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Utilization of Pineapple Residue for Pineapple Paste and Gluten-free Pie

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Abstract

This research was conducted to optimize the formula to produce pineapple paste and gluten-free pie products. The seven formulas of the pineapple paste consisting of pineapple residue (70-100%), pineapple juice (0-30%) and sugar (0-30%) were studied using Mixture Design. The properties and sensory evaluation by untrained panelists were investigated. The results showed that the pH of pineapple paste tended to decrease when the amount of pineapple juice increased. Apparently, the total soluble solid and brightness of pineapple paste varied directly as the amount of sugar. An appropriate formula of pineapple paste was 75% pineapple residue, 5% pineapple juice and 20% sugar, respectively. This formula had the highest score for all attributes. Next, the nine formulas of gluten-free pie products consisting of mixed flour (60-70%), salted butter (20-40%) and pineapple residue (0-10%) were studied using Mixture Design. The properties and sensory evaluation by untrained panelists were investigated. The results indicated that weight loss of pies varied directly with the amount of butter. The hardness and the brightness of pies varied directly with the amount of mixed flour. Obviously, a suitable formula of gluten-free pie product was 70% mixed flour, 20% salted butter and 10% pineapple residues, respectively. This formula had the highest score for all attributes. In conclusion, utilization of pineapple residue helps provide value-added on agricultural by-products in gluten-free foods.

Introduction

Pineapple is economically the most important crop in Thailand. At present, Thailand is the world's largest exporter of canned pineapple and pineapple juice concentrate in the world. Apparently, Thailand's the major pineapple exporter to markets include the European Union, the United States, Japan and the Middle East. The Thai pineapple sector-generates income into the country at about 23,000-25,000 million baht/year. There are three main products including fresh consumption (18%), canned pineapple and pineapple juice (80%) and other (2%.) (Office of agricultural economics, 2018). Generally, by-products from the processing industry consist of peel, crown, core, stem, and pulp or residue of flesh. By-products may have a particular part that is very different depending on the processing of each factory. However, if it is not used as a benefit, it will turn into fresh waste. Moreover, it becomes a major problem for the environment, and it has high cost for destroying

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the waste. Pineapple residues are by-products from squeezing or removing water from the pineapple flesh. Obviously, these can be consumed including core, and flesh in the shell. The chemical compositions of pineapple residues are protein (3.2-3.6%), fat (1.2-1.3%), fiber (4.7-8.9%) and ash (3.8-4.2%) (Thamkaew & Susirirut, 2017). At present, there are many studies on the utilization of pineapple residues, such as chicken sausage (Mapaya et al., 2016), body scrub (Susirirut et al., 2013), broiler chicken food (Chalermsan et al., 2011) and cookies (Utama-ang & Tepjaikad, 2001) etc. Specifically, the utilization of pineapple residue that can be consumed is very interesting; it not only reduces the amount of waste, but also has value added for by-products or waste from the pineapple processing industry.

Interestingly, pineapple residues are raw materials for food product. Pie is a bakery product which is made from wheat flour or wheat flour mixed with other types of flour. Other ingredients including water, fat, salt, sugar and milk are added in appropriate proportion. These are mixed together until homogeneous. Then, it is pressed into pie molds and baked. In terms of pie filling, it is made with various ingredients such as chicken, ham, preserved fruit, young coconut, corn, custard that can filled before or after baking (Thai industrial standards institute, 2012). However, some consumers have gluten allergic from a protein in wheat flour. The need of gluten-free product sales are forecast to increase by a compound annual growth rate of 10.4% between 2015 to 2020. Moreover, as the clinical utilization and the popularity of the gluten-free diet increase, consumer demands righteously continue to influence the food market and labelling standards of gluten-free products (Khoury et al., 2018). Wheat flour has viscosity and elasticity properties that able to form into the structure of dough by forming a disulfide bond between the amino acid molecules. Gluten contains glutenin and gliadin which has 30% of wheat protein (Surojanametakul, 2013). Utilization of low grade and pineapple residues for production of gluten-free pie product is a new product that can respond to needs of a hereditary intolerance consumer. The objective of this research is to study the prototype formula that is suitable for producing pineapple paste and gluten-free pie products from pineapple residues. Physical properties and sensory evaluation of consumers were investigated. These are keys for selecting the prototype formula. The knowledge gained from this research can be used as a guideline for the production of gluten-free foods and value-added from agricultural by-products.

Materials and methods

1. Raw materials

Low-grade pineapples (*Ananas comosus* cv. Smooth Cayenne) was used in this study which were small in size and of low cost. It was purchased from the local market in Sakaeo province. The ingredients used in pineapple paste and gluten-free pie formulas were composed of sugar (Mitrphol, Suphan Buri, Thailand), salt (Prungthip, Nakorn Ratchasima, Thailand), rice flour (Erawan brand, Nakhon Pathom, Thailand), cassava flour (Fish brand, Nonthaburi, Thailand), potato flour (McGarrett, Bangkok, Thailand), xanthan gum (Tookdee-chemipan, Bangkok, Thailand), salted butter (Orchids, Bangkok, Thailand), fresh eggs (Betagro, Bangkok, Thailand), cream cheese (Philadelphia, Bangkok, Thailand), icing (Imperial, Bangkok, Thailand) and whipping cream (Foremost, Bangkok, Thailand).

2. Pineapple residues and juice preparation

In terms of pineapple residues and juice preparation, low-grade pineapples were washed. Next, they were peeled and cut into small size. All edible parts of pineapple including core and flesh were used. These were blended by juice blender (Tefal DPA 130 La Moulinette, China). Then, it was squeezed and separated into two parts including residues or pulp (solid) and juice (liquid). In terms of residues, the moisture content was not over 10% which is close to residues or pulp from canned pineapple and pineapple juice production in the industry.

3. Pineapple paste preparation

The appropriate ratio of pineapple paste was studied by using mixture designs. The independent factors were the proportions of different components of pineapple residues (70-100%), pineapple juice (0-30%) and sugar (0-30%), respectively. The points on the designated triangle area were selected for studying. The seven formulas of pineapple paste from mixture design were investigated (Table 1). The pineapple residues, pineapple juice and sugar were weighed. Salt was added at 2% of all ingredients (consisting of pineapple residues, pineapple juice and sugar) in all formulas. In terms of pineapple paste production, all ingredients were mixed and stirred at 75 °C for 10 min. Then, it was kept in glass bottles.

Table 1 Formula of pineapple paste by a 3-component* mixture design

Formulas	1	2	3	4	5	6	7
Pineapple residue (%)	70	100	80	75	90	70	75
Pineapple juice (%)	0	0	10	5	5	30	20
Sugar (%)	30	0	10	20	5	0	5

Remark: * a 3-component mixture (100% in the mixture design) was 100% of the total formula.

4. Properties and sensory evaluation of pineapple paste

The appearance of pineapple paste from seven formulas was observed. Total soluble solid was investigated by hand refractometer (ATAGO MASTER-M, China). The pH value was measured by a pH meter (PH Meter 0.01, China). The color was investigated by color meter (Minolta colorimeter CR–400, Japan). The CIE system was evaluated by L * or brightness (0 = black, 100 = white), a * (+ a = red, -a = green) and b * (+ b = yellow, -b = Blue). Sensory evaluation by 30 untrained panelists were investigated. The importance of liking of appearance, flavor, taste, texture and overall liking were expressed by 9-point hedonic scale. The suitable formula was selected for the developmental pineapple paste product. The contour plot was overlapped to find the right ratio of the amount of pineapple residues, pineapple juice and sugar. The qualities of pineapple paste composed of total soluble solid, pH, color and sensory evaluation score were determined for selecting the appropriate formula of pineapple paste. It was produced as a pie filling in the next step.

5. Gluten-free pineapple pie preparation

The prototype formula of gluten-free pie product was studied. Specifically, mixed flour consisting of 65% rice flour, 25% potato flour, 10% cassava flour and 1.5% xanthan gum of mixed flour were used (Charoenphun & Kwanhian, 2018). The nine formulas of gluten-free pie products consisting of mixed flour (60-70%), salted butter (20-40%) and pineapple residue (0-10%) were determined by Mixture Design. The points on the designated triangle area were selected for studying. The nine formulas of pineapple paste from mixture design were determined (Table 2). Mixed flour, salted butter and pineapple residues were weighed. In other ingredients, cream cheese, icing, egg yolk and whipping cream were added at 15, 20, 25 and 20% all ingredients (consisting of mixed flour, salted butter and pineapple residue), respectively. In terms of pies production, salted butter and cream cheese were beaten by a food mixer (FRY KING, FR-089B, China) at medium speed until homogeneous. Icing, egg yolk, pineapple residues and whipping cream were added and mixed. Next, mixed flour was added and mixed until homogeneous. These were mixed and put in a plastic bag by rolling into a cylinder. It was chilled in refrigerator at 4°C for 30 min. Then, it was cut into small sizes at 20 g per piece, and was rolled onto a round sheet. After that, 20 g of pineapple paste that was selected from previous steps was added and molded. It was pressed into pie molds and was chilled in refrigerator at 4°C for 10 min. It was baked at 160°C for 10 min and then flipped over, and baked at 160°C for 10 min again.

Table 2 Formula of pie with pineapple paste by a 3-component* mixture design

Formulas	1	2	3	4	5	6	7	8	9
Mixed flour (%)	67.5	67.5	62.5	62.5	70	60	65	70	60
Salted butter (%)	25	30	30	35	30	30	30	20	40
Pineapple residue (%)	7.5	2.5	7.5	2.5	0	10	5	10	0

Remark: * a 3-component mixture (100% in the mixture design) was 100% of the total formula.

6. Properties and sensory evaluation of gluten-free pineapple pie

The appearance of pies from nine formulas was observed. Baking loss of cookies was investigated. The pies before baking and after baking were weighed by balance (Zepper EPS-3001, China). Baking loss was defined as follows: Baking loss (%) = [(Weigh of pies before baking- Weigh of pies after baking)/ Weigh of pies before baking] x 100 (Kotoki & Deka, 2010). The hardness of pies was measured by hardness instrument (Daiichi FG 520K, Japan). The unit of force was newton (N). Color of pies was measured by color meter (Colorimeter, WR10QC, China). The CIE system was defined by L * or brightness (0 = black, 100 = white), a * (+ a = red, -a = green) and b * (+ b = yellow, -b = Blue). Moreover, sensory evaluation by 30 untrained panelists were investigated. The number of panelists was appropriate that they had the proper qualifications in accordance with human research ethics. In the smaller tests, the 9-point hedonic scale of testing generally requires 25–50 participants, but will depend on the variability within the sample, as well as the test objective (Moskowitz et al., 2012). The importance of liking of appearance, flavor, taste, texture and overall liking were expressed by 9-point hedonic scale. The suitable formula was selected for developing gluten-free pie products. The contour plot was overlapped to find the right ratio of the amount of mixed flour, salted butter and pineapple residues. The quality of pies composed of weight loss, hardness, color and sensory evaluation score were used for selecting the appropriate formula of the pie. Chemical composition of pie including moisture content, protein, fat, carbohydrate and ash were investigated (AOAC, 2000).

7. Statistical analysis

The statistical technique one-way ANOVA was used for calculating. Duncan's new multiple-range Test (DMRT) was used to compare the difference in the average values at the 95% confidence level (Duncan, 1995).

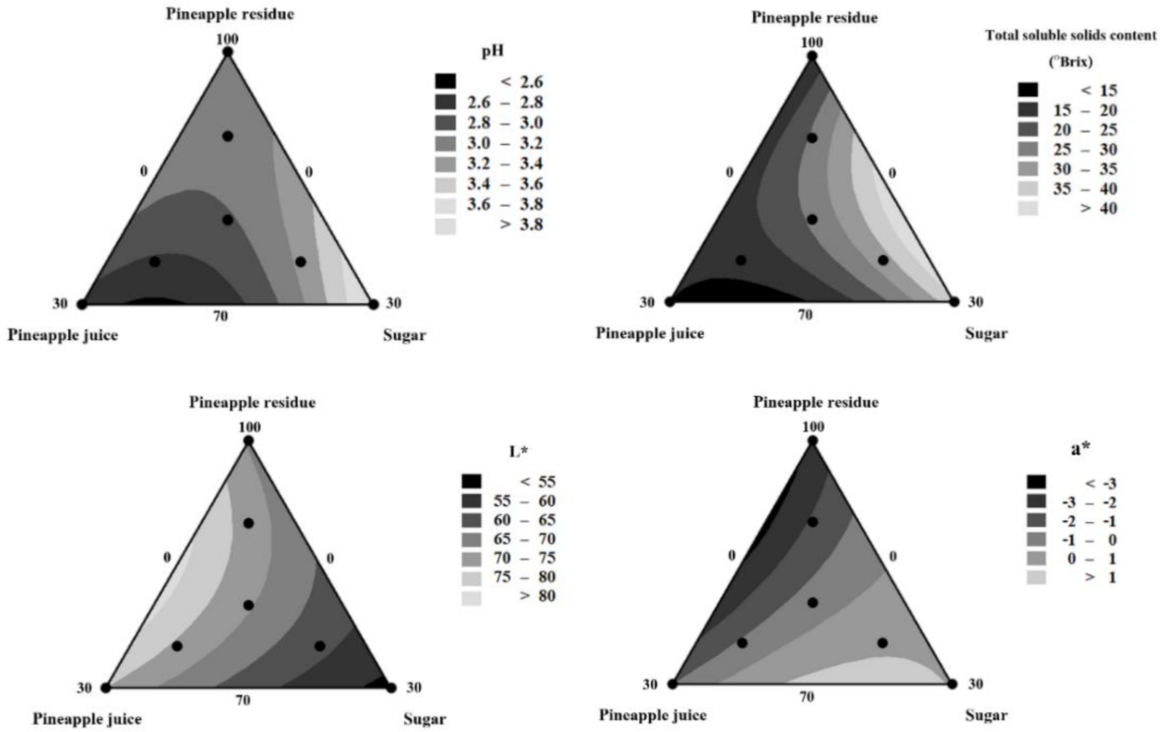
Results and discussion

1. Properties and sensory evaluation of pineapple paste

The appearance of pineapple paste for seven formulas by a 3-component mixture design were observed. It was found that all seven formulas of pineapple paste had a different appearance and characteristics. The pineapple pastes in formula 1 was overly sweet, orange-brown color, non-adhesion and over dry of texture. The pineapple pastes in formulas 2, 3, 5, 6 and 7 were very sour, yellow color, and non-adhesion. Interestingly, number 4 was the best formula which was similar to the general pineapple paste in the market. It was yellow color, appropriate texture and adhesion. In addition, it had a moderately sweet taste. As a result, the appearance of pineapple pastes is caused by the ratio of the main ingredients and the unit operation during production. Free water was removed during stirring due to heat transfer. Therefore, changing the appearance of pineapple pastes including flavor, color, and texture were found.

The pH, total soluble solids content and color of pineapple paste with a 3-component mixture design are shown in Fig. 1. The results show that pH from seven formulas had significant difference of the 95% confidence interval when $P \leq 0.05$. Apparently, pH value was decreased when the amount of pineapple juice increased. The amount of pineapple juice in formulas 4 and 5 are the same. Obviously, the pH in formula 4 higher than formula 5. However, the amount of pineapple residue in formula 5 is higher than formula 4. Presumably, there are left over of organic acids in pineapple residue. There were many organic acids in pineapple juice including oxalic acid, tartaric acid, malic acid, ascorbic acid, acetic acid, citric acid and succinic acid etc (Pongjanta et al., 2011). These had an effects on the pH value of pineapple paste. In this case, the pineapple species Pattawia (or Smooth Cayenne) was the most favorite among packers used for processing canned pineapple and also popular for fresh consumption. The distinctive characteristics of this pineapple species were sweet and juicy which were used for producing canned pineapple and pineapple juice in the industry. It had a total acidity in the range of 1.16-1.94%. Specifically, citric acid is the main acid which had a high volume of 70%, followed by acetic acid and malic acid, respectively (Pongjanta et al., 2011). The total soluble solid from seven formulas had significant difference of the 95% confidence interval, $P \leq 0.05$. It was found that the total soluble solids content varied directly as the amount of sugar. The major sugar substances that contribute to sweetness are glucose and fructose that playes a major role in taste. A strong positive correlation is observed between trained panel response to sweetness and total soluble solids content (Majidi et al., 2011). The amount of sugar in formulas 5 and 7 are the same. Apparently, the total soluble solids content in formula 5 is higher than formula 7. Nevertheless, the amount of pineapple juice that were sour in formula 7 is higher than formula 5. Presumably, the organic acids in pineapple juice may be related with total soluble solids. The total soluble solid was low and the total soluble solid/the total organic acid ratio was also low (Ikegaya et al., 2019).

The color of pineapple pastes from seven formulas had significant difference of 95% confidence interval when $P \leq 0.05$. The results show that L* (lightness) tendes to decrease when the amount of sugar increases. The a * value is the green range when pineapple residues increases. Furthermore, the b* is was the yellow range when pineapple juice increases. Obviously, the chemical composition is the main cause of color appearance in pineapples. There are many pigments in pineapples such as chlorophyll and carotenoid. Normally, chlorophyll in the pineapple peel changes to faded green color while carotenoid was develops into a yellow color according to the stage of maturity. In pineapple flesh, high amounts of carotenoids were found which were yellow-orange pigments depending on the varieties of pineapple species (Panyamongkol, 2017). It corresponds to the a* and b* values of pineapple paste which were measured in green and yellow ranges. Chlorophyll in pineapple causes the green color in pineapple paste. In particular, thermal processing induces structural and chemical variations to the tissue of vegetables that often result in color changes. Moreover, the reason for the green color loss during processing is mainly attributed to the conversion of chlorophylls to pheophytins by the influence of pH (Erge et al., 2008). Changing the lightness of pineapple paste occurred from many factors such as quality of raw materials, temperature and processing time, etc. In general, pineapple have a chemical composition consisting of moisture, protein, fat, carbohydrates, dietary fiber, vitamins, minerals, organic acids, sucrose, glucose and fructose with different according to varieties and harvesting periods. Moreover, chemical composition of pineapple



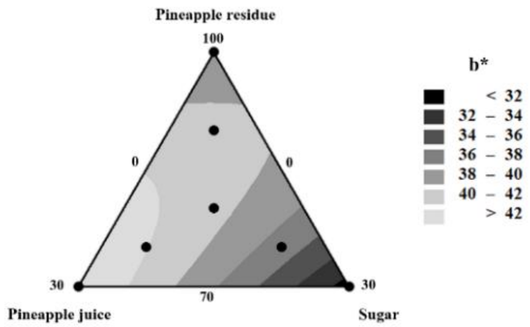


Fig. 1 pH, total soluble solids content and color of pineapple paste by a 3-component mixture design

and sugar is the main factors which have an effected on the color changes of the pineapple paste. Basically, the Maillard reaction was a form of non-enzymatic browning. It is a chemical reaction between an amino acid and a reducing sugar, usually requiring the addition of heat (Rattanapanone, 2006). Probably, the decrease of lightness value is caused by browning reaction.

The effects of pineapple residues, pineapple juice and sugar on the liking score for seven formulas of pineapple paste were shown in Table 3. The average score from 30 untrained panelists by 9-point hedonic scale including appearance, flavor, taste, texture and overall liking were investigated. The formula 4 consisting of 75 g pineapple residues, 5 g pineapple juice, 20 g sugar, and 0.2 g salt, had the highest score including an appearance (7.33±0.84), flavor (7.03±0.56), taste (7.20±0.89), texture (7.13±0.78) and overall liking (7.10±1.06) which were at a moderate level. This corresponds with the pH, total soluble solid, color and appearance of pineapple paste investigated. The formula 4 is similar to the general pineapple paste in the market. It had appropriate texture and adhesion. In addition, it is a moderately sweet taste.

Table 3 The liking score (n = 30) for seven formulas of pineapple paste

Formulas	Appearance	Flavor	Taste	Texture	Overall liking
1	5.90±0.71^{b}	5.90±0.66^{b}	4.20±0.71^{c}	4.67±0.76^{b}	4.73±0.78^{b}
2	3.40±1.90^{d}	5.20±1.40^{c}	3.13±1.25^{d}	2.80±1.45^{d}	3.13±1.20^{c}
3	4.23±1.52^{c}	5.37±1.13b^{c}	4.10±0.96^{c}	3.80±1.13^{c}	4.67±1.12^{b}
4	7.33±0.84^{a}	7.03±0.56^{a}	7.20±0.89^{a}	7.13±0.78^{a}	7.10±1.06^{a}
5	4.63±1.67^{c}	5.53±1.22^{bc}	5.10±1.18^{b}	4.50±1.48^{b}	4.93±1.34^{b}
6	4.20±1.88^{c}	5.53±1.22^{bc}	3.63±1.13^{cd}	3.10±1.56^{d}	3.60±1.22^{c}
7	4.33±1.83^{c}	5.67±0.96^{bc}	3.93±0.94^{c}	3.37±1.52^{cd}	3.70±1.21^{c}

Remark: mean ±SD with different superscripts in each column indicate significant differences ($P \leq 0.05$).

The pH, total soluble solid, color and sensory score were created the contour plot for optimum overlapping (A) of pineapple paste formulas (Fig. 2). The suitable formula was selected from the contour plot. The contour plot for optimum overlapping, pH (3-4), total soluble solid (25-35 0Brix), L * values (50-70), a * values (0-2), b *values (20-40) and sensory score (6-9) were the criteria for selecting suitable formula. The different factor levels (low-high) was the optimal range of pineapple paste that obtained from testing and compared with commercial samples. The results show that optimum overlapping (A) is a suitable area for pineapple paste production (Fig. 2). Formula 4 is in the overlapping area. The optimum proportion of pineapple residues, pineapple juice and sugar are 75, 5 and 20%, respectively. Obviously, pH, total soluble solid, color and the average score of sensory evaluation were taken into consideration together. All in all, the formula 4 was selected to produce gluten-free pie products in the next step.

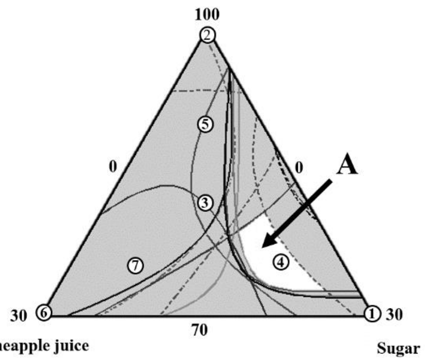


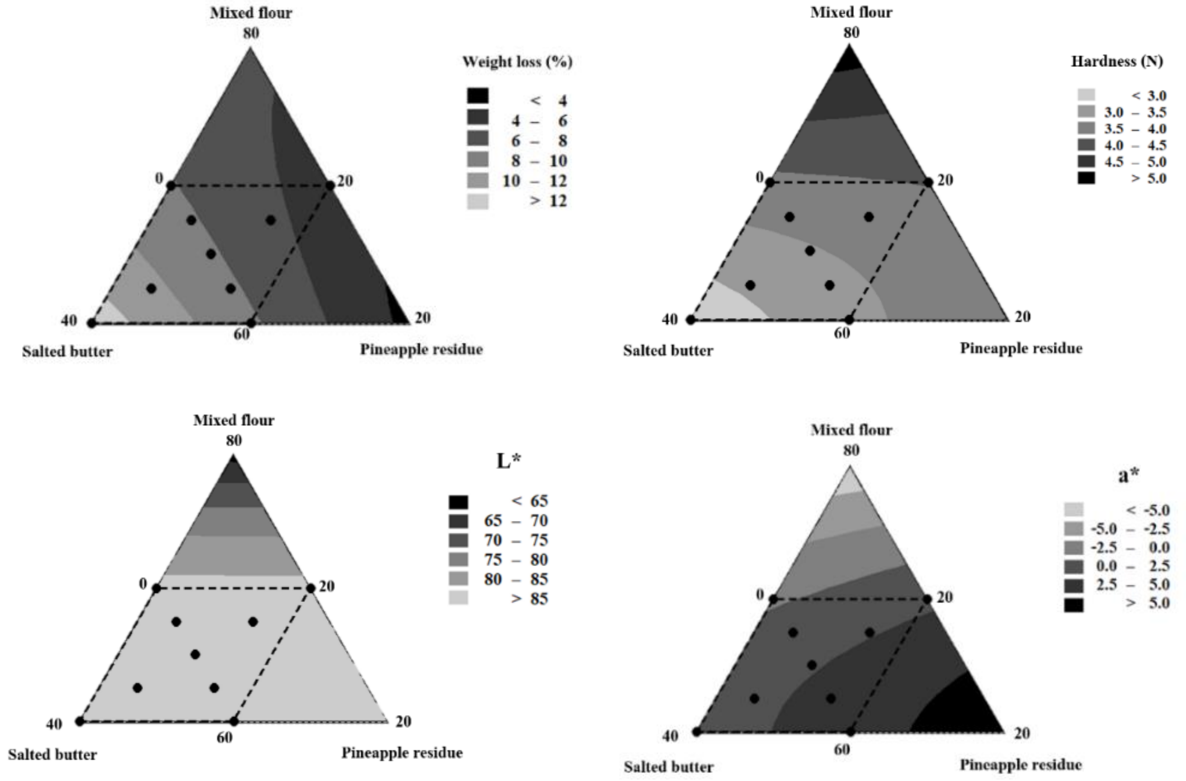
Fig. 2 Contour plot for optimum overlapping (A) of pineapple paste formulas

2. Properties and sensory evaluation of gluten-free pineapple pie

Weight loss, hardness and color of gluten-free pie products with a 3-component mixture design is shown in Fig. 3. The results shown that color of gluten-free pineapple from seven formulas have significant differences of the 95% confidence interval when $P \leq 0.05$. The weight loss varied directly with the amount of salted butter. Obviously, the moisture or free water in the structure of pies which decreased during baking was the main cause of weight loss of pies. The heat transfer, expansion, changing of structure and texture occurred during pie production (Kotoki & Deka, 2010). In this case, a large amount of salted butter was used of pie production. Therefore, the mixed composition of pie products had a high starting moisture content before baking and the moisture or free water in the structure of pies was removed. During baking of pies, the mass was transferred from the surface of pies and especially the surface area of pie was high temperature. Consequently, the free water in the pie structure evaporated which resulted in weight loss during baking.

The hardness of pies after baking from the surface mixture response surface contour plots is shown in Fig. 3. The hardness of the pies increased with an increase in the amount of mixed flour. Obviously, if the solid ingredients in the mixture increased, the hardness of pies increased. As a result, mixed flour was a dry powder that had the ability to absorb water well. At this point, if the mixed flour was added at the optimum ratio, pies had appropriate texture. However, there was a small number of mixed flours in the formula. It absorbed lots of water and had difficulty forming. In contrast,when a large number of mixed flours was in the formula, the amount of water in the mixture was limited. This resulted in the flour not absorbing the water fully. Thus, pies had very high hardness. The results corespond with the results of Luangsakul et al. (2012). Where the effects of wheat flour on the quality of fortune cookies was reported. The hardness of fortune cookies varied directly with the amount of wheat flour.

The color of pies after baking from the surface mixture response surface contour plots is shown in Fig. 3. The L* value varied directly with the amount of mixed flour. The a* value was the red range, and b* value was the yellow range. The a* and b* value varied directly with the amount of pineapple residues. Moreover, the tendency of gluten-free pie product was yellow-red color. These occurred during the baking of pies in the oven. In terms of heat transfer, both convection and radiation were transferred from the oven to the surface of pies. Consequently, it was transferred to inside of pies by conduction during baking. At the same time, mass transfer from the surface of pies caused a high temperature in the structure of pies, and the free water in pies structure evaporated. Subsequently, changing the quality of pies occurred including gelatinization of starch, protein denaturation, expansion of pies, hardness of pies crusts, air holes of pies, and brown color. Color changes of pies may occur by Maillard reaction that was non-enzymatic browning reaction. In theory, it was a reaction between proteins or amino acids and sugar under high temperature conditions (Rattanapanone, 2006). Moreover, the color of pies also depends on the composition of pigment in raw material that are used to produce the pies. Chlorophyll and carotenoid pigments presented in the pineapple as described earlier (Panyamongkol, 2017). Therefore, the b * value was the yellow range. Furthermore, the yellow color of salted butter was observed that it was the dairy product. The color of salted butter appears to be dictated by the concentrations of β-carotene and other compounds and pigments, deposited into the lipid phase of the milk from the cow's ingestion of green, grassy materials (Paine, 2013).



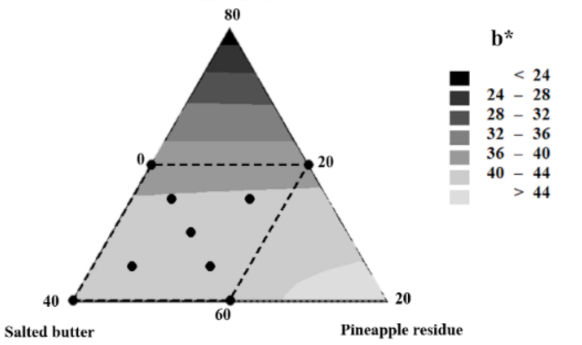


Fig. 3 Weight loss, hardness and color of gluten-free pie products by a 3-component mixture design

The effect of mixed flour, salted butter and pineapple residues in pies on sensory evaluation was investigated (Table 4). The average score from 30 untrained panelists by 9-point hedonic scale including appearance, flavor, taste, texture and overall liking were investigated. The results show that the formula 8, consisting of 70% mixed flour, 20% salted butter and 10% pineapple residues had the highest score including an appearance (7.50±0.78), flavor (7.80±0.76), taste (7.70±0.65), texture (7.53±0.86), and overall liking (7.63±0.85) which were at a moderate level.

Table 4 The liking score (n = 30) for nine formulas of gluten-free pie products

Formulas	Appearance	Flavor	Taste	Texture	Overall liking
1	6.20±0.41^{d}	7.10±0.71^{bcd}	7.20±0.71^{abc}	6.23±0.97^{c}	6.37±0.49^{c}
2	6.33±0.61^{cd}	6.70±1.12^{cde}	7.00±0.98^{bc}	6.37±0.85^{c}	6.57±0.68^{bc}
3	6.40±0.67^{cd}	7.00±0.64^{bcd}	7.13±0.68^{bc}	6.37±1.13^{c}	6.57±0.68^{b}
4	6.40±0.62^{cd}	6.57±1.19^{de}	7.10±0.92^{bc}	6.43±0.90^{c}	6.70±0.75^{bc}
5	5.63±1.03^{e}	6.17±1.32^{e}	6.33±1.56^{d}	4.07±1.41^{d}	4.53±2.00^{d}
6	6.33±0.61^{cd}	7.23±0.77^{bc}	7.37±0.76^{abc}	6.50±1.14^{bc}	6.57±0.68^{bc}
7	7.00±0.91^{b}	7.27±0.69^{b}	7.50±0.68^{ab}	7.00±0.91^{b}	7.03±0.85^{b}
8	7.50±0.78^{a}	7.80±0.76^{a}	7.70±0.65^{a}	7.53±0.86^{a}	7.63±0.85^{a}
9	6.73±0.83^{bc}	6.30±1.29^{e}	6.90±0.92^{c}	6.23±0.86^{c}	6.57±0.86^{bc}

Remark: mean ±SD with different superscripts in each column indicate significant differences ($P \leq 0.05$).

The weight loss, hardness, color and sensory evaluation were created to contour plot for optimum overlapping (A) of cookie formulas (Fig. 4). The suitable formula was selected from the contour plot. The contour plot for optimum overlapping, weight loss (0-6), hardness (3-5 N), L* values (70-90), a* values (1-3), b* values (30-59) and sensory score (6-9) were the criteria for selecting suitable formula. The different factor levels (low-high) was the optimal range of pies that obtained from testing and compared with commercial samples. The results showe that the optimum overlapping (A) was a suitable area for pies production (Fig. 4). Formula 8 was in the overlapping area. Mixed flour, salted butter and pineapple residues were 70%, 20% and 10%, respectively. Obviously, weight loss, hardness, color and the average score of sensory evaluation were taken into consideration together. All in all, the formula 8 was selected for gluten-free pie products (Fig. 5). In addition, the chemical composition of pies in formula 8 was analyzed. It was found that the gluten-free pie products had a moisture content (30.5±0.3%), protein (6.1±0.2%), fat (12.9±0.1%), carbohydrate (49.0±0.2%) and ash (1.5±0.2%), respectively. Specifically, the changes for adding pineapple residue in mixed flour was observed. Pineapple residue helps increase dietary fiber of pies. The following are the characteristics of gluten-free pie products. It is easily broken, if the very high content of pineapple residue was added. Presumably, chemical composition in pineapple residue may decrease the strength of mixed flour structure. However, the properties of gluten-free pies in this research are similar to the original pies that are made from wheat flour. It is an alternative product for consumers who want to avoid gluten-containing foods.

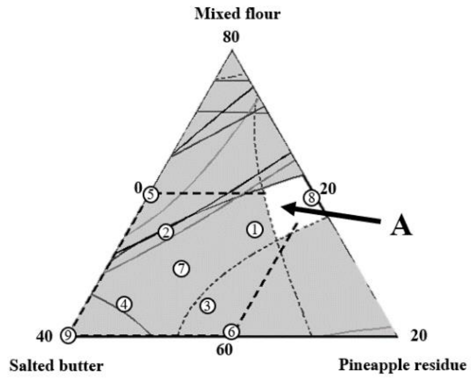


Fig. 4 Contour plot for optimum overlapping (A) of gluten-free pineapple filled pie formulas

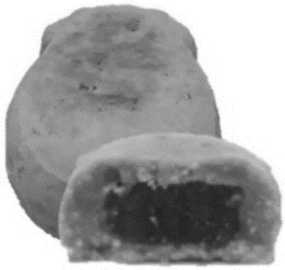


Fig. 5 Appearance of gluten-free pie products

Conclusion

The pineapple residue is the by-products of the pineapple processing industry that contains nutrients such as fiber and vitamin. Specifically, it is a good choice of low-cost ingredient for producing pineapple paste and gluten-free pie products that add value to the agricultural industry. The appropriate formula for pineapple pastes production from pineapple residues is a formula consisting of pineapple residues, pineapple juice and sugar in the range of 75%, 5% and 20%, respectively. In terms of pies, the suitable formula for producing gluten-free pie product is a formula with a mixture of flour, salted butter and pineapple residues, 70%, 20% and 10%, respectively. In total, the knowledge gained from this study can be used as a guideline for value adding process of pineapple residue in healthy food products that can be extended to commercial production in the future.

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