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TABLE OF CONTENTS PAGE

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Preference mapping of pineapples grown in Chiang Rai with different cultivars and cultivation methods for Thai consumers living in Chiang Rai

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Abstract

Cultivar and cultivation method have been considered to have some effects on sensory characteristics and consumer acceptability in many types of fruits. These two factors were studied by focusing on two local cultivars of pineapples grown in Chiang Rai (Phu Lae and Nang Lae). Three different cultivation methods including cultivation with chemical fertilizers, cultivation with 100% organic fertilizer, and cultivation with natural condition were all applied. Commercial pineapples from both cultivars were also included. Eight pineapple samples in total were evaluated by 100 consumers by asking to rate their liking scores. The liking scores were then collected and analyzed with multivariate analysis in conjunction with cluster analysis, internal preference mapping, and regression analysis. Three clusters were all found after performing cluster analysis based on overall degree of liking, appearance liking, flavor liking, and texture liking. For overall degree of liking, consumers in the biggest cluster preferred Phu Lae pineapple in all cultivation methods and commercial Nang Lae pineapple, whereas consumers in a smaller group preferred commercial samples from both cultivars than other samples. Consumers in the other cluster preferred most of samples except commercial Phu Lae pineapple. For appearance liking, consumers in all three clusters liked the appearance of Phu Lae pineapple in all cultivation methods and commercial Nang Lae pineapple. One of 3 clusters was a group of consumers who liked the appearance of all samples except Phu Lae pineapple with organic cultivation. As for flavor liking, Nang Lae with organic and natural cultivation were the least liked by consumers. Commercial and chemical cultivation of Phu Lae pineapple were two samples that preferred by consumers in all three clusters. In case of texture liking, three samples including Phu Lae pineapple with chemical cultivation and commercial pineapple in both

cultivars were preferred the most from consumers in all three clusters. Consumers in the main cluster showed their textural preference mainly on Phu Lae pineapple. Flavor was the main driver of liking for consumers in all 3 clusters. This result would be useful to understand effect of cultivar and cultivation methods on consumer acceptance toward pineapple.

Keywords: Pineapple, Phu Lae, Nang Lae, consumer acceptance, preference map

1. Introduction

Pineapple (*Ananas comoscs*) is an important tropical fruit that has been grown in many countries including Thailand. Pattavia, Intarachit, Phuket, Nang Lae and Phu Lae are all cultivars that are famous for producing and serving Thailand's pineapple industry. Pattavia cultivar, a member of Smooth Cayenne, is the major cultivar that is used in both fresh fruit markets as fresh cut pineapple and in the processing industry as pineapple juice or canned pineapple. However, in recent years, consumers have changed their behaviors by looking for locally produced food product and they are interested in specific regional foods (Aprile *et al*, 2016). With this food trend, many consumers are looking for new experience to try the locally grown food. Pineapples in Northern part of Thailand are considered to be one of the most interesting fruits that are highly recommended when consumers come to this area. Phu Lae and Nang Lae are two cultivars that have been successfully registered as the geographical indication (GI) of Chiang Rai Province since 2009 (Kongsuwan *et al*, 2009). Nang Lae is a pineapple cultivar in Cayenne group which has almost round shape and very thin skin. Nang Lae pineapples are mostly grown in Nang Lae sub-district, Chiang Rai province, Thailand. The main sensory characteristics of Nang Lae pineapple are a light yellow of flesh, a honey-like aroma when it is ripe, soft and juicy texture and a sweet taste. With its delicate skin, Nang Lae pineapple is not suitable to be transported. So, it is popular for fresh consumption in its local only as fresh cut pineapple. Besides the popularity of Nang Lae pineapple, Chiang Rai province also has another cultivar named Phu Lae which is considered to be a unique pineapple for Chiang Rai and now the demand for Phu Lae pineapple in Thailand has been increasing. Phu Lae cultivar is classified as a member of Queen group. Ban du, Tha sud, and Nang Lae sub−distract are the main area for producing Phu Lae pineapple in Chiang Rai. In fact, Phu Lae pineapple is not a special hybrid cultivar but the word "Phu Lae" came from "Phuket", a pineapple cultivar grown mostly in Southern part of Thailand, and "Nang Lae", the first location that pineapples were cultivated. The origin of Phu Lae pineapple started with a lecturer at Chiang Rai Rajabphat University brought some plants of Phuket pineapple cultivar from Phuket to Chiang Rai. He tried to grow this specific cultivar but the Phuket pineapples grown in Chiang Rai had significantly smaller and rounder in size and shape than original Phuket pineapples but they had some distinct aromas and flavors. These changes would be the effect of the cold weather and the high altitude of the growing area in the Northern part of Thailand. Many dominant sensory characteristics perceived in Phu Lae pineapple are a golden−yellow color in flesh, some aromas and flavors

including sugary aroma, sweet aroma and flavor, honey aroma and flavor, and ripe fruit aroma and flavor, a moderate sweet taste, and a crunchy texture. Unlike other pineapple cultivars, Phu Lae pineapples can be consumed in both flesh and core after peeling due to their crunchy texture.

Many factors affect to the growth, yield, and qualities of pineapple not only cultivar (Zheng *et al.*, 2012), but also grown location (Teai *et al.*, 2001), growing season (Liu *et al.*, 2011), ripening stage (Steingass *et al.*, 2015), storage condition (Thu *et al.*, 2017), and fertilization method (Chang *et al.*, 2010). Thus, the knowledge on how cultivar and cultivation methods affect to the qualities of pineapples would be very useful for farmers, marketers, and also plant breeders. Nowadays, food supply chain is extremely complex and many biosecurity issues are also food safety issues. The awareness of healthy food consumption and food safety has been increasingly concerned by consumers. They will take their time and carefully select the food products that can be proved to be safe for consumption. Organic certification is an example that is very attractive to many health-minded consumers. The main reason why this group of consumers is looking for organic products is that they want to avoid toxins in their food that they perceive as unhealthy.

The studies on bioactive compounds and antioxidant activities of pineapple were conducted (Hossain and Rahman, 2011; Kongsuwan et al., 2009; Yeoh and Ali, 2017). Some volatile compounds presented in pineapple were also classified (Wei et al., 2011; Zheng *et al.*, 2012). However, the comprehensive consumer acceptance on the Phu Lae and Nang Lae pineapple is very limited. The aims of this research were 1. to study consumer acceptance on pineapple samples, 2. to identify the driver of liking on pineapple samples and 3. to determine the effect of cultivar (Phu Lae and Nang Lae) and cultivation method (cultivation with chemical fertilizers, organic fertilizers, and natural condition) on consumer acceptance.

2. Materials and Methods

2.1 Materials

The pineapple samples used entire of this study were rainy season crop (harvesting time: June–July, 2018) and composed of 2 cultivars that represent Chiang Rai identity including Phu Lae and Nang Lae. All pineapples were grown by local pineapple farmers in Nang Lae sub-district, Chiang Rai Province, Thailand. To control the variations from soil and water supply, all pineapples were planted and cultivated in the same area. Moreover, the planting area for organic cultivation was followed with the general regulation for organic production which has not been used any chemical substances at least 3 years. Pineapples for organic and natural condition were planted separately with at least 10 meters apart. In case of organic cultivation, the pineapples were all treated with an organic liquid fertilizer and worm castings (vermicompost) produced by the Royal Project Foundation. The pineapple farmers would control amount of both organic liquid fertilizer and worm castings by following the instruction containing on the label. For natural cultivation, pineapples were not treated with any fertilizer or pesticide. In the matter of chemical cultivation, pineapples were purchased directly from other nearby pineapple farms that regularly applied chemical fertilizers. The pineapples that were ready to harvest for this study must had at least three-quarters of the shell color yellow. In order to control the pineapple qualities, additional criteria for screening the pineapple were set. The pH

of Plu Lae pineapple and Nang Lae pineapple had to be in the range of 3.5−4.5 and 4.0−5.0, respectively. The total soluble solid (°Brix) were controlled by setting the range as 13.0−15.0 for Plu Lae pineapple and 12.0−14.0 for Nang Lae pineapple. Lastly, commercial pineapples were obtained from local markets and freshly prepared within 3 hours before sensory tasting.

2.2 Sample preparation

After receiving the pineapple samples from farmers and local vendors, all pineapple samples would be kept in a refrigerator at 10 ± 2°C immediately to preserve their qualities and retard both physical and chemical changes. The pineapples which showed any defects would be removed from this study. To control the pineapple qualities, all pineapple samples in each batch would be used no longer than a week. The preparation for Nang Lae pineapple samples began with cleaning of the whole fruit with tap water to remove dirt, and then their skins were completely peeled. After peeling, each pineapple was sliced to remove the core and the flesh was cut into small pieces (2 cm. x 3 cm. x 1 cm.) In case of Phu Lae pineapple, the same sample preparation was used, except Phu Lae pineapple samples were needed to remove their dark, prickly spots known as eyes by v−shaped knife, then the flesh was cut in the same size as Nang Lae pineapple. It would be noted that the core of Phu Lae pineapple samples would not be removed due to its normal consumption. Consumers normally consume both core and flesh. For serving, each pineapple sample was randomly selected from different fruit's positions and weighed approximately 10 grams and was given to each consumer for tasting at room temperature. Each cup of sample was coded with a 3−digit random number. A glass of pure water and a cup of white bread were served to clean the palate between samples. The order of sample presentation was completely randomized to balance out any potential serving order or carry−over effects. All pineapple samples were subjected to a consumer acceptance test with 100 consumers who were living in Chiang Rai. The consumers were asked to rate their overall degree of liking, liking of appearance, flavor, and texture by using 9−point hedonic scale anchored from "dislike extremely" to "like extremely" (Lawless and Heymann, 2010). The detailed information of each sample is given in Table 1.

Table 1 Information of the 8 pineapple samples

Types of pineapple samples	Abbreviation
Phu Lae pineapple purchased from local markets	Phu Lae Commercial
Phu Lae pineapple grown by using chemical fertilizers	Phu Lae Chemical
Phu Lae pineapple grown with natural condition	Phu Lae Natural
Phu Lae pineapple grown by using organic fertilizers	Phu Lae Organic
Nang Lae pineapple purchased from local markets	Nang Lae Commercial
Nang Lae pineapple grown by using chemical fertilizers	Nang Lae Chemical
Nang Lae pineapple grown with natural condition	Nang Lae Natural
Nang Lae pineapple grown by using organic fertilizers	Nang Lae Organic

2.3 Statistical analysis

Some advanced statistics (internal preference mapping, cluster analysis, and partial least square regression (PLS)) were applied for the consumer acceptance data. Internal Preference Mapping (IPM) is a statistical method used to identify which samples correlate with groups of consumers based on the Principal Component Analysis (PCA) (NÃ *et al.,* 2011). The more consumers around a sample, the more acceptance that particular sample is. In order to show the differences of consumer profiles, cluster analysis was performed. Cluster analysis methods allow collecting consumers in classes (clusters) in such a way that consumer belonging to. Consumers in the same cluster are more similar to one another than consumers belonging to other clusters (MacFie, 2007). The Euclidean dissimilarity matrix and Ward's method of agglomerative hierarchical clustering technique were selected and used in this study. Consumer liking sores were further analyzed by Partial Least Square Regression (PLS) (XLSTAT version 2012, Addinsoft, Paris, France). Appearance liking, flavor liking, and texture liking were all used as predictors to predict overall degree of liking of consumers in each cluster. To express their relative influence independently of differences in consumer liking sores, weighted regression coefficients (coefficients weighted by the variable mean value) were calculated**.**

3. Results and Discussion

3.1 Cluster analysis

Generally, consumer acceptance or liking score result has been reported as mean scores and the researcher usually uses the mean scores to represent the preference of a group of consumers. However, drawing a conclusion by using mean scores seems to be bias due to the fact that each consumer has difference on his/her preference (Lawless and Heymann, 2010). To solve this problem, sensory scientists apply cluster analysis to segment the consumers into groups based on their similarity of liking scores. Three clusters were all revealed on the basis of overall degree of liking, appearance liking, flavor liking, and texture liking result. (Figure 1−4) To see the distribution of consumer preferences and pineapple samples, internal preference maps were created based on the cluster analysis results.

3.2 Internal Preference Map

Internal preference maps were illustrated to provide graphical representations of consumer responses and pineapple sample coordinates with the clusters derived from the cluster analyses. Mean scores of each sample in each type of cluster analysis were all used to confirm the results of preference maps.

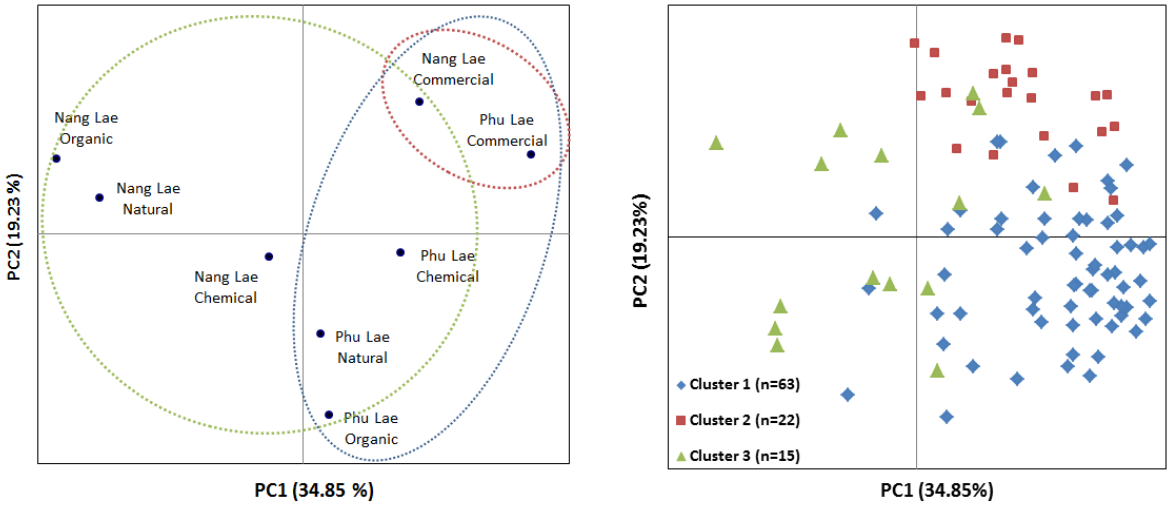

Figure 1 Internal preference map on principal component 1 and 2 for overall degree of liking (n = 100)

According to the plot of overall degree of liking (Figure 1), it was clear that the all Phu Lae pineapple samples were placed in the first and the fourth quadrant of the overall liking internal preference map. Commercial Nang Lae pineapple was the only Nang Lae pineapple sample that was grouped with the Phu Lae pineapple samples. When considering the dispersion on consumer plot, most of consumers were located in the first and the fourth quadrant of the overall liking internal preference map. Consumers in cluster 1 (n = 63) was the majority of the consumers when performing cluster analysis on overall degree of liking and they preferred all Phu Lae pineapple samples and only commercial Nang Lae pineapple. The other Nang Lae pineapples were the samples that consumers in this cluster liked the least. Consumers in cluster 2 (n = 22) had very specific preference of pineapples. Both commercial Phu Lae and Nang Lae pineapples were just two samples that consumers in cluster 2 liked the most. Lastly, consumers in cluster 3 preferred most pineapple samples except commercial Phu Lae pineapple. This cluster was the smallest cluster that had only 15 consumers. In conclusion, commercial Nang Lae pineapple was a pineapple sample that was liked by consumers in all three clusters following with all Phu Lae pineapple samples that were preferred by consumers in two clusters. Thus, in case of overall degree of liking, cultivar played more important role than cultivation method. Phu Lae pineapple samples seemed to have higher acceptance level from the majority of consumers than Nang Lae pineapple samples and cultivation method did not have effect on overall degree of liking on Phu Lae pineapple. More explanations on why consumers preferred Phu Lae pineapple samples more than Nang Lae pineapple samples would be described based on appearance, flavor, and texture liking.

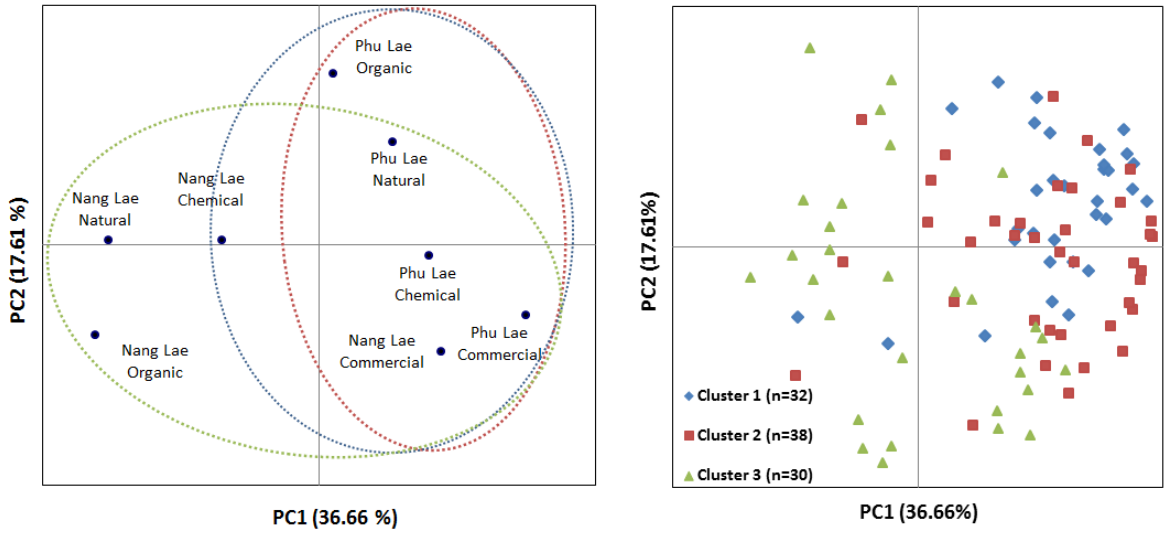

Figure 2 Internal preference map on principal component 1 and 2 for appearance liking (n = 100)

In the appearance liking plot (Figure 2), consumers in cluster 1 (n = 32) and cluster 2 (n = 38) had very similar preference on the appearance. Consumers in both clusters liked the look of all Phu Lae pineapple samples and just only commercial Nang Lae pineapple. Chemical Nang Lae pineapple was another pineapple sample that was liked by consumers in cluster 1 but it was less liked by consumers in cluster 2. The last cluster that contained 30 consumers was a group of consumers who accepted the appearance of almost pineapple samples in both Phu Lae and Nang Lae culitvars. Phu Lae pineapple with organic cultivation was the least liked pineapple sample by consumers in cluster 3. These results could be explained by a previous study on sensory characteristics of both cultivars as follows. According to the full sensory profile from Quantitative Descriptive Analysis (QDA™), the major differences of appearance were explained in terms of "Yellow color of flesh", "Surface wetness", "Opaqueness", "Fiber appearance", and "Hollow appearance" (Sirimuangmoon, 2018). Nang Lae pineapple samples had a significantly higher intensity of "Fiber appearance", "Surface wetness" than Phu Lae pineapple samples. On the other hand, Phu Lae pineapple samples had a significantly higher intensity of "Opaqueness", "Hollow appearance", and "Yellow color of flesh", than Nang Lae pineapple samples. Nang Lae pineapple is one of the members of Cayenne cultivar which is the most commonly grown worldwide and the most popular for canning industry. The flesh of Cayenne pineapple is described as close-textured, pale yellow to yellow color at maturity, soft, and juicy (Sanewski *et al.*, 2018). In contrast, Phu Lae pineapple is a Queen cultivar that is grown principally for fresh market. This cultivar is classified for deep golden-yellow color of flesh. The flesh of Queen cultivar is dry and porous (Abdullah, 2011). Based on the sensory characteristics in pineapple samples, consumers in cluster 1 and cluster 2 (accounting for 70% of total consumers) would prefer some sensory characteristics presented in Phu Lae pineapples samples more than Nang Lae pineapple samples. Deep golden−yellow color of flesh, dried−look surface, some small holes of flesh would be the characteristics that make

consumers liked the appearance of Phu Lae pineapple more than the look of Nang Lae pineapple. Interestingly, commercial Nang Lae pineapple was also a pineapple that consumers in both cluster 1 and cluster 2 liked. Based on the study of sensory descriptive analysis, it was found that cultivation method affected significantly to the intensity of yellow color of flesh. Pineapples treated with chemical fertilizers and commercial pineapples had a significant higher intensity of yellowness than pineapple grown with an organic fertilizer and natural condition (Sirimuangmoon, 2018). Besides all Phu Lae pineapple samples that were liked by consumers in both cluster 1 and cluster 2, they also accepted the appearance of Nang Lae pineapple but they did not like Nang Lae pineapple grown with an organic fertilizer and natural condition which might present very pale yellow color of flesh. Cultivation method did not affect to the liking of appearance of Phu Lae pineapple samples but it did affect directly to the liking of appearance of Nang Lae pineapple samples.

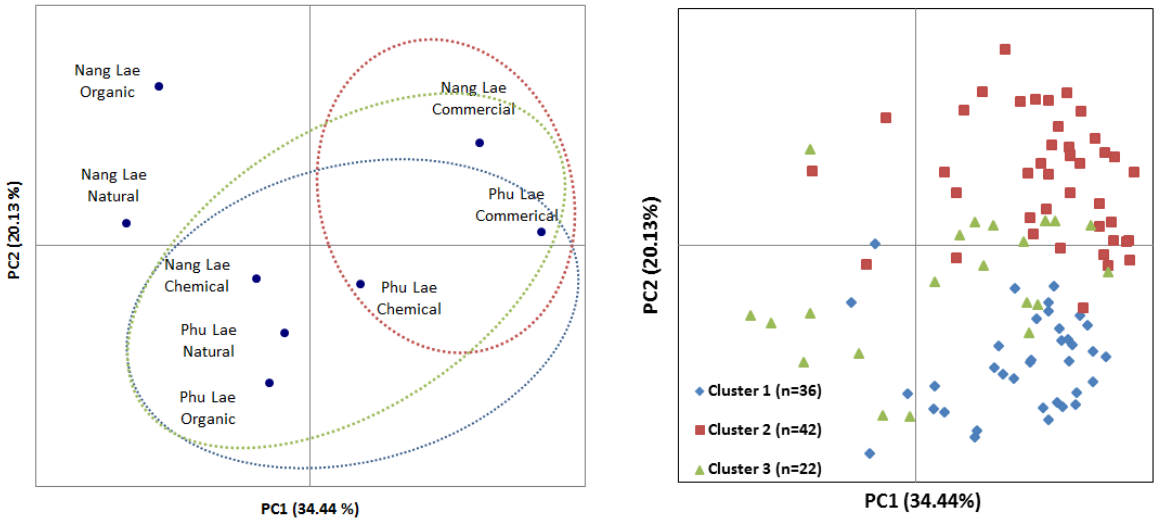

Figure 3 Internal preference map on principal component 1 and 2 for flavor liking (n = 100)

In the flavor preference map (Figure 3), it was clear that Nang Lae pineapple samples treated with an organic fertilizer and Nang Lea pineapple samples with natural conditions were two Nang Lae pineapple samples that were not liked by consumers in any clusters. Conversely, Phu Lae pineapple grown with chemical fertilizers and commercial Phu Lae pineapple were preferred by consumers in all three clusters. Consumers in cluster 2 (majority, n = 42) also had another sample they liked which was commercial Nang Lae pineapple. Consumers in cluster 1 (n = 36) and cluster 3 (n = 22) had almost the same flavor preference. Consumers in both clusters liked all Phu Lae pineapples in all cultivation methods and Nang Lae pineapple cultivated with chemical fertilizers. The difference of the flavor preference between consumers in cluster 1 and 3 was that consumers in cluster 3 also liked commercial Nang Lae pineapple sample, whereas consumers in cluster 1 did not liked commercial Nang Lae pineapple sample. Clearly, consumers in this study liked the flavor of Phu Lae pineapple samples and Nang Lae pineapple samples which were treated with chemical fertilizer and commercial one. These findings would be explained by the information obtained from sensory descriptive study. When

compared between Phu Lae and Nang Lae cultivar, it was found that Phu Lae pineapple samples had a significantly higher intensity of "Pineapple aroma identity" "Sweet aftertaste", "Overall flavor lasting", "Ripe fruit flavor", "Sweet flavor", "Pineapple flavor", "Honey flavor", "Sweet taste", "Sugary aroma", "Ripe fruit aroma", "Sweet aroma", and "Honey aroma" than those attributes in the set of Nang Lae pineapple samples (Sirimuangmoon, 2018). With stronger intensity of sensory characteristics, Phu Lae pineapples would be possibly gained more flavor liking than Nang Lae pineapples. Over 300 volatile compounds has been studied in pineapple, however, very few volatile compounds has been classified and related to the pineapple aromas. Common sensory terminology used to present the relationship between volatile compounds and sensory characteristics was 3−(Methylthio) propanoic acid ethyl ester for "Pineapple-like aroma", Hexanoic acid and ethyl ester for "Apple peel−like aroma", 2,5−Dimethyl−4−hydroxy−3(2H)−furanone for "Sweet aroma", and, Octanoic acid and methyl ester for "Fruity and citrus−like aroma" (Zheng *et al.,* 2012). Moreover, ethyl hexanoate and methyl hexanoate were reported to be the most important volatile compounds which contribute directly to the pineapple aroma (Takeoka *et al.,* 1989). Nevertheless, the relation of the dominant aromas and flavors of different pineapple cultivar has not been studied yet. The study on the correlation of chemical compounds obtained from advanced instrument and sensory descriptive analysis from trained panelist would be very useful for the food professionals to differentiate the significant aromas and flavors in each pineapple cultivar.

In case of effect of cultivations method on pineapple aromas and flavors, it was obvious that three pineapple samples (commercial Nang Lae pineapple, commercial Phu Lae pineapple, and Phu Lae pineapple treated with chemical fertilizers) were located on the same area that had high density of consumers (Figure 3) whereas the other pineapple samples were placed in the opposite side of internal preference map of flavor liking with a few of consumers (negative side of PC1). Thus, cultivation methods had a huge impact on the flavor liking. Pineapple sample treated with chemical fertilizers and commercial pineapple samples were liked by consumers more than the samples treated with an organic fertilizer and the samples grown with natural condition. Pineapple farmers generally use extensive chemicals including chemical fertilizers to ensure high yields and good qualities of pineapples (Liu *et al.,* 2013). The local pineapple farmers in Chiang Rai also mentioned that some specific types of fertilizers are also applied to increase the sweetness at the certain stage of growing. According to the result of flavor liking, pineapples with organic cultivation were not received high liking scores from consumers. Using just an organic liquid fertilizer and worm castings from the Royal Project Foundation might not be enough to provide the expected qualities and obtain a high consumer acceptance. The findings from this research consented to a previous study that applying chemical fertilizers affected significantly on the aromas and flavors. Phu Lae pineapple with natural cultivation and organic cultivation had less aromas and flavors than Phu Lae pineapple with chemical cultivation and the pineapple obtained from local markets (Sirimuangmoon, 2018). One last thing that should be noted in case of flavor liking was the effect from Phu Lae pineapple preparation found in commercial samples. Many local vendors intentionally soak peeled Phu Lae pineapple to Saccharin dipping solution to increase the sweetness and decrease the sourness in Phu Lae

pineapple. This finding was proved by the sensory descriptive result from trained panelist. Commercial Phu Lae pineapple sample that soaked with Saccharin solution had a significant higher on sweet taste and bitter aftertaste than other Phu Lae pineapple samples (samples with chemical cultivation, organic cultivation, and natural condition) (Sirimuangmoon, 2018). Saccharin is commonly used as a sugar substitute because it doesn't contain calories. This sugar substitute is 300–500 times sweeter than sucrose (Sharma *et al.*, 2016). Saccharine has previously classified as a generally recognized as safe status from the United States Food and Drug Administration (USFDA), however, preliminary evidence suggests Saccharin has the potential effect to gut bacteria and it may increase the risk of certain diseases including obesity, type 2 diabetes, inflammatory bowel disease, and cancer (Suez *et al.*, 2014; Suez *et al.*, 2015; Walsh *et al.*, 2014). Form the internal preference map of flavor liking, Phu Lae pineapple treated with chemical fertilizers had high acceptance from the consumers as well. Therefore, to prevent excess unnecessary food additive, consuming Phu Lae pineapple without soaking Saccharin would be a better choice for consumers who are aware of safety issues. Moreover, consumers would have a good chance to perceive the authentic aromas, tastes, and flavors from Phu Lae pineapple.

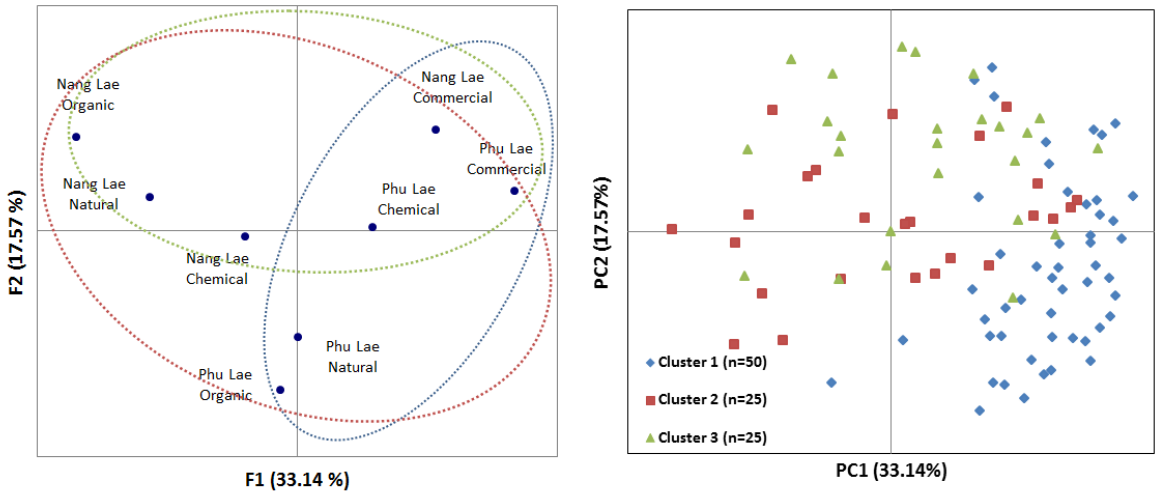

Figure 4 Internal preference map on principal component 1 and 2 for texture liking (n=100)

Consumers in the biggest cluster (cluster 1; n = 50) liked the texture of all Phu Lae pineapple samples and a commercial Nang Lae pineapple sample while another group (Cluster 3, n = 25) liked all Nang Lae pineapple samples, Phu Lae pineapple samples treated with chemical fertilizers and commercial Phu Lae pineapple sample. Consumers in cluster 2 did not have any specific texture liking on pineapple samples. Three pineapple samples including commercial Phu Lae pineapple, commercial Nang Lae pineapple, and Phu Lae pineapple treated with chemical fertilizers were all liked by consumers in all three clusters. Clearly, cultivar had some effects on texture liking. Consumers in cluster 1 liked the texture of all Phu Lae pineapple samples and a Nang Lae pineapple whereas consumers

in cluster 3 liked the texture of all Nang Lae pineapple samples and some Phu Lae pineapple samples. The difference of the internal structure of flesh between two cultivars would be the main reason to support this result. As mentioned earlier, Nang Lae pineapple is a member of Cayenne cultivar which its flesh is considered to have dense, soft, and juicy texture while Phu Lae pineapple, a Queen cultivar, had special characteristics of flesh by having dry and porous texture which makes Phu Lae pineapple has crispy in both flesh and core (Abdullah, 2011). These findings agreed with the results from sensory descriptive analysis. Phu Lae pineapples were considered to have a significantly higher textural characteristic of "Crunchiness" and "Denseness" than Nang Lae pineapples; in contrast, Nang Lae pineapples had a significantly higher intensity of "Juiciness" and "Fibrousness" (Sirimuangmoon, 2018). Thus, the majority of consumers tended to like Phu Lae pineapple which presents dense and crunchy texture. As for the effect of cultivation method on the texture liking, the internal preference map was noticeable that high density of consumers was found on the first and the fourth quadrant the internal preference map which all Phu Lae pineapple samples were located. Therefore, cultivation methods did not have much effect on texture liking for Phu Lae pineapples. The results of sensory descriptive analysis could be used to confirm this finding. There was no significant difference on "Crunchiness", "Denseness", and "Fibrousness" among cultivation methods in Phu Lae pineapples. However, in Nang Lae pineapples, the pineapple treated with chemical fertilizers and commercial one had a significantly higher on "Juiciness" and "Fibrousness" (Sirimuangmoon, 2018). Thus, in case of texture characteristics, cultivars play more important role than cultivation method and cultivation methods had some significant effect on Nang Lae pineapple more than Phu Lae pineapple.

As presented in all four internal preference maps, the direction of the preference was clearly illustrated. However, the relative importance of sensory parameters (appearance, flavor, and texture) towards overall degree of liking was not discovered yet. Thus, partial least square regression (PLS) is analyzed in each type of liking score.

3.3 Prediction of overall degree of liking from appearance liking, flavor liking, and texture liking

Overall degree of liking was predicted by a modeling method using liking of appearance, flavor, and texture from consumers as predictors. The regression coefficients expressed numerically the link between variations in the predictors. Weighted regression coefficients (i.e. coefficients weighted by the variable mean value) were used to express their relative influence independently of differences in sensory parameters. Figure 5−7 are plots of weighed regression coefficients for a model predicting overall degree of liking. Flavor was the most important sensory characteristics for all three clusters based on overall degree of liking result. For consumers in cluster 1 (Figure 5), texture was another most important predictor affecting overall liking. Appearance was the least important predictor for consumers in this cluster. Unlike the result of consumers in cluster 1, consumers in cluster 2 (Figure 6) perceived that appearance was the second most important predictor following texture. Result of consumers in cluster 3 (Figure 7) shows that texture was the second most important predictor which had more important than appearance. As the majority of consumers was grouped in cluster 1 (n = 63), both flavor and texture

were most important sensory characteristics affecting overall degree of liking. Pineapple growers, vendors, and also plant breeders should maintain these sensory characteristics in pineapples to gain the highest overall degree of liking from pineapple consumers.

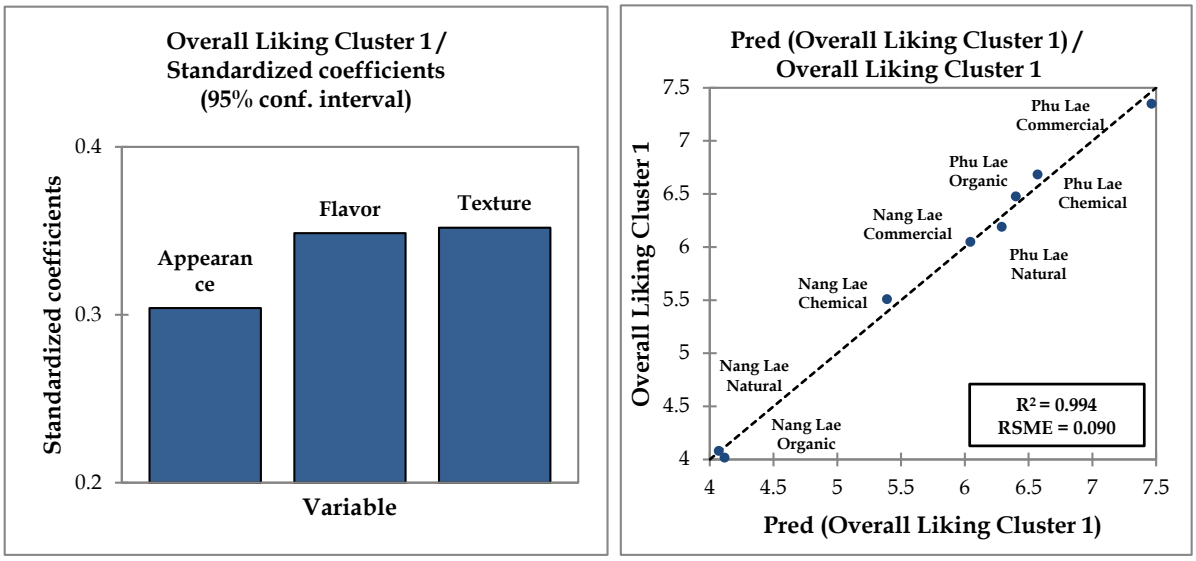

Figure 5 Predicted versus observed overall degree of liking and weighted regression coefficients for the partial least square regression model predicting overall degree of liking from appearance liking, flavor liking, and texture liking (consumers in cluster 1)

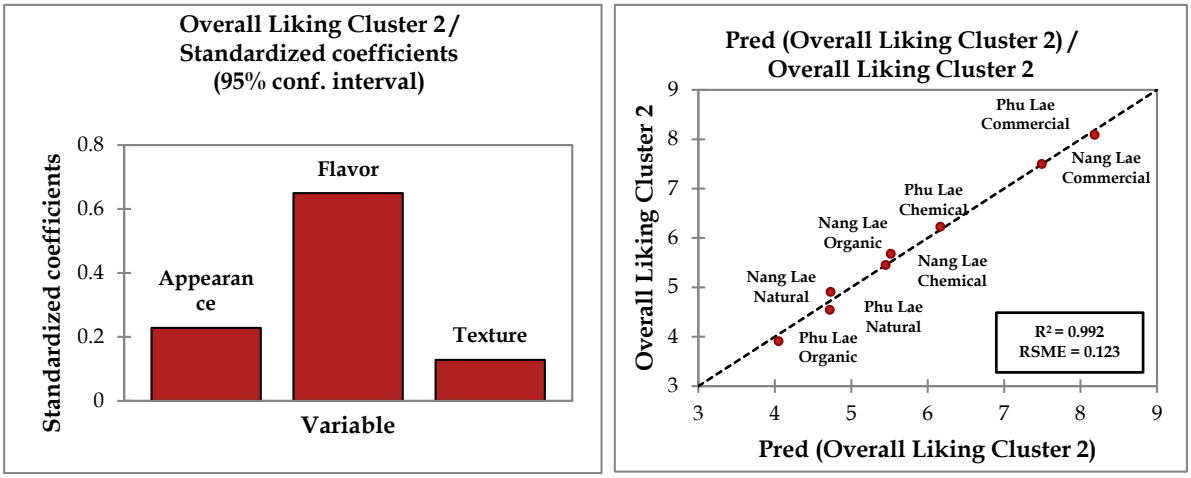

Figure 6 Predicted versus observed overall degree of liking and weighted regression coefficients for the partial least square regression model predicting overall degree of liking from appearance liking, flavor liking, and texture liking (consumers in cluster 2)

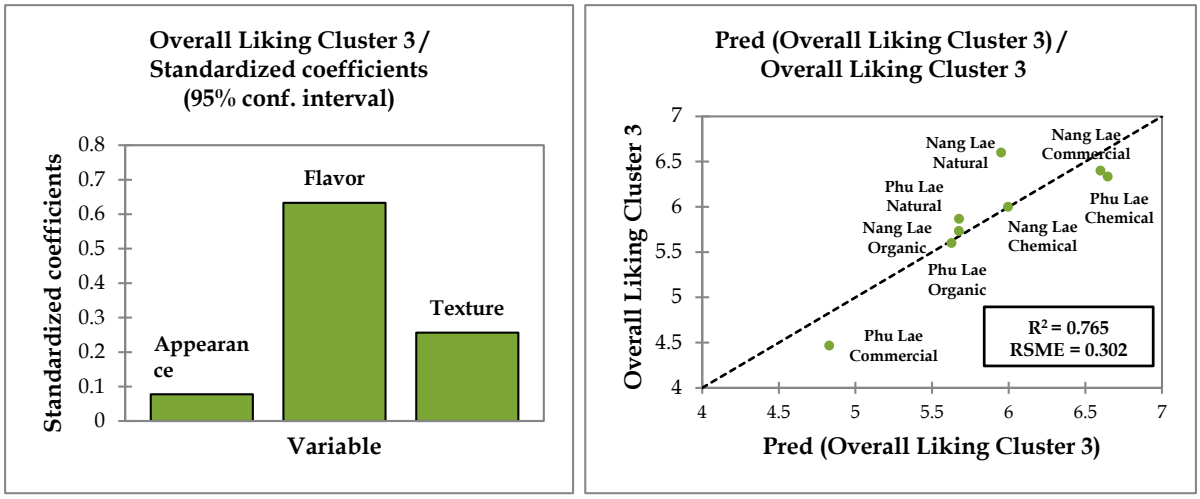

Figure 7 Predicted versus observed overall degree of liking and weighted regression coefficients for the partial least square regression model predicting overall degree of liking from appearance liking, flavor liking, and texture liking (consumers in cluster 3)

4. Conclusion

Cultivar and cultivation methods affected to the consumer liking scores on pineapple. Cultivar plays more important role than cultivation method in overall degree of liking, appearance liking, and texture liking. Phu Lae pineapple samples trended to have higher liking scores from consumers on overall degree of liking, appearance liking, and texture liking than Nang Lae pineapple samples. Cultivation method showed a significant effect on flavor liking. In both Phu Lae and Nang Lae cultivar, pineapple samples grown with chemical fertilizers and commercial pineapple were rated to have higher flavor liking scores than pineapple samples treated with an organic fertilizer and grown with natural condition. Organic cultivation is still needed to develop to meet the same acceptance level that commercial pineapple samples and pineapple samples treated with chemical fertilizers have. Flavor was considered to be the most important factor influencing overall degree of liking. These findings would be useful for any food professionals, plant breeders, and marketers to understand the effect of cultivar and cultivation method on pineapples grown in Chiang Rai.

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