Quality Changes and Volatile Compounds in Fresh-Cut 'Phulae' Pineapple during Cold Storage

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Abstract

The effect of cold storage temperature on quality changes and volatile compounds in fresh-cut 'Phulae' pineapple was determined. Samples were cut and dipped in 2% NaCl solution for 1 min, packed inpolypropylene bag and stored at 5, 10 and 15°C ± 1°C. Physico-chemical characteristics, microbiological quality and volatile compounds using headspace gas chromatography-mass spectrometry (GCMS-HS) were evaluated every 2 days until 2 weeks of storage. The lighter flesh color, the bright visual good appearance retained at all storage temperatures. Ascorbic acid content was in the excellent source for all temperatures (30 - 19 mg/100g fresh weight). More than 30 volatile compounds were identified. The predominant compounds were ethyl acetate, acetic acid, ethyl butanoic acid, hexanoic acid, octanoic acid, dodecanal, nonanol, butanol, butanoic acid ethyl ester (methyl ester), butanoic acid 2-methyl-, ethyl ester (methyl ester) and so on. The increasing of storage temperature also increased two times of the ethyl acetate and acetic acid productions. A relationship between microorganisms and carbon dioxide productions were observed. The ethyl acetate and acetic acid amounts in fresh-cut sample were found in increasing numbers as increased yeast and mold counts at all storage temperatures. Total plate count was in safety range (2-5 log CFU/g) along 14 days at 5±1°C according to the Regulation of Department of Medical Sciences. The results obtained from this experiment could be used for the development of spoilage indicator that can be applied for fresh-cut 'Phulae' pineapple in order to maintain the quality and safety products for consumers.

Keywords: carbon dioxide, GCMS-HS, 'Phulae' pineapple, quality changes, volatile compounds

1. Introduction

'Phulae' pineapple (*Ananas comosus* (L.) Merr.) is famous as a precious fruit because it can grow only in Nang Lae, Ban Du and Thasud District and was registered as a Geographical Indication (GI) of Chiang Rai Province, Thailand. 'Phulae' pineapple belongs to a variety of Queen with a small size ranged from 150 to 1,000 g per fruit with unique taste and a core of 'Phulae' is edible and crispy. Its preference texture, taste, aroma and color are very attractive to consumers and became one of famous fruits in Thailand. However, due to a small size and deep fruitlet, peeling and cutting 'Phulae' pineapple is not easy therefore the consumers prefer to buy the ready-to-eat product and the price can be increased up to 180-200 Baht per kg (15-35 Baht per kg fresh fruit).

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Fresh-cut processing may increase the respiration rate, biochemical changes and microbial spoilages of pineapple. Fermentation occurred during storage also affects organoleptic quality especially odor of fresh-cut product. Deterioration of fresh-cut fruits is due to the fermentation of sugar, water soaking, enzymatic condition and discoloration and they can enhance the off-aroma and off-flavor formation. Moreover, deterioration and odor can also be related to microorganisms, carbon dioxide and storage conditions. Many researchers reported about the relation between microbial growth and storage temperature. O'Connor-Shaw *et al.* [1], observed the growth of molds in fresh-cut pineapple after 14 days storage at 4°C but only 4 days when increased the storage temperature to 20°C. Acetic acid, ethanol and CO_2 may be detected in a case of fermentation by yeast and mold. Shelf life of fresh-cut product is mostly affected by the temperature condition. Changes in odor and the presence of microorganism above safety level are the main problems of fresh-cut 'Phulae' pineapple. These will occur without any changes in the appearance so consumers perceive the fermented smell just only after they open the package. Therefore the relationship among quality parameters and safety of fresh-cut 'Phulae' pineapple has become interesting.

Volatile organic compound or volatile compound (VoC) is the indicator of fruit and vegetable aroma during ripening and has provided as flavor and taste of fruits and vegetables even in small amount but it can be detected by human olfaction [2]. The aroma and flavor of complex VoC profiles are varied depending on the cultivar, ripeness, pre-and post-harvest environmental conditions, fruit sample (either intact fruit, slices, or homogenized samples), and analytical methods utilized [3]. VoC is caused by tissue disruption from the intact fruit tissue, can be classified as primary or secondary compounds then aroma compound is released from these cell disruption and enzymes interaction. Aroma components of the flavor of tropical fruits and some varieties of pineapple are mainly identified by headspace method of gas chromatography-mass spectroscopy (GCMS-HS). They are very effective method due to simple and quick without using the carrier solvents. Some researcher found that nearly 380 volatile constituents had been identified in pineapple flavor that are alcohols, aldehydes, esters, ketones, lactones, terpenes and terpenoids, hydrocarbons, lactones, and others in 2005 [4, 5]. Although 'Phulae' pineapple has the unique flavor, aroma and odor, it might be related in the deterioration between microorganism and volatile compounds production and also affected the shelf-life of fresh-cut fruit. Moreover, the physico-chemical characteristics of 'Phulae' pineapple are rarely studied in other research especially in volatile compound. Therefore, the main objective of this study was to investigate and identify of aroma and volatile compound characteristics of 'Phulae' pineapple using GCMS-HS method. Then they were compared with carbon dioxide, microbial growth and physico-chemical properties of fresh-cut 'Phulae' pineapple.

2. Materials and Methods

2.1 Raw materials

'Phulae' pineapples were purchased from the field as peeled fruit and fruitlets were removed before immediately transported to the Postharvest Technology Laboratory, Mae Fah Luang University. The pineapple was selected as one yellow and third green portions to be processing and 5 months cultivated period fruits.

2.1.1 Sample Preparation

'Phulae' pineapple was vertically cut into 4 pieces and soaked in 2% sodium chloride (NaCl) solution for 1 min. The excess water was removed, then packed in a polyethylene bag (200-220 g) and stored at 5 ± 1, 10 ± 1 or 15 ± 1°C.

2.2 Determination of Physical Quality

Weight loss was measured by using a scale balance (± 0.01 g), model PB1502-S (Mettler-Toledo, Menlo Park, CA, USA) in every 2 days for each storage temperature. The results were expressed as percentage loss of initial weight. Juice leakage was measured according to Montero-Calderon *et al.* [6] with some modification by tilting the packages at a 20° angle for 5 min and recovering accumulated liquid with a 5-mL syringe. Results were reported as liquid volume recovered of fresh-cut fruit in the package. The firmness of the pineapples' flesh was determined using a stable micro-systems TA-TXT2i texture analyzer (Stable Micro Systems Ltd., UK). The maximum force (N) was recorded for each sample [7]. The L*, a* and b* values of each side of samples were measured by using Ultra Scan PRO Spectrophotometer, according to Hunter Lab.

2.3 Determination of Chemical Quality

The pH value of fresh-cut pineapple was determined using a digital pH meter (Eutech, pH 510) at room temperature. Titratable acidity was measured using 5 mL of juice titrated with a standardized 0.1 N sodium hydroxide (NaOH) up to pH 8.2, expressed as a percentage of citric acid (g citric acid/100 g fresh weight). The TSS content (°Brix) was determined using a digital refractometer (Pocket PR-101, ATAGO Company, Japan) [7].

2.4 Determination of Vitamin C Content

Vitamin C (ascorbic acid) was analyzed by dichlorophenol/indophenol titrimetric following the AOAC method 967.21. The titration volume was recorded and used to quantify vitamin C content of the sample. Results were expressed as mg/100 g sample. The indophenol solution was standardized by titrating an ascorbic acid standard solution at the concentration of 1 mg/mL.

2.5 Determination of Microbiological Quality

Total plate count (TPC) and the amount of yeast and mold were analyzed using Petri film and expressed in log CFU/g. These plates were incubated at 35°C for 48 h (TPC, AOAC method 990.12) and 25 °C for 3-5 days (yeast and mold, AOAC method 997.02). The analysis was done in 0, 4, 7, 9, 11 and 14 days after storage at different temperatures.

2.6 Determination of Gas Composition in Package

The gas content in all packages was determined using Dansensor Checkamate 3 Headspace Gas Analyzer in every 2 days. The carbon dioxide (CO_2) and oxygen (O_2) were recorded in three replications.

2.7 Determination of Volatile Compounds

The fresh 'Phulae' pineapple was cut into small pieces and added to vial bottle. After that, this bottle was subjected to GCMS-HS, the operation ran automatically (TriPlus 300 Headspace Autosampler). Headspace gas was drawn using a 1 mL syringe (oven temperature 65°C) and injected into a TRACE GC gas chromatograph. Headspace autosampler is chemically inert and all the heated zones can be set between 30°C and 300°C for the widest applicability. A retention time and a standard curve of ethyl acetate and acetic acid in 'Phulae' pineapple solution were both used for peak identification and quantification.

2.8 Sensory Evaluation

Thirty panelists were employed to evaluate the acceptance score of fresh-cut 'Phulae' pineapple stored at 5±1, 10±1 and 15±1°C. The attributes of color, texture, odor and overall acceptability were scored using 7 hedonic scales (7= like very much, 1= dislike very much).

2.9 Statistical analysis

All experiment was conducted by triplicate determination and data were subjected to analysis of variance, Duncan's multiple range test using SPSS program (version 16) at $P<0.05$.

3. Results and Discussion

3.1 Physical and Chemical Qualities of Fresh-cut 'Phulae' Pineapple during Storage

Quality in terms of physical and chemical of fresh-cut 'Phulae' pineapple stored at 5±1, 10±1 and 15±1°C were determined during 14, 11 and 7 days of storage, respectively. The rate of weight loss (1-5%) and juice leakage (0-10mL) increased dramatically along the storage time but it was not significantly different among storage temperature at the day of determination (data not shown). The environmental conditions including storage temperature conduct the important role in terms of water loss in the fruit [7]. Bartholomew *et al.* [8] reported that pineapple stored at 9°C was higher inpercentage of weight loss than 12°C due to the chilling injury which can affect in browning, dulling, discoloration, drying and wilting in fruits. Firmness of all samples slightly decreased (23.4±2.32 N to 18.13±2.02 N) during storage time (data not shown). This might be related to carbohydrates are modified during ripening period and then their insoluble pectin changed into soluble pectin due to respiration condition [9].

The respiration rate and the amount of total pectic substance depend on the water status in the fruit and vegetable. Some stress may lead to increasing of respiration where monosaccharides attached to pectin molecules might serve as additional substrate for respiration, resulted in the breakdown of insoluble to soluble pectic substances. Thus, degradation can modify the softer cell wall deterioration and decrease in firmness of the fruit [10]. In addition, firmness of fruit and vegetable also related to the turgor pressure and cell membrane modification. These affected to the cell rigidity by the accumulation of osmotic solute in the cell wall space as well as water losing from the tissue during ripening of fruit and processing. The critical quality attribute of consumer acceptability concerned the firmness and total soluble solid content of fruits. Quyen *et al.* [7] reported that the reduction of firmness due to chilling injury was observed in Queen pineapple stored at low temperature. However, the chilling injury was not found in fresh-cut 'Phulae' pineapple until the end of storage time.

The L* parameter describes the darkness to whiteness color in the range of 0 to 100, while the b* shows the browning or loss of yellow. Decreasing in L* values might be related to the pineapple flesh darkening in color. However, L* (72.61±0.912 to 68.46±0.011) and b* values (33.82±0.96 to 28.42±0.42) were not significant in each other (data not shown). The color of the pineapple flesh was retained a slightly yellow color in all storage temperatures. Pre-treatment with 2% sodium chloride (NaCl) solution may help to maintain the yellow color of pineapple and prevent browning on the surface of sample [11]. NaCl can be used as antimicrobial and antibrowning agent. It can prevent the destruction of cell compartments as well as the contact of polyphenoloxidase with polyphenol in the cell. The pH, TA and TSS showed slightly changed during all storage temperature. Their values were in the range of 3.42±0.10-4.15±0.04, 0.43±0.09% - 0.72±0.09% and 15.74±0.50 _ 11.93±1.30 (°Brix), respectively. The similar result was found in Quyen *et al.* [7]. TA and TSS are also related in each other upon their parameters (data not shown). TA and TSS can increase before/after ripening and then increasing and decreasing respectively due to sugar (sucrose, glucose and fructose), respiration condition, volatile compound production and microbial growth until the end of storage time. Vitamin C content in fresh-cut sample significantly decreased in the range of 27.48-19.62 mg/100g, 29.65-19.55mg/100g and 30.83-24.43 mg/100g for 5±1, 10±1 and 15±1°C, respectively, that was found almost similar with Kongsuwan *et al.* [12], Raiputta *et al.* [13] and Jatturaspaiboon *et al.* [11]. Decreasing of Vitamin C may due to break down in light, temperature and cutting or blending. Moreover, minimal process could induce the nutrient loss especially vitamin C [14].

3.2 Microbial Quality of Fresh-cut 'Phulae'Pineapple

According to the Notification of Department of Medical Science [15], safety level of microbial population (TPC) and yeast in ready-to-eat food must be lower than 6 log CFU/g and 4 log CFU/g, respectively [15]. TPC in fresh-cut sample was in a range of 2.53-5.44 log CFU/g for all temperatures and storage conditions (Table 1). According to these results, it was found that microorganisms were ascended as increased in temperature thus 5°C was in national acceptance level than other temperature for 14 days. Yeast and mold also observed 2.76-7.69 log CFU/g during storage for all temperatures. The off-odor and volatile compound from fermentation of samples were found in relationship with increasing number of yeast and mold count at higher temperature. However, slightly fermentation odor was observed in the end of storage time at 5°C. There were also found that the volatile compound peak area had increased from 4 days at 5°C and 2 days at 10°C and 15°C.

Table 1. Total Plate Count (Log CFU/g) in Fresh-cut 'Phulae' Pineapple during Storage

TPC	Day of Storage						
	0	2	4	7	9	11	14
5°C	2.53±0.16 ns	2.67±0.27 ns	3.39±0.94 ns	4.23±0.25 ns	4.17±0.69 ns	5.18±0.46 ns	5.44±0.11
10°C	2.53±0.16 ns	2.91±0.37 ns	3.89±0.81 ns	4.45±0.02 ns	5.08±0.18 ns	5.39±0.13 ns	-
15°C	2.53±0.16 ns	3.57±0.54 ns	4.19±0.45 ns	-	-	-	-

*Means ± SD (n=3), within a column followed by the same letter are not significantly different (P>0.05). **ns means not significant different.

Babic *et al.* [16] reported that yeast count more than 5 log CFU/g can make the ethanol, organic acid and volatile esters production that can produce off-flavor in fresh-cut fruit and vegetable. Also, the volatile compound of ethyl acetate and acetic acid were showed the relationship betweenCO_2 and microorganisms which increased dramatically during storage (Figure 1). Results at lower temperature of storage were a critical point to slow down the yeast and mold growing. Martinez-Ferrer *et al.* [17] reported a relationship between increased shelf life and reduced populations of yeasts and molds on both cut mangoes and pineapples during storage. Babic *et al.* [16] identified that yeast can grow at anaerobic condition (in absence of O_2), the fermented yeast can convert the sugars into carbon dioxide and ethanol (alcohol) then they might spoil the fresh-cut fruit and vegetables during pH <4.5. The volatile compound can be produced by microorganisms and fermentation of sugar, although the characteristics of aroma volatile compound are originally presented in fruits profile. The volatile compound condition can change upon refrigeration condition, processing, extraction, filtration and others which affected by color, sugar, acidity, softening and loss texture, aroma and flavor depletion. The fruit may spoil even keeping in the package under controlled temperature because it produce the internal gas inside the package and then oxygen concentration decrease and later bacteria, yeast and mold can multiply. These undesirable condition leads to the presence of off-flavor. Therefore, the unpleasant odor production and deterioration may cause by the growth of microorganisms especially yeast during storage. The loss of ester and changes in volatile aroma composition will also affect the fruit flavor, color, texture and odor during storage. Thus, the presence of microorganisms relates to volatile compound production while the microbial growth rate is influenced by the temperature, relative humidity and gas composition of the ambient atmosphere [18].

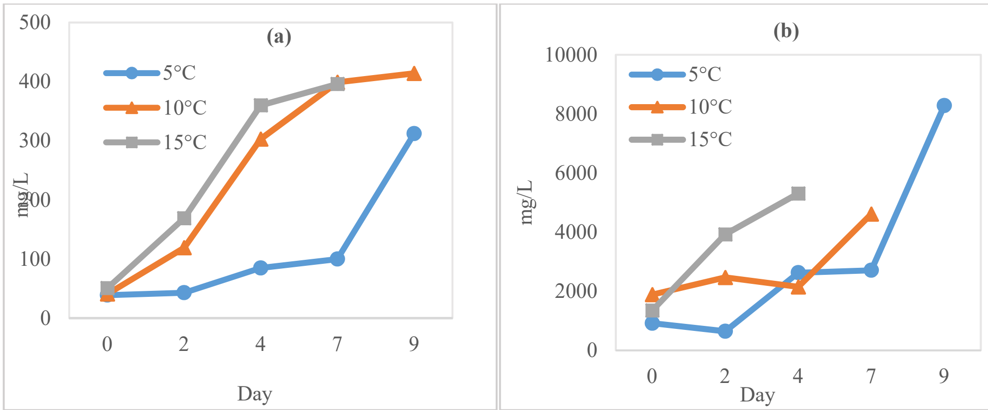

Figure 1. (a) Ethyl Acetate Content (b) Acetic Acid Content of 'Phulae' Pineapple during Storage

3.3 Gas Composition in Package during Storage

The changes of O_2 and CO_2 were significant in each storage temperature because O_2 level decreased as the increasing of CO_2 level during storage in different temperatures along 14 days of storage. These occurred due to the highrespiration rate of fresh-cut fruits which have a lot of surface area and metabolic acidity of an injured cell by cutting [19]. The composition about 20% of $CO_2$and 0.1% $O_2$was observed in the sample stored at 5°C. Jatturaspaibool [11] reported that the modified atmosphere of 2% O_2 and up to 17% CO_2 was recommended for fresh-cut 'Phulae' pineapple to achieve the storage life for 12 days at 5°C. Nevertheless, the off-odor was not observed in the sample stored at 5°C until the end of storage in this study even the concentration of O_2 was lower than 2%. The deterioration and metabolization of fruit were higher in 10 ± 1 and 15 ± 1°C.

3.4 Volatile Compounds in Fresh-cut 'Phulae' Pineapple

Gas Chromatography Mass Spectrometry (GC-MS) is one of the appropriate technique to identify the active compounds like phytochemical and fatty acid presented in fruits, vegetables and plants. The aroma components were ascertained by searching reference of NIST and Wiley Libraries and then the relative contents were counted based on the apex area. The GC-MS-HS analysis of fresh-cut 'Phulae' pineapple appeared the presence of many compounds as shown in Table 2 with their retention time (RT), odor description and peak area (approximately % of concentration). From this analysis, it was found that 'Phulae' pineapple contained more than 30 compounds including esters, terpenes, aldehydes, ketone and hydrocarbons. Ester such as hexanoic acid methyl ester, butanoic acid 2-methylmethyl ester and octanoic acid methyl ester were important components in the pineapple flavor [20]. Spanier *et al*. [21] identified the volatile compound which was similar to the ones found in this study as acetic acid and nonanal.

There also included Hexanoic acid methyl ester, Hexanoic acid ethyl ester, Ocimenes, Butanoic acid, 2-methyl-, ethyl ester, Butanoic acid, methyl ester, Butanoic acid, 2-methyl-, methyl ester, Octanoic acid, methyl ester, Ethyl acetate, Acetic acid, 1-Butanol, 3-methyl-, acetate, Nonanal and Decanal which are the predominate factors of fragrance in 'Phulae' pineapple. The concentration of these volatile compounds was found higher in fresh-cut sample stored at high temperature and related to the deterioration and shelf life. This deterioration affected to the changes in color, texture, taste and odor.During storage time, increasing or decreasing of some volatile compounds was found in a relationship with the changing of odor and off-flavor in fresh-cut 'Phulae' pineapple.

According to the Montero-Calderón *et al*. [18], storage condition such as temperature and lightaffects to the aroma components accumulation. High storage temperature was found related to high intensity of aroma components. In addition, too strong and weak light may reduce the aroma compound synthesis while the moderate light condition could maintain the fruit aroma. Therefore, the result of 10°C and 15°C demonstrated a lot of compounds in higher concentration after 2 days of storage. Moreover, ethyl acetate (312 mg/L and 414 mg/L) and acetic acid (917 mg/L and 8282 mg/L) were found as the highest components and peak areas (Figure 1) in this study. Increasing and decreasing of ethyl acetate and acetic acid might be related to total soluble solid content and especially fermentation of microbial activities. Higher temperature caused the high concentration of compound during storage hence the ethyl acetate and acetic acid contents were found as high two times at 15°C and 10°C than 5°C storage condition. According to the result of 'Phulae' pineapple volatile organic compounds in Table 2 and Figure 1, the shelf life can be predicted depend on their peak area, some compounds produced, the fresh compound reduced/disappeared that found in initial day and odor description.

3.5 Sensory Evaluation

The score in terms of color and texture were in a range of 5.83±0.94 to 4.73±1.48 and 5.77±1.25 to 4.73±1.14. However, the panelists accepted the odor of fresh-cut sample stored at 5±1°C until 14 days (5.80±1.25 to 5.13±1.17) but only 4 days storage at 10±1 and 15±1°C (5.47±1.17 to 4.13±2.03). The odor score was in 5.80±1.03 to 3.23±1.35 for all storage temperatures. The presence of acetic acid and ethyl ester may cause unacceptable of fresh-cut product.

Table 2. 'Phulae' Pineapple Volatile Compounds and Odor Description

Day	RT	Compound name	5°C	10°C	15°C	Odor description [22]
			S	S	S	
0	5.3	Butanoic acid, 2-methyl-, ethyl ester	+	++	++	Sharp, sweet, green and apple
	8.19	Hexanoic acid, ethyl ester	+	++	+	Sweet, alcohol, fruity, waxy and green
	9.27	á-Ocimene	+	+	+	Floral
	13.24	Octanoic acid, ethyl ester	-	++	+	Orange sweet
2	3.33	Ethyl Acetate	-	+	+	Fruity, pleasant
	4.35	Acetic acid, butyl ester	-	+	+	Sour, vinegar-like
	4.38	Butanoic acid, 2-methyl-, methyl ester	-	-	+	Sharp, sweet, green and apple
	5.28	Butanoic acid, 2-methyl-, ethyl ester	+	+++	++	Sweet, fruity, apple odor, sour
	5.72	1-Butanol, 3-methyl-, acetate	-	+	++	Sweet, strong, pleasant in banana and pear
	6.59	Hexanoic acid, methyl ester	-	+	++	Sweet, alcohol, fruity, waxy and green
	8.16	Hexanoic acid, ethyl ester	+	++	+	Sweet, alcohol, fruity, waxy and green
	9.25	á-Ocimene	+	+	+	Floral
	11.31	Octanoic acid, methyl ester	+	+	+	Orange sweet
	13.22	Octanoic acid, ethyl ester	-	+	+	Fruity, winey and musty
4	3.33	Ethyl Acetate	+	++	+++	Fruity, pleasant
	4.35	Acetic acid, butyl ester	-	+	+	Sour, vinegar-like

Table 2. 'Phulae' Pineapple Volatile Compounds and Odor Description (cont.)

Day	RT	Compound name	5°C	10°C	15°C	Odor description [22]
			S	S	S	
	4.39	Butanoic acid, 2-methyl-, methyl ester	++	+	-	Sharp, sweet, green and apple
	4.64	Butanoic acid, ethyl ester	++	+	+	Fruity, sweet and ethereal apple, fresh and lifting tastes in pineapple
	5.28	Butanoic acid, 2-methyl-, ethyl ester	+	++	+++	Sharp, sweet, green and apple
	5.71	1-Butanol, 3-methyl-, acetate	-	+	+	Sweet, strong, pleasant in banana and pear
	5.75	1-Butanol, 2-methyl-, acetate	-	-	+	Sweet and fruity (coming out when overripe)
	8.17	Hexanoic acid, ethyl ester	+	+	+	Sweet, alcohol, fruity, waxy and green
	11.3	Octanoic acid, methyl ester	+	-	-	Orange sweet
	13.23	Octanoic acid, ethyl ester	-	+	+	Orange sweet
7	3.32	Ethyl Acetate	+	++	+++	Fruity, pleasant
	4.33	Acetic acid, butyl ester	-	+	++	Sour, vinegar-like
	4.38	Butanoic acid, 2-methyl-, methyl ester	+	-	-	Sharp, sweet, green and apple
	4.63	Butanoic acid, ethyl ester	+	+	+	Fruity, sweet and ethereal apple, fresh and lifting tastes in pineapple
	5.28	Butanoic acid, 2-methyl-, ethyl ester	+	+	+	Sharp, sweet, green and apple
	5.72	1-Butanol, 3-methyl-, acetate	+	++	++	Sweet, strong, pleasant in banana and pear
	5.75	1-Butanol, 2-methyl-, acetate	+	+	++	Sweet and fruity (coming out when overripe)
	8.17	Hexanoic acid, ethyl ester	++	+	+	Sweet, alcohol, fruity, waxy and green
9	3.31	Ethyl Acetate	+	++	-	Fruity, pleasant
	5.27	Butanoic acid, 2-methyl-, ethyl ester	+	+	-	Sharp, sweet, green and apple
	5.69	1-Butanol, 3-methyl-, acetate	+	++	-	Sweet, strong, pleasant in banana and pear
	5.74	1-Butanol, 2-methyl-, acetate	+	+	-	Sweet and fruity (coming out when overripe)
	7.35	Nonanal	+	-	-	Effervescent, fresh rose, orange peel and fatty
	8.16	Hexanoic acid, ethyl ester	++	+	-	Sweet, alcohol, fruity, waxy and green
	12.05	Decanal	+	-	-	floral and sweet; effervescent, fresh rose, orange peel and fatty
	13.22	Octanoic acid, ethyl ester	+	-	-	Fruity, winey and musty
	23.92	Palmitic acid P530 (l-(+)-Ascorbic acid 2,6-dihexadecanoate)	+	-	-	Sour
11	3.34	Ethyl Acetate	+	+	-	Fruity, pleasant
	4.39	Butanoic acid, 2-methyl-, methyl ester	+	-	-	Sharp, sweet, green and apple
	4.64	Butanoic acid, ethyl ester	+	+	-	Fruity, sweet and ethereal apple, fresh and lifting tastes in pineapple
	5.29	Butanoic acid, 2-methyl-, ethyl ester	++	+	-	Sharp, sweet, green and apple
	5.71	1-Butanol, 3-methyl-, acetate	+	-	-	Sweet, strong, pleasant in banana and pear
	5.74	1-Butanol, 2-methyl-, acetate	-	+	-	Sweet and fruity (coming out when overripe)
	6.58	Hexanoic acid, methyl ester	+	-	-	Sweet, alcohol, fruity, waxy and green
	7.65	Nonanal	+	-	-	Effervescent, fresh rose, orange peel and fatty
	8.15	Hexanoic acid, ethyl ester	++	+	-	Sweet, alcohol, fruity, waxy and green

Table 2. 'Phulae' Pineapple Volatile Compounds and Odor Description (cont.)

Day	RT	Compound name	5°C	10°C	15°C	Odor description [22]
			S	S	S	
	23.93	Palmitic acid P530 (l-(+)-Ascorbic acid 2,6-dihexadecanoate)	+	-	-	Sour
14	3.35	Ethyl Acetate	+	-	-	Fruity, pleasant
	4.35	Isobutyl acetate	+	-	-	Sweet, fruity, floral and ethereal
	4.64	Butanoic acid, ethyl ester	+	-	-	Fruity, sweet and ethereal apple, fresh and lifting tastes in pineapple
	5.28	Butanoic acid, 2-methyl-, ethyl ester	+	-	-	Sharp, sweet, green and apple
	5.71	1-Butanol, 3-methyl-, acetate	+	-	-	Sweet, strong, pleasant in banana and pear
	8.17	Hexanoic acid, ethyl ester	+	-	-	Sweet, alcohol, fruity, waxy and green
	23.92	Palmitic acid P530 (l-(+)-Ascorbic acid 2,6-dihexadecanoate)	+	-	-	Sour

(+) sign present, (++, +++) sign means higher in peak area than (+) sign, (-) sign absent, RT – retention time, S - Sign

4. Conclusions

Storage temperature affected to the qualities of fresh-cut 'Phulae' pineapple. From the results of this study, 5$\pm$1°C was recommended for storage of fresh-cut 'Phulae' pineapple. Changes in volatile compound especially ethyl acetate and acetic acid were found related to the presence of CO_2 and microbial growth. This information will be further used to develop spoilage indicator that be applied to use with fresh-cut 'Phulae' pineapple and then to maintain the quality and safety for consumers.

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