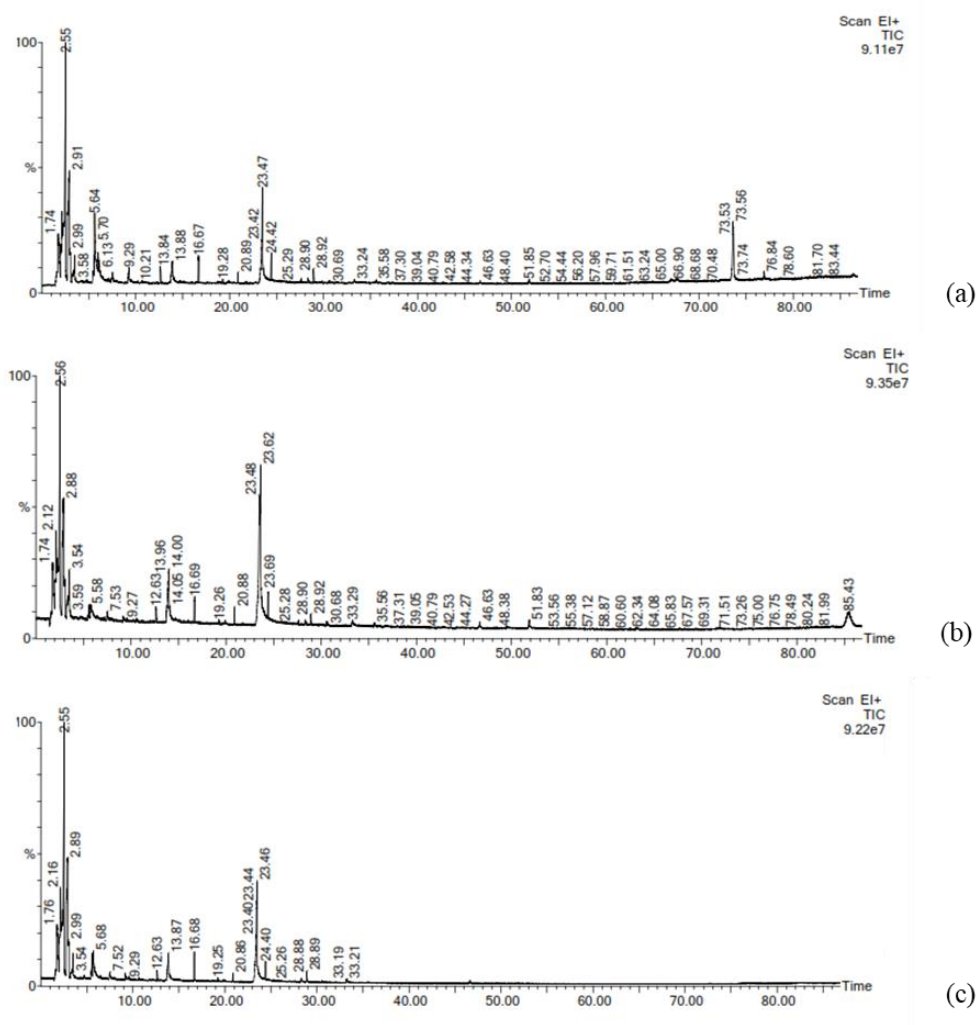

Figure 4. The volatile compounds of *pliek-u*: (a) sample number 1, (b) sample number 4 and (c) sample number 12.

4. Discussion

The central production of *pliek-u* in Aceh is Bireuen District. It can be seen that *pliek-u* processors are rarely found in other parts of Aceh. This warrants attention from universities and the government to conserve this old tradition of coconut endosperm processing. Simple technology can be applied to these small-scale enterprises to improve the situation and attract young people to get involved in preserving the tradition. In addition, the product needs better packaging and labeling in order to be sold, not only in local markets, but also in bigger markets such as supermarkets and online markets. The use of glass material for packaging can also prolong the shelf life of *pliek-u* [21]. So, it is also important to introduce modern packaging methods to processors in Aceh, Indonesia. The short shelf life of the *pliek-u* in local markets (less than 2 months) is presumed to be associated with high moisture, and the improper storage and packaging of the products.

Considering the organoleptic assessment, five out of the 12 samples received an average score of 4, namely, sample numbers 1, 3, 4, 8 and 12. Using these selected samples, we found the *pliek-u* samples to have a moisture content of 12–18%, ash content of 5–7%, fat content of 33–46%, protein content of 18–24%, fiber content of 2–3%, carbohydrate content of 13–26% and pH value of 4.0–4.3. In the same manner, based on 3 best samples selected, the expected color of *pliek-u* is with Red-value ranged from 101 to 113, Green-value ranged from 85 to 94 and Blue-value ranged from 80 to 87.

Based on the PCA results, only five out of seven parameters were used to determine the *pliek-u* quality. They were the moisture content (x_1), pH value (x_2), protein content (x_3), ash content (x_4) and carbohydrate content (x_5). The statistic descriptive of these parameters can be seen in Table A. 1. The excluded parameters were fat content and fiber content. The PCA was conducted by applying the Kaiser-Meyer-Olkin (KMO) value of 0.505 (Table A. 2). The first principal component (PC_1) contributed to 34.111% of the variance, with the highest correlation value being attributed to the pH value of about 0.510; the second principal component (PC_2) contributed to 24.968% of the variance, with the highest correlation value being attributed to the protein content of 0.537 (The contribution can be seen in Table A. 4 and the correlation value can be seen in Table A. 3). PC_1 and PC_2 can be written as follows (Table A. 5).

$$PC_1 = 0.738x_1 + 0.313x_2 + 0.824x_5,$$

$$PC_2 = 0.049x_3 + 0.813x_4.$$

Here, it can be seen that the pH value and protein content play the most important roles in determining the quality of *pliek-u* compared to the other parameters. The importance of the pH value was demonstrated by sample number 4; even though it had a moisture content of 18%, the quality could be maintained without mold. According to the experts, acidity is an important characteristic of *pliek-u*. The use of a starter culture lowered the pH value from 5.16 to 4.3–4.5 after 3 days of fermentation [24]. A similar pH value can be achieved without a starter culture by extending the fermentation process [10]. The fermentation step is the core of *pliek-u* processing because, during this step, the volatile components of *pliek-u* are also developed. The maximum fermentation was 15 days, according to the age of the lactic acid bacteria, as was determined by Tsukamuto method [25]. Further studies are necessary to determine the condition of the fermentation process and its effects on *pliek-u*

quality; improving the technology of the fermentation kettle should be conducted.

Both components (PC_1 and PC_2) had eigenvalues higher than 1, and the cumulative contribution of these components was 59.079%. According to the component plot in rotated space and biplot (Figure 5), the carbohydrate content was located in the same quadrant as the ash content, while the moisture content was located in the same quadrant as the pH value. About five samples were located in quadrant 1, i.e., sample numbers 2, 4, 6, 10 and 11, which had the characteristics of high ash and carbohydrate content. Then, two samples were located in quadrant 2, i.e., sample numbers 7 and 9, which had the same characteristics. Only one sample was located in quadrant 3, i.e., sample number 12, which had no prominent characteristics according to the PCA results, but this sample actually had high fat and protein content (as can be seen in Table 1). Also of importance is the origin of the sample, as sample number 12 was from the Aceh Besar district, which may have caused the different characteristics of the *pliek-u*. Four samples, i.e., numbers 1, 3, 5 and 8, were located in quadrant 4, indicating the characteristics of a high pH-value and high moisture content. The distribution of samples across all quadrants showed that the quality of the *pliek-u* highly varied among processors. Therefore, the standardization of *pliek-u* processing should be formulated.

Besides the pH value and protein content, the moisture content is commonly important for the quality. This fact was supported by a previous study that indicated that maintaining a moisture content for *pliek-u* that is below 10% can extend the shelf life up to 2 years [2]. Moisture content below 14% is very important for dried products since it can inhibit the growth of microorganisms. It can be the reason why sample numbers 2 and 10, which had moisture contents above 14%, had mold infestation after a week of storage.

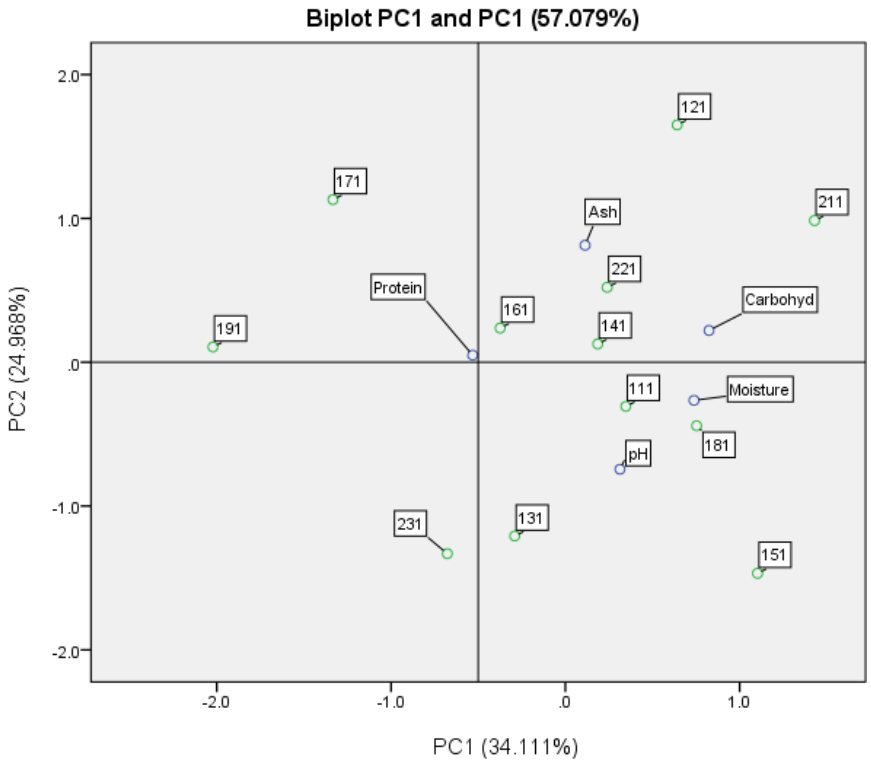

Figure 5. The biplot graph of *pliek-u* quality.

The protein content of *pliek-u* was stable among all processors at 17–24%, with a deviation of about 1.75%. It is interesting that the protein content of *pliek-u* is higher than the protein content of coconut endosperm. Increasing the protein content was also confirmed in a previous study as the impact the fermentation process [26]. Therefore, *pliek-u* can be used as healthy food due to its high protein content. However, the fat content of *pliek-u* was highly varied among processors; this could be caused by the method of pressing. High fat content can increase the rancidness during storage of the *pliek-u*. An appropriate fermentation should increase the crude fat content due to microbial activity producing heat [26], but the later separation procedure of oil and *pliek-u* through the use of pressing technology should reduce the fat content of *pliek-u*.

The ash content of *pliek-u*, on average, was 5.41%, with a deviation of 1.37%. It was explained that the fermentation could decrease the ash content, as well as the moisture content [26]. A previous study has shown that the ash content of *pliek-u* was about 4.63% [19]. Introducing technology could reduce the contamination during processing and maintain the ash content of *pliek-u* below 7%.

According to the GC-MS results on volatile compounds, sample numbers 4 and 12 had better components compared to sample number 1 since the urea content in *pliek-u* sample number 1 was identified. However, sample number 1 also contained beneficial components such as azulene and octasulfur. Azulene is an aromatic hydrocarbon and isomer of naphthalene. Azulene and its derivatives occur naturally as a component of many plants [27]. In medicine, the potential use of this compound has been associated with anti-inflammatory, antineoplastic, antidiabetic, antiretroviral with HIV-1 and antimicrobial properties [28]. Octasulfur is an inorganic substance that is present in all living tissues. Sulfur is an indispensable food component for human health and disease prevention. Apart from *pliek-u*, sulfur is also found in abundance in garlic oil, which is often used for health therapy [29].

It can be seen that sample number 12 had the best quality since it contained larger amounts of methyl formate; butanal, 3-methyl; octanoid acid; Ag^+ salt and amino acids. According to the PCA results, sample number 1 was located in quadrant 4, sample number 4 was located in quadrant 1 and sample number 12 was located in quadrant 3. This implies the different characteristics among these samples significantly, which was confirmed later by the differences in volatile compounds. It could be influenced by the unstandardized *pliek-u* processing. Further studies are recommended to find out the best processing steps in order to produce the beneficial volatile compounds expected from *pliek-u*.

Finally, *pliek-u*, as a traditional fermented food, can usually be consumed safely. However, mycotoxins could form during the fermentation of *pliek-u* [11]. A previous study has shown that *pliek-u* at traditional markets in Aceh had been infected with *Aspergillus flavus* [18]. Although the mycotoxin was not identified in our study, the incidence of urea in sample number 1 was also an example of failure production. Generally, the fermentation of coconut endosperm is predominantly a lactic acid fermentation process [4]. To avoid the occurrence of hazardous material in *pliek-u*, it is important to improve the *pliek-u* manufacturing process by giving skill and knowledge to the processors and developing simple technologies that can be used in the production. Last but not least, this study has also confirmed that the sensory quality could not stand alone and should be supported by the physicochemical quality to guarantee not only the taste, but also the quality and safety of *pliek-u*.

5. Conclusions

Twelve random samples of *pliek-u* were used to determine the quality of *pliek-u* produced in Aceh, Indonesia. According to the results of PCA, from the seven parameters evaluated, the most important

parameters contributing to *pliek-u* quality were the pH value (4 to 4.5) and protein content (> 19%). However, the three best samples selected by experts were located in different quadrants of the biplot derived from PCA, which revealed that they have different characteristics. The GC-MS results regarding the volatile compounds of these samples confirmed these unique characteristics, which could have been caused by the unstandardized *pliek-u* processing applied in the community. The step that most significantly affects *pliek-u* quality is the fermentation step. Further studies are also necessary to determine if a causal relationship exists among these parameters and how certain fermentation conditions would impact the volatile compounds in *pliek-u*.

Appendix

Table A. 1. Descriptive statistics of chosen parameters.

	Mean	Std. Deviation[a]	Analysis N[a]	Missing N
Moisture	14.8416667	3.07419415	12	0
pH	4.3025000	0.33871750	12	0
Protein	19.8841667	1.75104363	12	0
Ash	5.4116667	1.37156071	12	0
Carbohydrate	22.2375	5.89233574	12	0

Note: a. For each variable, missing values are replaced with the variable mean.

Table A. 2. The KMO and Bartlett's tests.

Kaiser-Meyer-Olkin measure of sampling adequacy.		0.505
Bartlett's test of sphericity	Approx. Chi-Square	4.371
	DoF	10
	Sig.	0.929

Table A. 3. The anti-image matrices.

		Moisture	pH	Protein	Ash	Carbohydrate
Anti-image covariance	Moisture	0.720	-0.229	-0.038	0.060	-0.328
	pH	-0.229	0.808	0.163	0.211	0.089
	Protein	-0.038	0.163	0.910	0.028	0.186
	Ash	0.060	0.211	0.028	0.906	-0.102
	Carbohydrate	-0.328	0.089	0.186	-0.102	0.747
Anti-image correlation	Moisture	0.508[a]	-0.300	-0.047	0.074	-0.447
	pH	-0.300	0.510[a]	0.190	0.247	0.115
	Protein	-0.047	0.190	0.534[a]	0.031	0.225
	Ash	0.074	0.247	0.031	0.537[a]	-0.125
	Carbohydrate	-0.447	0.115	0.225	-0.125	0.477[a]

Note: a. Measures of sampling adequacy (MSA).

Table A. 4. The total variance explained by component.

Component	Initial eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.706	34.111	34.111	1.706	34.111	34.111	1.617	32.341	32.341
2	1.248	24.968	59.079	1.248	24.968	59.079	1.337	26.739	59.079
3	0.912	18.234	77.313						
4	0.684	13.679	90.992						
5	0.450	9.008	100.000						

Note: Extraction method: principal component analysis.

Table A. 5. Rotated Component Matrix[a].

	Component	
	1	2
Moisture	0.738	-0.265
pH	0.313	-0.744
Protein	-0.532	0.049
Ash	0.113	0.813
Carbohydrate	0.824	0.221

Note: Extraction method: principal component analysis; Rotation method: quartimax with Kaiser normalization; a. Rotation converged in three iterations.

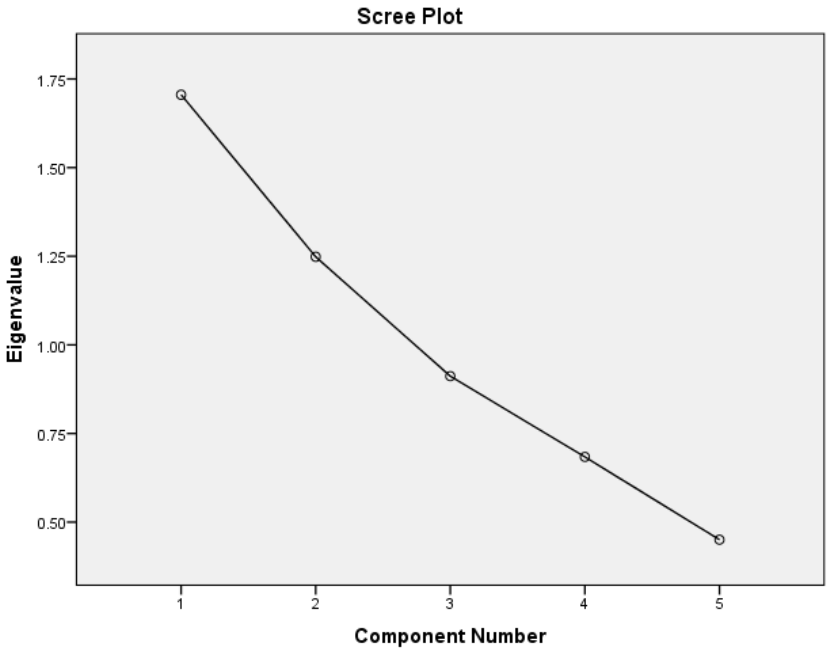

Figure A. 1. The scree plot of components.

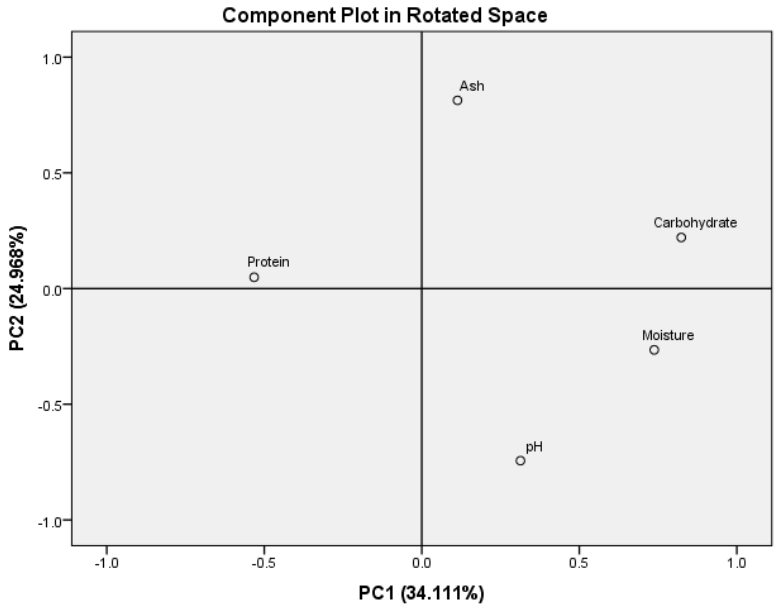

Figure A. 2. The component plot in rotated space.

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Conflict of interest

We would like to declare that there is no conflict of interest that could affect the publication of this research.

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