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Sensory Evaluation of the Quality of Kaffir Lime (*Citrus hystrix* DC.) Leaves Exposed to Different Postharvest Treatments

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Abstract

This study aimed to evaluate the sensory attributes such as aroma, color and texture of kaffir lime leaves in response to various postharvest treatment. The hedonic test approach was conducted by inviting 70 untrained panelists on seven postharvest treatments, i.e. (D1) post-sortation fresh leaves, (D2) pre-sortation fresh leaves, (D3) cold-storage leaves, (D4) low temperature-storage leaves, (D5) brown dry leaves, (D6) fresh leaf-flour, and (D7) brown dry leaf-flour. The result showed that most of panelist agreed that aroma was the most important quality attribute that determined the level of preference in kaffir lime leaf products. Among seven tested products, the aroma, color, texture and overall impression of D1 was the most favorite one, while D4, D5, and D7 were assessed as low preference products. This work showed the importance of sortation and cold storage to maintain consumer likeliness. The criteria for sortation were green, clean, pest-disease free, scar free, high uniformity and fresh condition of leaves. Cold-storage at -20°C maintained the color and texture of kaffir lime leaves better than low temperature storage (5°C). To make leaf flour, the use of fresh green leaves was significantly better than brown dry ones. This finding might become the baseline data for the development of kaffir lime leaf product in the future.

Keywords: aroma, leaf flour, hedonic test, sortation, untrained panelists.

Introduction

The leaves of kaffir lime (*Citrus hytrix DC.*) tree is considered economically important due to many used bring about by the naturally pleasant fragrance (Budiarto et al., 2019a). The leaves display unique morphological characteristics, i.e., bifoliate leaflets with dark green shiny in adaxial and pale green in abaxial (Budiarto et al., 2021a; 2021b). The leaves can be used as spice and raw material for essential oil (Sato, 1990). In Indonesia, the use of kaffir lime leaves as spice is more popular than as raw material for essential oil (Budiarto et al., 2019a). Spices from kaffir lime leaves can be found in numerous Indonesian and other Asian dishes such as beef soup of *rawon*, coconut milk-beef soup of *soto*, coconut milk-beef dish of *rendang*, curry, fried *tempe*, *laksa* and *tom yum* (Setiyoningrum et al., 2018). In recent years, the high demand for spice is associated with a rapid promotion of exotic and traditional food ingredients by the food industry to support the modern healthy lifestyle (UNIDO and FAO 2005). Thus, it is important that production and quality of kaffir lime leaves should be well monitored. Previous study has reported the success of mild shading to boost production through harvesting more and larger leaves being harvested (Budiarto et al., 2019b).

Proper postharvest handling of kaffir lime leaves in farms is important in order to maintain quality and to reduce losses. Improper handling during post-harvest period has been seen in previous practices and usually results in reduced yields (Irtwange, 2006). In general, the yield loss in the citrus fruit industry as a result of careless post-harvest handling can reach 25% (Asni, 2015). To reduce the yield loss, sortation (Yildiz, 1994) and proper cold storage is promising, especially for aromatic horticultural commodity with its perishable characteristic (Magray et al., 2017; Tananuwong and Lertsiri, 2010). Currently, the only post-harvest handling being practiced locally involves leaf stripping (*mitil*) and packing in plastic woven sacks (Budiarto et al., 2019b). Additional postharvest treatment such as sortation and appropriate storage handling should be formulated to help the quality assurance of products.

In the kaffir lime leaf spice industry, quality is not fully defined and elaborated yet. In the citrus fruit commodities industry, however, the quality is well characterized by attributes such as fruit size, weight, color, shape, texture and contamination level (Sutopo, 2011). The Indonesian government has issued a quality guideline for mandarin citrus fruit in SNI 3165-2009 (Balitjestro, 2021). As preliminary study, the quality of product can be assessed simply based on consumer acceptance and preference. Sensory evaluation can be used to determine the quality of product before chemical testing is carried out (Putri et al., 2020). Sensory evaluation by using hedonic scale test is a technique used to analyze the level of consumer preference for a product (Lyon et al., 1999). Sensory-hedonic test is commonly reported in citrus fruit preference studies (Morales et al., 2020; Reis et al., 2017; Sawamura et al., 2004). However, there is still limited similar study specifically for kaffir lime leaf spices. The aim of this study was to evaluate the sensory attributes, such as aroma, color and texture of kaffir lime leaves in response to various postharvest by using hedonic test approach.

Material and Methods

Sampling

The work was carried out in March 2019 at Postharvest Laboratory, Agriculture Development Polytechnic of Bogor, Indonesia. Fully developed leaves of kaffir lime were harvested from Pasir Kuda experimental farm of IPB University, Indonesia (-6.609042, 106.783605 and 263 meters above sea level). Seven postharvest treatments were set up namely (D1) post-sortation fresh leaves, (D2) pre-sortation fresh leaves, (D3) cold-storage leaves, (D4) low temperature-storage leaves, (D5) brown dry leaves, (D6) fresh leaf-flour, and (D7) brown dry leaf-flour (Figure 1). Approximately 500 grams of leaves and or leaf flour was prepared in every treatment. Only green, clean, pest disease-free, scar-free, with high uniformity and fresh condition of leaves were selected for D1. The sortation and the hedonic test were done during the harvesting day. Pre-sortation leaves for D2 were composed of fresh leaves with low uniformity, including green normal leaves, those with gall, leaves with yellow/brown spots, and pest disease-damaged leaves. Pre-sortation leaves was prepared at the same day with hedonic test. To prepare cold-storage leaves for D3, fresh green leaves were harvested from the field at 10 days before the day of hedonic test. The leaves were stored in freezer at -20^{o}C for 10 days. Low temperature-storage leaves for D4 were harvested at the same day as the cold-storage leaves. These D4 leaves were stored at 5^{0}C for 10 days. Brown dry leaves for D5 were picked 10 days prior to test, and then stored in open air condition at 25-31^{0}C for 10 days. Both fresh leaf-flour and brown dry leaf-flour for D6 and D7, respectively, were prepared one day before the test, by using milling machine with 1 mm sieve size.

Data Collection

The hedonic test method following protocols documented by Meilgaard et al., (2007) and Setyaningsih et al. (2010) was used to test the post-harvest quality of kaffir lime leaves through 70 randomly chosen untrained panelists composed

Figure 1. Seven post-harvest treatments tested on kaffir lime leaves, i.e. (D1) post-sortation fresh leaves, (D2) pre-sortation fresh leaves, (D3) cold-storage leaves, (D4) low temperature-storage leaves,

of 17-29 years old students. Untrained panelists is defined as people who have no formal sensory training experience, but are still able to differentiate and show any preferences to the product being tested (Hersleth et al., 2005). The number of untrained panelists invited in certain hedonic experiment could vary from 25 to 100 people (Ayustaningwarno, 2014). Previous study by Mareta (2019) and Putri et al. (2020) did hedonic test with 35 and 20 untrained panelists, respectively. In the current study, among the 70 panelists, there were 47 males and 23 females. The use of untrained panelists was favoured due to the lack of sufficient trained panelists.

All seven kaffir lime leaf products were labelled prior to testing and were presented at the same time to the panelists. All invited panelists were asked to assess the aroma, color, texture and overall impression of product based on five hedonic scoring scales, similar to previous studies (Mareta et al., 2019, Basyuni et al., 2019; Jariyah et al., 2018; Baba et al., 2015), from highly like to highly dislike (1 for highly dislike, 3 for dislike, 5 for neutral, 7 for like and 9 for highly like). After the test, panelists were also asked to answer briefly three questions regarding (i) how often they used kaffir lime leaf product; (ii) which quality attributes are important when assessing kaffir lime leaf products, and (iii) which kaffir lime leaf product was their favorite. Drinking water was provided to serve as neutralizing agent every time the panelists finished testing one product.

The data from the hedonic test results were tabulated for analysis of variance (ANOVA) using Statistical Analysis Software (SAS) version 9.4. When significant difference in values were detected, Tukey test using 95% confidence level was conducted.

Result and Discussion

Profile of Panellists

Among the panelists, only 8% had never known and used kaffir lime leaves, while approximately 92% of them had experienced using kaffir lime leaves. Of the 92%, 43% are monthly users, 41% are weekly users and 4% are daily users (Figure 2). The variation of gender and experience of the panelists was thought to increase the representation and accuracy of the results.

Attributes for Hedonic Test

The results of the hedonic test could be considered as the baseline data for product development in the future (Ayustaningwarno, 2014). The rate of likes or dislikes given by a panelist for the tested product is a good indicator consumer preference (Kotler and Armstrong, 2001). In-depth understanding of consumer preferences greatly influences consumer decisions in choosing and buying a product. The results of the consumer preference test could be used to determine the order of the product attributes in determining product quality (Simamora, 2003). In this study, four attributes, namely aroma, color, texture and overall impression, were used to assess the quality of kaffir lime leaves postharvest.

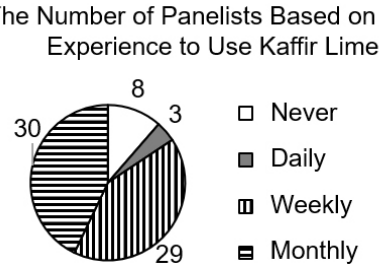

Figure 2. The number of panellists based on their experience to use kaffir lime leaf product

Aroma is defined as the response of human sensory to volatile compounds from sample that enters the nasal cavity and sensed by the human olfactory system (Kemp et al., 2009). Volatile compounds could be easily reached the olfactory system at the upper part of the nose and then interacted with one or more olfactory receptors in the nasal organs (Tarwendah, 2017). As a species of *Citrus*, kaffir lime is known to be rich in essential oil throughout the plant body, especially in the leaves (Budiarto et al., 2019a; Othman et al., 2016). In this study, based on aroma, D1 or post-sortation fresh leaves is the most preferred kaffir lime leaf product (Figure 3A). The second preferred product was the D6 or fresh leaf-flour and D2 or pre-sortation fresh leaves. The aroma of the cold-storage leaves (D3) was relatively neutral and it was not significantly different from the D2 product. In contrast, panelists showed dislike to the aroma of kaffir lime leaves stored in low temperatures (D4), brown dry leaves (D5) and brown dry leaf-flour (D7).

Approximately 52 panelists believed that aroma was the most important attribute among five attributes in kaffir lime leaf product (Figure 4A). Better understanding of aroma in herb and spice commodity was important since this attribute highly determines consumer acceptability and palatability (Tananuwong and Lertsiri, 2010). Among other *Citrus* species, the aroma of kaffir lime leaf is distinct and strong, so that it can be used either for spices or essential oil. The major portion of L-citronellal is reported to be key factor for production of specific aroma of kaffir lime

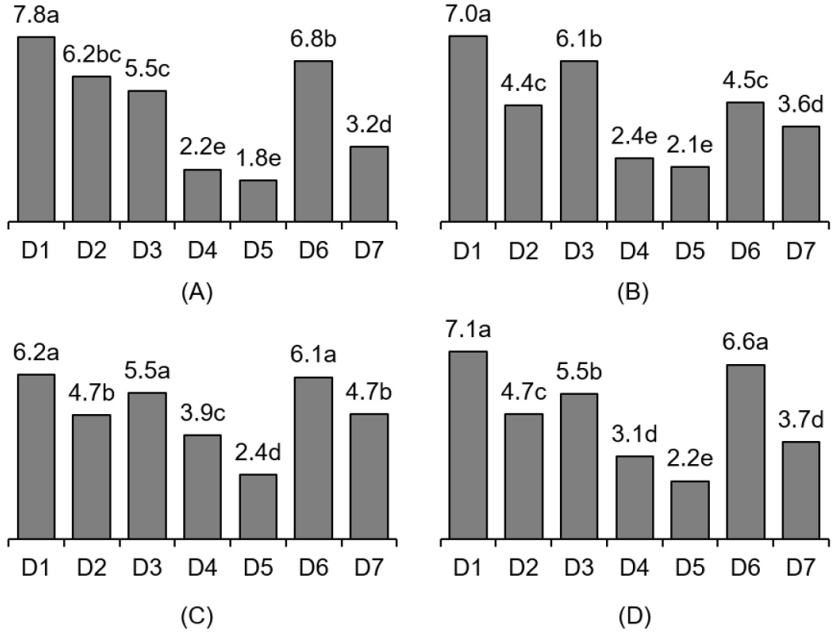

Figure 3. The result of hedonic test on aroma, color, texture and overall impression of seven postharvest treated kaffir lime leaves, i.e (D1) post-sortation fresh leaves, (D2) pre-sortation fresh leaves, (D3) cold-storage leaves, (D4) low temperature-storage leaves, (D5) brown dry leaves, (D6) fresh leaf-flour, (D7) brown dry leaf-flour.

leaves that seemed like the combination of citrus and lemongrass aroma (Sato, 1990). Other important metabolites determining as main composition of kaffir lime leaves essential oil were citronellol (Efendi et al., 2021), linalool (Gonzalez-Mas et al., 2019), and caryophyllene (Gonzalez-Mas et al., 2019; Riyadi, 2012). Previous study reported that pre harvest factor, including agroclimatic variables, soil and leaves nutrient status could affected the yield and main composition of kaffir lime leaves essential oil (Efendi et al., 2021). The yield of essential oil could be obtained from steam distillation, with a yield ranged from 0.5-0.6% (Budiarto et al., 2019).

Our results show that there is lower preference for products of kaffir lime leaves that have undergone post-harvest treatment, such as storage, drying, and flour milling process. Milling process using fresh green leaves was better than brown dry leaves in maintaining desirable aroma as manifested in the reduced preference of panelists by 12.8% and 58.9%, respectively. To support the production of leaf flour that had been initiated in production area (Budiarto et al., 2019a), it was seen in this study that there is a higher potential to develop when using fresh green leaves, instead of brown dry leaves.

At 10 days after harvesting, better storage performance was noticed at regime -20^{0}C than at 5^{0}C, as indicated by the higher desirable aroma. However, the preference for aroma from cold storage leaves was still lower than fresh leaves. This is a common result supported by earlier study showing that likeliness and freshness were reported to decline due to storage effects (Obenland et al., 2008). The least preferred aroma was observed in brown dry leaves that were obtained from open air drying for about 10 days after treatment. This finding could be attributed to the loss of volatile oil and the change of metabolite profile in remained oil. Setiyoningrum et al., (2018) reported the significant reduction of essential oil yield of kaffir lime, for almost 50%, due to drying. As the leaves are exposed to heat and subsequently dry out, there is a breakage on trichomes and other leaf tissues resulting in the loss of essential oil into the air (Diaz-Maroto et al., 2002; 2003).

Color was chosen by 19 panelists as the most important attribute for kaffir lime leaves (Figure 4A). In terms of color, panelists determined the D1 product as the most preferred product, due to its evenly green look (Figure 1), followed by D3, indicating the success of frozen treatment to maintain appearance quality of kaffir lime (Figure 3B). These findings agree with earlier study by Wingler and Roitsch (2008) that show the importance of cold treatment to delay senescence or further deterioration. Although the pre-sortation leaves (D2) were green in color, panelists could have been put off by the presence of yellow/brown spots as a result of pest attack on certain leaf parts. The leaves which were stored at low temperature (D4) were not favored by the panelists because they had a brownish yellow color which was thought as indicator of leaf deterioration. Green fresh leaf-flour (D6) was

more preferable than brown leaf-flour (D7), as proved by the higher color preference. The brown dry leaves (D5) product was determined as the least preferred one in term of color.

Post-harvest treatment such as milling and drying results in coloration that was least preferred by panelists (Figure 3B). In post-milling condition, the leaves were getting softer and less green compared to the fresh ones (Setiyoningrum et al., 2018; Arslan et al., 2010; Buchaillot et al., 2009). The lowering of green color intensity was also noticed in post-drying condition rather than in fresh condition (Naidu et al., 2016). Moreover, earlier studies also noted the increasing yellow intensity after milling and drying treatments (McGuire, 1992). The decline of green intensity followed by the increase of yellow intensity is attributed to the breakdown of chlorophyll molecules in leaves that are sensitive to the heat (Buchaillot et al., 2009). This phenomenon is obviously observed with greater heat exposure duration and regime of heat treatment (Schwartz and Lorenzo, 1991). It was likely that heat exposure stimulates the transformation of chlorophyll into pheophytin that is identical with brown color (Singh and Sagar, 2010; Rudra et al., 2008).

Texture was the third preferred attribute of kaffir lime leaf products (Figure 4A). Statistical analysis showed that the most preferred texture was the D1, however this result was not significantly different than the fresh leaf-flour (D6) and the cold-storage leaf (D3) (Figure 3C). This finding proved the success of cold storage to maintain texture of leaves. The pre-sortation leaves (D2) had lower texture preference because of the presence of pest and disease damaged causing the uneven leaf surface. The least preferred texture was from the brown dry leaf product (D5) because of coarseness due to loss of water during the drying process (Figure 4A).

The least preferred attribute of kaffir lime leaf was overall impression, that is a combination of aroma, color and texture. The order of panelists preference level based on the overall impression was post-sortation fresh leaves (D1) ≥ fresh leaf-flour (D6) > cold-storage leaves (D3) > pre-sortation fresh leaves (D2) > brown dry-leaf flour (D7) ≥ low temperature-storage leaves (D4) > brown dry leaves (D5) (Figure 3D). The only products that received a very high preference were the D1 and the D6. There was neutral impression for the D2 and D3. D4 and D7 product were not preferred, while D5 was the least preferred among all products.

The fresh leaves from the D1 set-up was the highly preferred kaffir lime leaf product by most of the panelists indicating the success of sortation process during post-harvest period. However, this postharvest treatment is rarely implemented yet by the local farmers (Budiarto et al., 2019a). The importance of sortation to eliminate undesired product in horticulture commodity is frequently emphasized in earlier studies (Yossi et al., 2017; Kader 2013; Alipour et al., 2013). Undesired products usually show malformation, over ripening, pest-pathogen attacks and rotten condition (Magray et al., 2017).

None of the panelists preferred kaffir lime stored at low temperature (D4), brown dry leaves (D5), and brown dry leaf-flour (D7) as their favorite products. It was likely that these products had declined in quality due to senescence, so that it was no longer suitable for consumer. Leaf senescence is a natural phase of final leaf development that involves a series of biochemical and physiological process, mostly in the form of macro-molecule degradation, organelles breakdown, nutrient reallocation and eventually cell death (Guo, 2013; Lim and Nam, 2007; Guo and Gan, 2005). Both abiotic and biotic stress could trigger the occurrence of leaf senescence (Wingler and Roitsch, 2008). Improper post-harvest treatment allows leaves to exposed to abiotic and biotic stress leading to the occurrence of severe senescence.

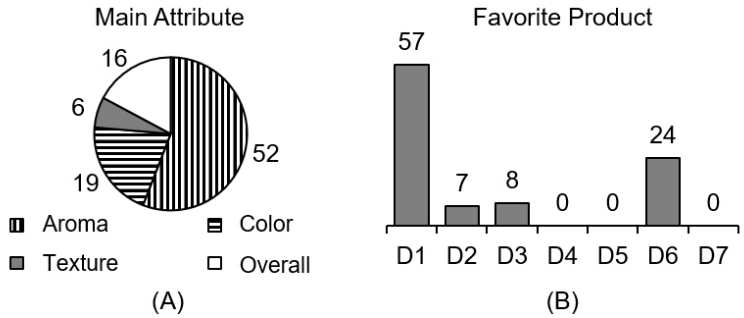

Figure 4. The main attribute (A) among aroma, texture, color and overall impression; and the favourite product (B) among seven postharvest treated kaffir lime leaves, i.e. (D1) post-sortation fresh leaves, (D2) pre-sortation fresh leaves, (D3) cold-storage leaves, (D4) low temperature-storage leaves, (D5) brown dry leaves, (D6) fresh leaf-flour, and (D7) brown dry leaf-flour.

So far, no similar studies have been conducted to assess leaf quality of kaffir lime, especially in response to different post-harvest handling, leading to the lack definition of quality in kaffir lime leaf as leaf spices. Previous studies on kaffir lime highlighted the leaf morphological (Budiarto et al., 2021a), leaf allometric modelling (Budiarto et al., 2021b), leaf production improvement by shading and pruning (Budiarto et al., 2019b), leaf essential oil quality (Efendi et al., 2021), and current status of production, post-harvest and marketing of leaf in kaffir lime production center area (Budiarto et al., 2019a). This finding might fill the research gap and become the baseline data for the development of kaffir lime leaf product in the future.

Conclusion

In the hedonic test conducted to assess the quality of post-harvest kaffir lime leaves, majority of 70 untrained panelists agreed that aroma is the most important attribute that determines their level of preference in kaffir lime leaf products. Among the seven kaffir lime leaf products tested, the post-sortation fresh leaves was the most favorite one, while low temperature-storage leaves, brown dry leaves, and brown dry leaf-flour were assessed as low preference products. In term of product diversification, kaffir lime leaf powder could be made from green leaves, instead of brown dry leaves. This hedonic assay emphasized the importance of sortation and cold storage to prolong the quality of kaffir limes leaves. The criteria for sortation were a green, clean, pest-disease free, scar free, high uniformity and fresh condition of leaves. Cold-storage at -20^{o}C maintained the color and texture of kaffir lime leaves better than low temperature storage (5^{o}C). Further study related to the alteration of essential oil content and composition in response to post-harvest treatment was prerequisite to have better understanding in maintaining the quality of kaffir lime leaves.

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