Volatile Compounds Content and Sensory Profile of Katuk (*Sauropus androgynus*) Leaves After Household Scale Heating

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ABSTRACT

Katuk (*Sauropus androgynus*) is an indigenous Indonesian plant, and the leaves are often consumed as fresh or processed vegetables. Despite its potential, there are no reports on the volatile compounds content and sensory profile of Katuk leaves after being processed using household scale heating. Therefore, this study aimed to determine the volatile compounds content and sensory profiles of Katuk leaves after household scale heating (steaming and boiling). The extraction of constituents was carried out using the headspace-solid phase microextraction method, followed by identification with gas chromatography-mass spectroscopy. The sensory profile analysis was performed using the free choice profiling method with untrained panelists. The analysis results showed the presence of 16 volatile compounds derived from 7 groups, including aldehydes (5 compounds), alcohol (3 compounds), other components (3 compounds), ketones (2 compounds), as well as benzene, terpenoids, and esters (1 compound). The dominant compounds found in fresh Katuk leaves were alcohol [(Z)-3-hexene-1-ol]. Meanwhile, aldehydes (benzaldehyde, nonanal, benzeneacetaldehyde, and (E)-2-pentenal) and alcohol (1-Heptanol and Nerolidol) were dominant in the steamed samples, with benzene (naphthalene) being predominantly found in the boiled samples. The sensory profile analysis results showed that fresh Katuk leaves had a grassy and earthy aroma with a grassy flavor, while the boiled samples had a smooth and juicy texture. The dominant attributes found in steamed Katuk leaves included moist, tender, and tasteless. Based on these findings, household scale heating could modify the composition of volatile compounds, thereby affecting the sensory profile. The results obtained were expected to serve as a foundation for the processing of Katuk leaves at both industry and household levels.

Keywords: Boiling; Katuk leaves; sensory profile; steaming; volatile compounds

INTRODUCTION

Katuk (*Sauropus androgynus*) is a widely used medicinal plant that can be consumed in the form of vegetables. In addition, its leaves are often found in several tropical countries, including China, India, Sri Lanka, Vietnam, Malaysia, Papua New Guinea, and the Philippines (Hayati et al., 2016). In Indonesia, Katuk leaves have been consumed for generations by the community both in fresh and processed forms (Susanti et al., 2019).

Several studies have shown that the consumption of fresh and processed Katuk leaves provides various health benefits, including being a breast milk facilitator for new mothers (Rahmanisa and Aulianova, 2016). Another essential benefit is their rich content, comprising

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various compounds, such as tannins, saponins, flavonoids, and alkaloids, which are traditional medicine ingredients for the treatment of ulcers and constipation (Santoso, 2019). In line with previous studies, the constituent flavonoids have the potential to serve as antioxidants (Zuhra et al., 2008).

Katuk leaves are often preferred over cosmos, *poh-pohan* (*Pilea melastomoides*), rendeu (*Staurogyne elongata*), and basil leaves due to their beneficial food attributes. These include flavor, availability, ease of processing, type of processing, price, ease of chewing, active ingredient content, and color (Nahraeni et al., 2016), with flavor playing an essential role in consumer acceptance.

According to previous studies, flavor is a sensation caused by chemical components with volatile properties during the consumption of food or beverages. In addition, it is typically formed due to the presence of volatile compounds, which are organic components that evaporate quickly and serve as secondary metabolites in plants (Marsiany et al., 2020). Previous reports have shown that these compounds can provide a sensation of aroma in food products (Ardiansyah et al., 2021).

In terms of cooking methods for Katuk leaves, household cooking processes, such as steaming and boiling can affect the content of phytochemical and volatile compounds due to evaporation caused by various reactions (Wieczorek et al., 2014). Several studies have explored the effect of home-scale heating process on various aspects, such as total phenolic compounds (TPC) content. A previous report revealed a reduction in TPC content due to the boiling process at 70 °C and 100 °C (Ardiansyah et al., 2019). Another report showed that there was an increase in TPC content in Katuk leaves after one-minute microwave heating process (Ardiansyah et al., 2016). In addition, there was also a reduction in antioxidant activity after boiling at 100 °C as well as an increase in the microwave heating process for 3 minutes (Ardiansyah et al., 2016). Organic vegetables, such as potatoes, carrots, onions, broccoli, and cabbage expressed a decrease in TPC content after cooking (boiling and steaming) (Faller and Fialho, 2009). A previous study also reported that household-level cooking by boiling and steaming could maintain the TSF content and antioxidant activity in sweet potato leaves (Sun et al., 2014).

Despite the numerous existing literature, there are still no studies on the sensory profile and volatile compounds content of Katuk leaves after processing with household-scale heating (boiling and steaming). The majority of available reports have predominantly focused on fingerprinting metabolism, antimicrobial activity, and anticancer activity (Bose et al., 2018; Wei et al., 2011; Yunita et al., 2019). Therefore, this study aimed to investigate the volatile compounds content and sensory profile of Katuk leaves after household-scale heating (steaming and boiling). The results obtained were expected to serve as a basis for processing Katuk leaves at the household and industrial scales, as well as other product development.

METHODS

Materials

The materials used for the test included Dodecane standard (Sigma-Aldrich, Saint Louis, MO, USA), C8-C22 standard (Sigma-Aldrich, Saint Louis, MO, USA), water, helium gas (He), and young Katuk leaves, which were trimmed by ± 10-15 cm. The chemicals for analysis were GCMS grade, while the water used was standard drinking water. In addition, samples of Katuk leaves were obtained from the yard of a house in the Cijantung area, East Jakarta.

The tools used in preparing Katuk leaves and the stages of extraction were scales, a set of Headspace-Solid Phase Microextraction (HS-SPME) extraction tools, a 500 mL measuring cup, a 5 mL headspace vial, a water bath, a medium-sized pot with a volume of approximately 2.86 cm^3, a household-scale gas stove, and a Gas Chromatography-Mass Spectrometry (GC-MS) 7890A-5975C instrument (Agilent Technologies, Palo Alto, CA, USA).

Sample Preparation

Fresh Katuk leaves were weighed and divided into 3 groups, including fresh, boiled (3 and 5 minutes), and steamed samples (3 and 5 minutes). The household-scale heating process was based on the method developed by Ardiansyah et al. (2016) with slight modifications. A total of 10 g of fresh Katuk leaves were boiled using a closed pot with 500 mL of water, where the water was brought to a boil before the sample was added. Furthermore, the boiling process was carried out for 3 and 5 minutes, with 3 repetitions. The same method was used for Katuk leaves for the steaming process, where the sample was placed in a pot with boiling water. The steaming process was carried out for 3 and 5 minutes, with 3 repetitions.

Extraction of Volatile Compounds by Headspace-Solid Phase Microextraction

The extraction of Katuk leaves was based on the method developed by Ardiansyah et al. (2021). Fresh and boiled/steamed Katuk leaves were extracted using the HS-SPME method. Fiber with a thickness of 50/30 μm and a length of 2 cm divinylbenzene/carboxen/polydimethylsiloxane (DVB/CAR/PDMS) was used to extract the aroma components in the samples. A total of 10 g of fresh Katuk leaves that had been cut into pieces were added with 0.6 μL (0.0001%) of dodecane as an internal standard. Meanwhile, 10 g of boiled/steamed Katuk leaves were cut into pieces, added with 0.2 μL (0.0001%) of dodecane as internal standard, placed into the headspace of a 5 mL vial, and closed with a silicon septum. The extraction fiber was then placed into the vial to be extracted in a water bath at 50 °C for 30 minutes.

Analysis and Identification of Volatile Compounds

Analysis of volatile compounds was carried out based on the study of Ardiansyah et al. (2021) with slight modifications. The analysis used GC-MS Agilent 7890A-5975C (Agilent Technologies, Palo Alto, CA, USA), and the column used was DB-5MS type with 30 m length, 0.25 mm diameter, and 0.25 μm thickness. In addition, the extracts were injected using the splitless method at 250 °C, and the temperature setting started at 40 °C for 2 minutes and then increased to 230 °C at a rate of 3 °C/minute. The carrier gas used was helium gas (He) with a constant flow rate of 0.8 ml/min, pressure of 60 kPa, and Ionization voltage of 70 eV. Tentative volatile compounds were identified by comparing their mass spectra with the NIST 2005 library database. The LRI values of the compounds in the samples were confirmed with their LRI values in the literature.

Sensory Analysis

Sensory analysis was conducted to determine the sensory profile of Katuk leaves, consisting of appearance, aroma, flavor, and texture. The analysis was carried out using the free choice profiling (FCP) method using untrained panelists (Punter, 2018), totaling 22 individuals (10 men and 12 women) aged 18-21 years. In addition, the panelists were asked to fill out a concern form before testing was carried out. The testing procedures were divided into 2 sessions, and in the first session, the impressions obtained on the samples presented were described. The panelists were also assisted with several terms related to attributes. The panel leader then collected all the attributes most frequently mentioned to be presented in the second session. The panelists in the second session rated the attributes that had been agreed upon in the first session. Samples preparation of Katuk leaves was carried out with 5 different treatments, namely boiling (3 and 5 minutes), steaming (3 and 5 minutes), and fresh samples (control). Prepared samples were placed into plastic glass containers and covered to keep the aroma from evaporating. Each container was assigned a randomly generated samples code (trivial code).

Data Analysis

The analysis was carried out using principal component analysis (PCA) to determine the dominant volatile compounds contained in the samples. Meanwhile, the sensory profile analysis used generalized procrusters analysis, and both analyses were processed with the XLSTAT 2019 program.

RESULTS AND DISCUSSION

Volatile Compounds of Katuk Leaves

Volatile compounds of Katuk leaves were identified using Gas Chromatography-Mass Spectrometry (GC-MS). These compounds could contribute to aroma and were components that provided an odor sensation, gave an initial impression (top notes), and could evaporate quickly. Figure 1 presents a diagram of volatile compounds of fresh, boiled (3 and 5 minutes), and steamed (3 and 5 minutes) Katuk leaves. The dominant compounds belong to the aldehyde group (5 compounds), alcohols (3 compounds), other components (3 compounds), ketones (2 compounds), as well as benzenes, terpenoids, and esters of one compound each.

The names of the compounds were presented in Table 1, where 16 volatile compounds were identified in fresh, boiled, and steamed leaves. In addition, a total of 4, 4, 6, 13, and 15 compounds were obtained from fresh samples, 3 minutes boiling, 5 minutes boiling, 3 minutes steaming, and 5 minutes steaming. These components could be grouped into alcohol, ketone, aldehyde, benzene, terpenoids, esters, and others. Compounds (Z)-3-hexene-1-ol, naphthalene, (Z)-4-Methyl-2-hexene, and 2-Pentenal-2-methyl were identified in fresh Katuk leaves. Table 1 showed that some volatile compounds were not detected in the heating treatments, such as 1-Heptanol, nerolidol, 6-Methyl-5-hepten-2-one, benzaldehyde, nonanal, benzenacetaldehyde, (E)-2-Pentenal, trans-β-Ocimen, Cis-3-Hexenyl valerate, (Z)-4-Methyl-2-hexene. This was likely because, during boiling (heating), chemical reactions (hydrolysis, oxidation, or other chemical reactions) occurred, leading to a decrease or increase in the levels of certain volatile compounds or their synthesis (Wieczorek et al., 2014).

In Table 1, a total of 3 volatile compounds were identified in the alcohol group, including (Z)-3-hexene-1-ol, 1-Heptanol, and Nerolidol. In fresh Katuk leaves, only the volatile compound (Z)-3-hexene-1-ol was

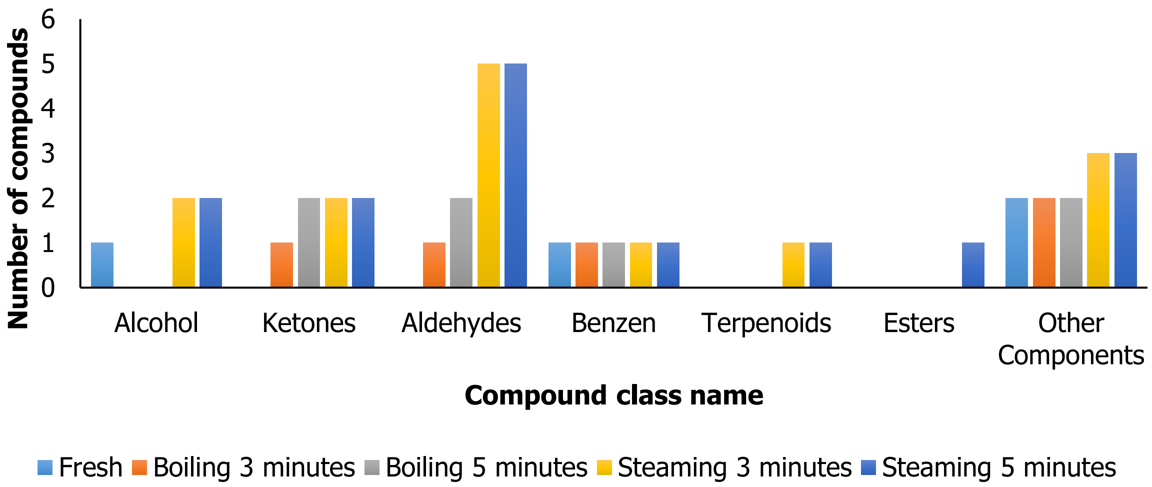


Figure 1. Diagram of volatile compounds in fresh, boiled (3 and 5 minutes), and steamed (3 and 5 minutes) Katuk leaves

detected., while 1-heptanol and Nerolidol were only detected in the steaming sample. In addition, (Z)-3-hexene-1-ol was a group of green leaves volatiles (GLVs) with a characteristic green aroma. GLVs were produced from polyunsaturated fatty acids bound to thylakoid membranes in chloroplasts in a series of enzymes (Mikiko et al., 2016). (Z)-3-hexene-1-ol could also give the characteristic cut grass aroma because alcohol group compounds were formed due to the enzymatic hydrolysis reaction of glycosides through the lipoxygenase pathway. This was carried out through the oxidation of linoleic acid and endogenous enzymes, such as lipoxygenase, and endogenous enzymes, including lipoxygenase, hydroperoxidase, alcohol dehydrogenase, and alcohol acetyltransferase, leading to the production of aldehyde ((Z-3-hexenal), alcohol (Z)-3-hexene-1-ol), and ester ((Z)-3-hexenyl-acetate) (Lima et al., 2017; Lai, 2016). 1-Heptanol was an alkyl alcohol derived from heptane hydride where one of the methyl groups was replaced by a hydroxy group. In addition, this compound was a primary alcohol, alkyl alcohol, and volatile organic compound, which was considered to have a green, herb aroma description (PubChem, 2022).

A total of 2 ketone-class compounds were detected, including 6-Methyl-5-hepten-2-one and 1,4-Dimethyl-3-cyclohexenyl methyl ketone. Furthermore, ketones could be formed based on oxidative reactions in leaves with the blanching heating process (Lima et al., 2017). 6-Methyl-5-hepten-2-one was formed due to oxidation reactions, where ozonolysis gas from linalool was converted into 6-methyl-5-hepten-2-one and was thought to have sweet, floral aroma characteristics (The Good Scents Company). Meanwhile, the compound 1,4-Dimethyl-3-cyclohexenyl methyl ketone was thought to have a 'green' aroma characteristic (The Good Scents Company, 2022).

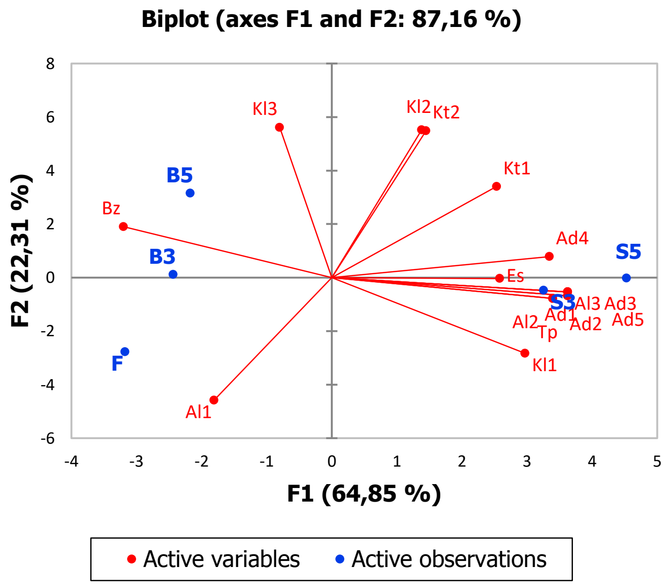
Aldehydes were intermediate compounds between alcohols and acids, which had lower molecular weight. Based on Table 1, a total of 5 aldehyde compounds were detected, including benzaldehyde, nonanal, benzeneacetaldehyde, decanal, (E)-2-Pentenal. Benzaldehyde was an aromatic aldehyde containing a single formyl group that was believed to have sweet, floral aroma characteristics. Meanwhile, nonanal was a class of weakly saturated aldehyde compounds, n-alkanes, produced due to the reduction of nonanoic acid carboxy groups and was thought to have green aroma characteristics. Several studies had shown that benzeneacetaldehyde had a green aroma. Decanal was a saturated fatty aldehyde produced from reducing the carboxy group of capric acid (decanoic acid), which was believed to give a characteristic floral aroma. (E)-2-Pentenal was an (E)-configured double bond that acted as a plant metabolite and provided a characteristic green aroma (PubChem, 2022). Table 1 showed that volatile compounds of the aldehyde group were not identified in the fresh samples. This was because fresh Katuk leaves had no identified precursor compounds, and after the heating process, boiling/steaming could trigger new compounds. The difference in temperature and time of the heating process greatly affected the change or formation of volatile compounds (Wieczorek et al., 2014). In the boiling process, benzaldehyde compounds had formed but were not detected by the detection system in this report. Therefore, further study must be carried out to support this finding.

In Table 1, one compound of benzenes, terpenoids, and esters was detected. The benzene group was found in fresh, boiled (3 and 5 minutes), and steamed (3 and 5 minutes) Katuk leaves. Based on Table 1, a naphthalene compound was detected, which gave a grass aroma (Flavornet, 2022). Naphthalene was an aromatic hydrocarbon with 2 fused benzene rings (PubChem, 2022).

Terpenoids were a diverse group comprising thousands of volatile compounds found in vegetables. In addition, these compounds were dehydrogenated and oxygenated derivatives of terpene compounds with carbon and hydrogen atoms (Yahia, 2018; Heliawati, 2018). In Table 1, one class of terpenoids compounds was detected, namely trans-β-Ocimen, which gave earthy, herb, and floral aroma (Flavornet, 2022). The results showed that terpenoids components were only found in the steaming process due to the effect of temperature and heating time on their formation (Wieczorek et al., 2014). However, further studies were needed to explain the mechanism of β-Ocimen compound formation in detail.

Esters were formed by esterification between carboxylic acid derivatives and alcohols (Lee et al., 2019). In this group, volatile compounds could be formed due to dissolution and evaporation (Guo et al., 2019). In addition, the compound detected in this group was cis-3-hexenyl valerate or methyl butyrate, which was believed to have green, ripe, fruity, and green aroma characteristics (The Good Scents Company, 2022). The results of the relative number of compounds in Table 1 revealed that the ester group was only identified in the 5-minute steaming Katuk leaves. This was because the heating process with a longer time than 3 minutes of steaming could change the chemical structure of methyl butyrate. C-C and C=O bonds could experience homolytic fission or chemical bond dissociation (Ali and Violi, 2013). Meanwhile, no compounds were identified in Katuk leaves with the boiling process because methyl butyrate compounds were soluble in water (PubChem, 2022).

Other compound groups identified included (Z)-4-methyl-2-hexene, 2-pentenal, 2-methyl, and 2- Ethylhexyl maleate. The compound 2- Ethylhexyl maleate of fresh samples was not detected because maleic anhydride after heating formed 2- Ethylhexyl maleate (Gelbard, 2005). In addition, the compound 2-pentenal-2-methyl was identified in all samples, but in the steaming samples, this compound had a higher relative amount of compound area compared to the fresh or boiled variants. This was because using steam as a heating medium prevented the samples from being in direct contact with water, hence, the content of volatile compounds remained.



Description: F: (fresh); S3: (steam; steamed 3 min); (S5: steam; steamed 5 min); B3: (boiling; boiled 3 min); B5: (boiling; boiled 5 min); Ad1: benzaldehide, Ad2: nonanal, Ad3: benzeneacetaldehide, Ad4: decanal, Ad5: (E)-2-Pentenal; Al1: (Z)-3-hexene-1-ol; Al2: 1-heptanol; Al3: nerolidol; Bz: napthalene; Kt1: 6-Methyl-5-hepten-one; Kt2: 1,4-Dimethyl-3-cyclohexenyl methyl ketone; Es: cis-3-Hexenyl valerate; Kl1: (Z)-4-Methyl-2-hexene; Kl2: 2-Pentenal-2-methyl

Figure 2. Overall biplot of Katuk leaves' volatile compounds

PCA of Volatile Compounds of Katuk Leaves

PCA was conducted to determine the volatile compounds that were dominant in fresh, boiled (3 and 5 minutes), and steamed (3 and 5 minutes) Katuk leaves. Figure 2 presents the overall biplot of volatile compounds of fresh, boiled (3 and 5 minutes) and steamed (3 and 5 minutes) Katuk leaves.

The results showed that household-scale heating process could change the composition of volatile compounds contained in Katuk leaves when compared to fresh samples, as presented in Figure 2. In the upper right quadrant, volatile compounds that dominated the samples steamed for 5 minutes (S5) included Kt1, Kl2, Kt2, and Ad4. Meanwhile in the samples steamed for 3 minutes (S3), the dominant constituents were Ad1, Ad2, Ad3, Ad5, Al2, Al3, Tp, and Kl1. The predominant volatile compounds in leaves steamed for 3 and 5 minutes (B3 and B5) were Bz and Kl3 from the benzene group. Meanwhile, the dominant constituents in fresh Katuk leaves were Al1 ((Z)-3-hexene-1-ol compounds.

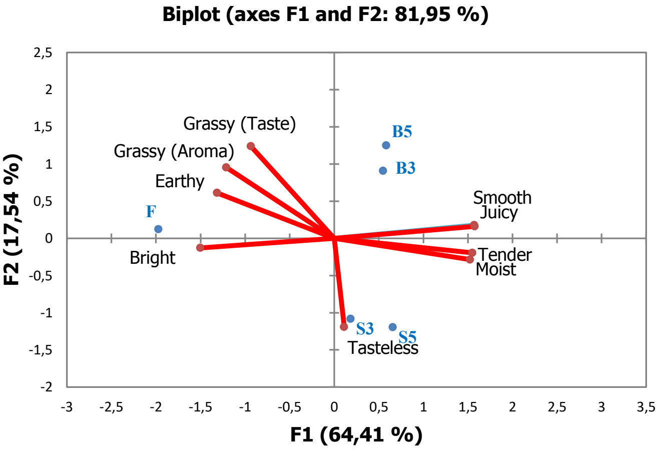
Table 1. Volatile compounds in fresh, boiled (3 and 5 minutes) and steamed (3 and 5 minutes) Katuk leaves

Compound Name	Experimental LRI	Code	Literature LRI	Relative compound area (μg/g) Katuk leaves Fresh	Boiled 3 minutes	Boiled 5 minutes	Steamed 3 minutes	Steamed 5 minutes	Aroma Description
Alcohol									
(Z)-3-hexene-1-ol	864	Al1	853[a]	0.00414 ± 0.000175	nd	nd	nd	nd	Grassy f, cut grass, green, fresh g
1-Heptanol	1072	Al2	974[b]	nd	nd	nd	7.67E-06 ± 1.60E-06	6.82E-06 ±	Green, herb [f]
Nerolidol	1451	Al3	1559[c]	nd	nd	nd	1.81E-05 ± 5.95E-06	3.20E-05 ± 3.36E-06	Green, floral [b]
Ketone									
6-Methyl-5-hepten-2-one	987	Kt1	989	nd	nd	1.34E-05 ± 8.79E-07	7.02E-05 ± 2.39E-05	9.24E-05 ± 2.70E-05	Sweet/ floral [g]
1,4-Dimethyl-3-cyclohexenyl methyl ketone	1217	Kt2	-	nd	3.22E-06 ± 1.21E-07	1.01E-05 ± 6.44E-06	9.49E-06 ± 1.377E-06	9.66E-06 ± 1.98E-06	Green [g]
Aldehyde									
Benzaldehyde	961	Ad1	961[e]	nd	nd	6.36E-05 ± 1.08E-05	0.00014 ± 1.77E-05	0.00014 ± 3.67E-05	Sweet, floral [c]
Nonanal	1104	Ad2	112[d]	nd	nd	nd	0.00011 ± 2.90E-06	0.00011 ± 4.20E-05	Green [c]
Benzenacetal-dehyde	1040	Ad3	1043[e]	nd	nd	nd	1.54E-05 ± 3.24E-06	1.61E-05 ± 3.44E-06	Green [g]
Decanal	1205	Ad4	1207[e]	nd	2.32E-05 ± 3.44E-06	1.89E-05 ± 4.63E-06	2.84E-05 ± 1.01E-06	2.87E-05 ± 6.44E-06	Floral [g]
(E)-2-Pentenal	1158	Ad5	-	nd	nd	nd	3.14E-06 ± 4.93E-07	2.90E-06 ± 4.255E-07	Green [g]

Compound Name	Experimental LRI	Code	Literature LRI	Relative compound area (µg/g)					Aroma Description
				Katuk leaves					
				Fresh	Boiled		Steamed		
					3 minutes	5 minutes	3 minutes	5 minutes	
Benzene									
Napthalene	1177	Bz	1182[a]	8.75E-05 ± 2.88E-06	6.56E-05 ± 2.28E-05	9.76E-05 ± 3.22E-05	5.26E-05 ± 4.55E-06	3.72E-05 ± 9.69E-06	Grass [f]
Terpenoid									
trans-β-Ocimen	1049	Top	1051[d]	nd	nd	nd	9.44E-06 ± 2.16E-06	1.34E-05 ± 1.60E-06	earthy, herb, floral [f]
Ester									
Cis-3-Hexenyl valerat	1233	Es	-	nd	nd	nd	nd	2.63E-05 ± 2.01E-07	Green, fruity [g]
Other Components									
(Z)-4-Methyl-2-hexene	-	Kl1	-	6.81E-06 ± 7.78E-07	nd	nd	8.30E-05 ± 2.81E-05	7.67E-05 ± 1.14E-05	-
2-Pentenal, 2-methyl	831	Kl2	832[e]	2.62E-06 ± 2.34E-07	8.13E-05 ± 3.44E-06	0.00022 ± 2.62E-05	0.00019 ± 2.63E-05	0.00019 ± 3.62E-05	-
2- Ethylhexyl maleate	-	Kl3	-	nd	1.82E-05 ± 3.62E-06	2.95E-05 ± 7.09E-06	1.71E-05 ± 1.91E-06	1.46E-05 ± 2.3E-06	-

Description:
- Presentation of data on the relative amount of compounds from the calculation of the average relative area of compounds with 3 replicates ± standard deviation; nd = not detected
- Literature LRI obtained from references analyzed using DB-5MS
- Description of aroma references from journals and flavor websites

  Description:
  a. Flamini et al. (2003)
  b. Goodner (2007)
  c. Dionísio et al. (2012)
  d. Pino (2003)
  e. Bos et al. (2002)
  f. Flavornet (2022)
  g. The Good Scents Company (2022)



Description: F: (fresh); S3: (steam; steamed 3 minutes); (S5: steam; steamed 5 minutes); B3: (boiling; boiled 3 minutes); B5: (boiling; boiled 5 minutes)

Figure 3. Biplot of the sensory profile of Katuk leaves

Sensory Profile of Katuk Leaves

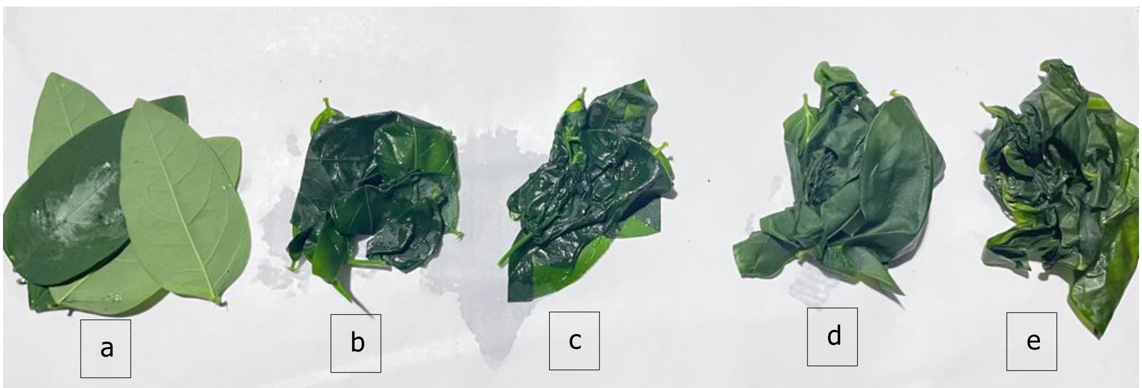
Based on the analysis using the FCP method, a total of 9 sensory attributes were frequently mentioned by the panelists, including appearance (moist), surface texture (smooth), texture in the mouth (tender and juicy), aroma (grassy and earthy), and flavor (tasteless and grassy). The results of the analysis using Generalized Procruster Analysis (Figure 3) could be seen as the dominating attributes of each sample of Katuk leaves.

Based on biplot analysis, the brightness attribute did not dominate Katuk leaves. This was because panelists considered Katuk leaves not to have high color brightness in both fresh, boiled (3 and 5 minutes), and steamed (3 and 5 minutes) samples. In the biplot in the upper right quadrant, samples B5 and B3 also showed that the dominating attributes were smooth and juicy. In addition, this was likely because the boiling process could cause Katuk leaves to be smoother and juicier compared to fresh or steamed samples. In other biplots for S3 and S5, the dominant attributes included tender, moist, and tasteless. For steamed Katuk leaves, the samples were exposed to water vapor, giving the impression of moist, tasteless, and tender. Meanwhile, in fresh Katuk leaves (F) the dominant attributes were earthy, aroma (grassy), and flavor (grassy).

The study conducted by Borowski et al. (2015) carried out sensory analysis (color intensity, aroma, bitter flavor, and hardness) on Broccoli. The results showed that the intensity of the bitter flavor of broccoli could be removed by evaporation. Values of 8.6 and 8.1 were the best color intensity in broccoli with hot steam combo heating (125 °C) using 90% air saturation for 8 minutes and 100 °C boiling for 7 minutes, respectively. Meanwhile, heating with a convection steam oven at 90 °C for 30 minutes resulted in the lowest color intensity. The highest aroma intensity was obtained with 125 °C convection steam oven heating for 12 minutes, while the lowest aroma intensity was obtained with hot steam combination heating.

Heating Process

Based on visual observation, fresh, boiled (3 and 5 minutes), and steamed (3 and 5 minutes) Katuk leaves were seen from the color comparison, with the results showing the presence of significant differences (Figure 4). Fresh Katuk leaves were dark green, while boiled and steamed variants (3 and 5 minutes) were yellowish green. Chlorophyll was a green pigment responsible for giving plants their green color and could undergo



Description: a). fresh; b). boiled 3 minutes; c). boiled 5 minutes; d). steamed for 3 minutes; e). steamed 5 minutes

Figure 4. Fresh, boiled, and steamed Katuk leaves

chemical changes comprising color changes. Heating treatment could lead to the formation of feofitin because the magnesium in chlorophyll was easily replaced with 2 hydrogen atoms (Paciulli et al., 2018; Putriani et al., 2020). In processed foods, chlorophyll loss often caused a color shift from bright green to pale green. Factors, such as pH, temperature, the presence of salt, and surface-active ions had been reported to affect the stability of chlorophyll (Paciulli et al., 2018).

The purpose of heating in food processing was to kill pathogenic bacteria contained in food ingredients, making it safe for consumption. However, heating with high temperatures led to the evaporation of volatile compounds and caused hydrolysis and oxidation reactions (Marsiany et al., 2020). This caused damage to the components of the food ingredients and a decrease in the nutritional value.

In this report, there were changes in the volatile profile and sensory components in Katuk leaves after boiling and steaming processes. However, there were limitations in this study, such as quantitative color measurements, functional properties of Katuk leaves after boiling and steaming processes, and detailed mechanisms for the formation of new components due to boiling or steaming processes. This was the basis for the need for further reports to obtain more comprehensive data. The data obtained was expected to be used as basic information in developing functional products from Katuk leaves either on a household or industrial scale.

CONCLUSION

In conclusion, the sensory attributes most described by panelists using the FCP method included appearance (moist), surface texture (smooth), texture in the mouth (tender and juicy), aroma (grassy, earthy), and flavor (tasteless, grassy). Based on the PCA results, fresh Katuk leaves gave a strong grassy and earthy aroma with a grassy flavor, while boiled Katuk leaves were associated with a smooth and juicy texture. In steamed samples, the dominant attributes were moist and tender as well as tasteless flavor. A total of 4, 5, 7, 14, and 15 compounds were identified from fresh, 3 minutes boiling, 5 minutes boiling, 3 minutes steaming, and 5 minutes steaming samples. The volatile compounds were grouped into various categories, including aldehyde (5 compounds), alcohol (3 compounds), other components (3 compounds), ketone (2 compounds), benzene, terpenoids, and esters (1 compound). Alcohol ((Z)-3-hexene-1-ol) volatile compounds were identified in fresh Katuk leaves. In steamed samples, aldehyde (benzaldehyde, nonanal, benzenacetaldehyde, (E)-2-pentenal) and alcohol groups (1-heptanol, nerolidol) were obtained, while boiled leaves comprised benzene (naphthalene). Some volatile compounds were contained in fresh Katuk leaves or newly formed, such as the ketone, aldehyde, terpenoid, and ester groups. In addition, the results showed that the heating process could change the composition of volatile compounds, and the majority of new volatile compounds were formed after the heating process.

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CONFLICT OF INTEREST

The authors declared no conflict of interest in this report.

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