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Production and Shelf-Life of Low Sucrose Lime Juice Papaya Jam

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Abstract: Consumers are becoming more aware of the deleterious effects of a high-sucrose diet. This research developed low sucrose jam from ripe papaya meat and green lime juice. The shelf-life was studied: (A) in a refrigerator, (B) at room temperature with preservatives added and (C) at room temperature with steaming after filling. The developed jam was composed of 32% papaya, 8% lime juice, 0.55% low ester pectin, 0.5% konjac flour, 9% glucose syrup, 0.03% salt and 0.01% calcium lactate and consisted of 52.10% moisture, 45.61% total carbohydrate, 0% fat and 1.52% dietary fiber with only 7.71×10^5 J/100 g. It contained 36.46% sucrose, 46°B total soluble solids and had a pH of 3.22. The average sensory evaluation score was moderate preference and 79.31% of consumers liked it. The shelf-life of jam from A and B methods was more than six months but the C method was only five months.

Key words: Low sucrose jam, lime, papaya, low ester pectin, konjac flour

INTRODUCTION

Diets that are high in sugars is correlated with a great weight gain, increased risk for development of type 2 diabetes increased risk of metabolic syndrome (Schulze *et al*., 2004; Apovian, 2004; Gross *et al*., 2004), may increase carcinogenesis by stimulating the synthesis of insulin and insulin-like growth factor-I (IGF-I) (Kaaks and Lukanova, 2001) and inducing oxidative stress (Ceriello *et al*., 1999). Sucrose is a kind of sugar that is a pure carbohydrate comprising fructose and glucose and has an energy content of 1.6548×10^4 J/g. Today's increasingly health-conscious consumers demand foods that are especially low in sugar content. Papaya (*Carica papaya* L.) fruit is planted and consumed widely throughout Thailand and the world. It is a good source of vitamin A (2020 IU/100 g) approaching that of mango (2500 IU/100 g) and is also a source of other vitamins such as thiamine, riboflavin, nicotinic acid and ascorbic acid, contains 9% of the Dietary Reference Intake (DRI) for Cu and 6-8% of the DRI for Mg (Wall, 2006). Ripe papaya in Thailand is usually consumed fresh but is also processed into many kind of foods such as canned papaya in syrup, fruit cocktail, dehydrated fruit and frozen papaya (Nongnuch, 2003).

Jam is a semi-solid food preservation made from fruit added with high sugar amounts of about 58-61% for preservation and a longer shelf-life. According to Thai FDA (Ministry of Health, 2000), the TSS (total soluble solids) content of jam, mostly from sugar, is not less than 65% by weight. There has been no papaya jam available in the markets of Thailand but papaya jam has been many researches of mixed fruits as ripe papaya with lime or tangerine or pomelo (Teangpook *et al*., 2004), ripe papaya with carambola and pineapple (Abdullah and Cheng, 2001), bean and ripe papaya pickle (Tomio, 1989), ripe papaya with orange (Kouzou, 1982), ripe papaya with star apple or plum (Aina and Adesina, 1990) and ripe papaya with pineapple (Badrie and Barbaste, 2000), mainly because the odour of ripe papaya is not highly charming (Sharma *et al*., 2008) and emits a bad flavor when it comes to cooking (Teangpook *et al*., 2004) so pure papaya jam from unripe papaya fruit was developed (Rattanakoson *et al*., 2007). Pectin (E440) is a complex structure with an α-(1→4)-linked D-galacturonic acid polysaccharide backbone grouping of acidic structure; it is found in fruit and vegetables. Functionally, pectin is mainly used as a gelling agent, but it can also be a thickener, water binder and stabilizer. Low methoxyl pectins (<50% esterified) form thermo-reversible gels in the presence of calcium ions and at low pH (3-4.5) whereas high methoxyl pectins rapidly form thermo irreversible gels in the presence of sufficient (for example, 65% by weight) sugars such as sucrose and at low pH (<3.5) (Chaplin, 2012).

Konjac flour (KF) (E425) is a non-ionic, relatively rigid gelling agent and a naturally partially acetylated polysaccharide possessing a mixed (1→4)-linked β-D-mannopyranose/β-D-glucopyranose backbone with about 8% β-(1→6)-glucosyl branch points (Katsuraya*et al*., 2003) extracted from the tuber of Amorphophallus konjac C. Koch (Tye, 1991). It forms highly viscous solutions when dissolved in water and so has capability

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use as a thickener for gravies, soups and sauces and enhancing the rheological properties with xanthan gum, kappa carrageenan and starches (Nishinari *et al*., 1992). Xanthan gum (XG) (E415) is a polymer produced by aerobic, submerged fermentation of Xanthomonas campestris (Palaniraj and Jayaraman, 2011). XG is an anionic polyelectrolyte with a β-(1→4)-D-glucopyranose glucan backbone with side chains of -(3→1)-α-linked D-mannopyranose -(2→1)-β-D-glucuronic acid-(4→1)-β-D-mannopyranose on alternating residues (Chaplin, 2012).

Carrageenan (E407) is a collective term for polysaccharides extracted from red seaweeds. Kappa carrageenan (KC) is isolated mostly from the tropical seaweed Kappaphycus alvarezii with a molecular structure of -(1→3)-ß-D-galactopyranose-4-sulfate-(1→4)-3,6-anhydro-α-D-galactopyranose-(1→3)- (Chaplin, 2012). KC is popular as a gelling agent in desserts because it has negatively charged sulfate groups (Snoeren *et al*., 1975).

The objective of the current research was to study the production, quality and shelf-life of low sucrose jam made from ripe papaya flavored with unripe, green lime juice.

MATERIALS AND METHODS

Raw materials: Khakdam papaya (*Carica papaya* Linn.), 70-80% ripe was used with an average weight (from 10 fruits) of 857.04 g/fruit and average blended meat was TSS using hand refractometer (Atago) = 9.70°B, pH with pH meter (Orion Model 410A) = 4.86 and its color using Data Color International Measurement Model Color (Spectraflash 600 plus, USA) Tools for CIE values (Commission International de l'Eclaerage) at D65 10 Deg (Light source Illuminant D), recorded as L* = lightness (0 = black, 100 = white), a* (-a* = greenness, + a* = redness) b* (-b* = blueness, + b* = yellowness) of L* = 55.19, a* = 34.09 and b* = 44.75. Unripe green lime (*Citrus aurantifolia*) was used with an average weight (from 10 fruits) of 42.75 g/fruit and average blended meat and juice with 8.25°B TSS, pH = 2.06, L* = 85.35 a* = 2.36 and b* = 13.55. All fruit were obtained from the See Mum muang market, Pathum Thani province, Thailand. LP (GENU pectin type LM-104AS, 31% of degree of esterification, 17% of degree of amidation, extracted from citrus peel) was obtained from Food and Cosmetic Ltd. KF, XG and KC were obtained from APK Food Ingredients. Calcium lactate pentahydrate powder, potassium sorbate and sodium benzoate were obtained from Thai Food and Chemical Co., Ltd. White sucrose, glucose syrup (dextrose equivalent = 42.0%) and sodium chloride were purchased from a local market.

Papaya flesh and lime juice preparation: Each papaya fruit was washed and the peel removed and the seeds taken out. The meat of the papaya was blended in an electric blender and then it was packed in a plastic bag and kept at -18°C. The limes were washed and the skin removed and the peeled limes were then cut in half, squeezed for the collection of juice and the seeds removed by passing the juice through a colander after which the juice was packed in a plastic bag and kept at -18°C.

Steps in jam production: Using a gas stove, there were six steps in the jam production under constant stirring: (1) LP-KF-XG and KC colloidal preparation (with protection against clumps forming) by mixing LP-KF-XG and KC with about six times their weight of white sucrose and then twice their weight of water was added and mixed; (2) blended papaya meat was put into a stainless steel pot and heated until it had boiled for about 3-5 min; (3) Residual white sucrose and sodium chloride were added and heated and the mixture was heated until it boiled; (3) The LP-KF-XG and KC colloidal preparation was added and the mixture heated until it boiled; (4) glucose syrup, calcium lactate and lime juice or preservative (if included) were added and the mixture heated until it boiled; (5) The amount of soluble solids was checked with a refractometer until it was about 45-46°B; (6) the sample was poured quickly into sterile glass bottles (steamed on a gas stove for 5 min), the lids (steamed on a gas stove for 5 min) were tightly closed at 80-85°C and then the bottles were allowed to cool at room temperature.

Effect of KF, XG and KC: The experiment was conducted using a completely randomized block design (RCBD) with two replications. The three treatments were studied by replacing white sucrose with: (1) 0.4% KF, (2) 0.2% KF and 0.2% XG and (3) 0.2% KF and 0.2% KC. Every treatment used 32% blended papaya, 8% lime juice, 0.2% LP, 9% glucose syrup, 0.03% sodium chloride, 0.01% calcium lactate and 36% sucrose of finished product weight. The products were analyzed for TSS, pH and color value. Twenty trained panelists (aged 22-58 year), who were staff members of the Institute of Food Research and Product Development, evaluated the samples for their sensory attributes with bread using Quantitative Descriptive Analysis (QDA), where on a scale of 0-5, 0 = no intensity, up to 5 = very strong intensity in color, odor, sweetness, sourness and thickness. Thirty untrained people (aged 20-58 year) evaluated samples with bread for liking using a hedonic scale of 1-7, where 1 = dislike very much, up to 7 = like very much. Data were subjected to analysis of variance of the RCBD and Duncan's new multiple range test for inspection of mean differences at a significance level of 0.05, using the SPSS version 12 statistical software (now a part of IBM Corp.; White Plains, NY, USA).

Optimum levels of LP: LP levels of 0.45, 0.55 and 0.65% of the finished product weight were studied by replacing white sucrose in a RCBD with two replications. All treatments used 32% blended papaya, 8% lime juice, 0.5% KF, 9% glucose syrup, 0.03% salt and 0.01% calcium lactate of the finished product weight. The products were analyzed as above except for the sensory evaluation which used only liking.

Quality of the developed jam product: The optimum jam product was analyzed for moisture (T-CM-002 based on AOAC 2000, 925.45), fat (T-CM-075 based on AOAC 2000, 989.05), protein (TCM-003 Kjeldahl method, based on AOAC, 2000, 991.20 using 6.25 as the conversion factor), dietary fiber (T-CM-076 based on AOAC, 2000, 985.29), ash (T-CM-001 based on AOAC, 2000, 938.08) and carbohydrate contents (using the calculation 100-% moisture-% fat-% protein-% ash), with two replications. The product was evaluated for liking and for purchase by 117 general consumers.

Shelf-life of the developed jam product: The shelf-life of the optimum product was studied for six months. The three methods of storage were: (A) samples kept in the refrigerator at 4-8°C; (B) samples kept in a dark drawer at room temperature with preservative reagents (0.04% sodium benzoate and 0.04% potassium sorbate) and (C) samples kept in a dark drawer at room temperature with steaming for 5 min after rapid filling. All products were examined every month for color, pH, TSS, ascorbic acid (AOAC, 1995, 967.21 using 3% metaphosphoric acid and titrated with 2,6-dichlorophenol iodophenol (DCPIP), microbiology tests of total plate count (Maturin and Peeler, 2001), yeast and mold (Tournas *et al*., 2001), Coliform bacteria (Feng *et al*., 2002), Staphylococcus aureus (Bennett and Lancette, 2001) Clostridium perfringens (Rhodehamel and Harmon, 2001), *Salmonella* sp., (ISO 6579, 2002), Bacillus cereus (Tallent *et al*., 2001), beta-carotene (T-CM-011, based on Munzuroglu *et al*., 2003), reducing sugar (Lane and Eynon method, Atkinson and Strachan, 1941) and evaluated samples with bread for liking using a hedonic scale as detailed as above.

RESULTS AND DISCUSSION

The jam had TSS about 46% of less than 65% because it was low in sucrose and so it used the LP as a gelling agent; however from pre-experimental work, it was found that the texture of this jam was not firm and not viscous so the calcium ions from small amounts of added calcium lactate helped to firm the gel and was better than calcium chloride which imparted undesirable bitterness (Luna-Guzman and Barrett, 2000) although this jam used amidated-LP that needs less calcium to gel and is less prone to precipitation at high calcium levels (May, 1990). Glucose syrup, having a very sticky characteristic, was added to increase the viscosity of the jam texture, to reduce the water activity and to protect sugar crystallization (Farahnaky *et al*., 2010). Furthermore, KF, XG, KP and LP were used to study options for better gelling.

Effect of KF, XG and KP: The differences in color among treatments were slight, with the lowest lightness of the KC treatment with L* values of 65.83, 74.95 and 51.84 for the 0.4% KF, 0.2% KF+0.2% XG and 0.2% KF+0.2% KC, respectively. The intensity of the flavored jam is shown in Fig. 1. It was found that only the thickness was significantly different. Jam with added KC had the greatest thickness with strong intensity while the others had moderate intensity. The results of the sensory evaluation by liking are shown in Fig. 2. The color, odor

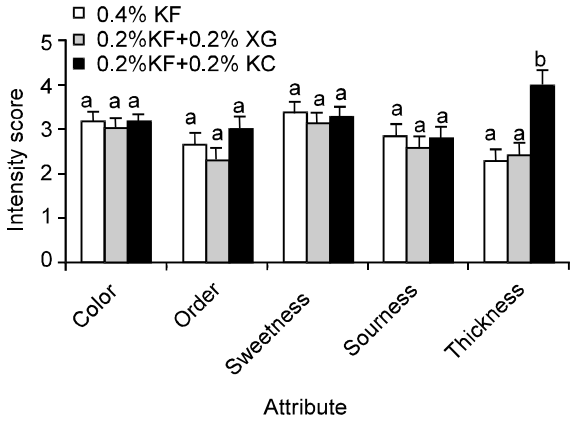

Fig. 1: Intensity of jam using QDA sensory evaluation. For comparison between treatments, the different lower case letter above a bar indicates that such a mean value is significantly different ($p \leq 0.05$). (The error T bar indicates the upper range of the mean plus the standard deviation)

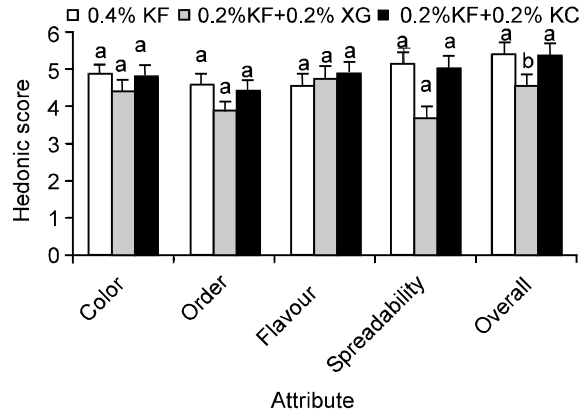

Fig. 2: Sensory evaluation quality of jam. For comparison between treatments, the different lower case letter above a bar indicates that such a mean value is significantly different ($p \leq 0.05$). (The error T bar indicates the upper range of the mean plus the standard deviation)

and flavor were not significantly different, except for the spread ability and overall, the treatments of 0.4% KF and 0.2% KF+0.2% KC were not significantly different. The jam with XG added had the lowest score because it was not set. XG has a high molecular weight and its formation of aggregates via hydrogen bonds (Argin-Soysal *et al*., 2009) resulted in a solution showing high viscosity (Viebke and Williams, 2000) so it was suitable as a thickener and stabilizer of emulsions (Shen *et al*., 2010) but, it does not form gels even at high concentrations (Maier *et al*., 1993). However this jam contained LP, XG and KF, so their proportions may not have been suitable because XG can produce synergistic interactions with KF (Katsuraya *et al*., 2003) and pineapple jam comprising 55% fruit with 1.1% aspartame was produced using 50:50 ratio of KF:XG (Akesowan, 1996). The gel of the treatment with KF+KC was brittle, resulting in the spread ability being recorded as difficult. This was mainly caused by the KC gel characteristics (Snoeren *et al*., 1975). At high temperature, the KC polymer is a coil; when it is cooled, it converts to a double helix leading to gelation (Hjerde *et al*., 1998), so it is suitable for making better jelly as jelly with 1% of KF and carrageenan in a ratio of 50:50 (Srisamatthakarn *et al*., 2005). Tye (1991) reported that gel of KF and carrageenan in a 50:50 ratio was stronger than at 70:30. The 0.4% KF treatment gained the highest score being little like, so the quantity of KF and LP in this research must be improved. This result was consistent with Nitimongkonchai (2002) who used 0.55%KF mixed with pectin at a ratio of 1:2 to improve the cohesiveness of the gel of Leb Mu Nang banana jam because KF and LP can improve the structure of the gel.

Optimum level of LP with KF 0.5%: KF is a dietary fiber that many health benefits to have effects in lowering cholesterol concentrations (Arvill and Bodin, 1995; Terasawa *et al*., 1979), triglycerides and systolic blood pressure (Arvill and Bodin, 1995) and glycemia (Doi *et al*., 1979; Shima *et al*., 1982) so the aim of this paper was to add more KF. However a level of just 0.5% was considered a lot because it makes the jam hard to spread because it produces a very viscous solution with water at room temperature (Kato and Matsuda, 1969). The optimum LP quantification determined by the results of the sensory scores in Fig. 3, (though they were not significantly different in color, odor and flavor but were in the spread ability and overall) was 0.55% LP with the highest score being moderately like. Consequently, 0.55% LP was selected for the best formula. This papaya jam used a low amount of pectin because ripe papaya meat has a higher pectin concentration of about 1.84% by dry weight in calcium pectate (Carrea and Haynes, 1922). The correlations between color, odor, flavor, spread ability and overall impression are shown in Table 1 with all attributes showing a high correlation,

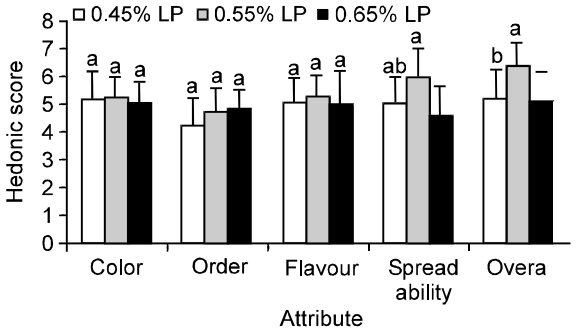

Fig. 3: Sensory evaluation quality of jam with different LP levels. For comparison between treatments, the different lower case letter above a bar indicates that such a mean value is significantly different ($p<0.05$). (The error T bar indicates the upper range of the mean plus the standard deviation)

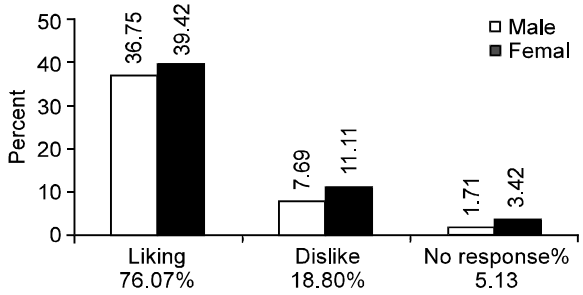

Fig. 4: Consumer liking percentage of developed jam product

especially flavor and overall impression. The correlations indicated that flavor was the most important attribute of the jam.

Quality of the developed jam product: The optimum product was composed of 0.55% LP, 0.50% KF, 36.46% white sucrose, 9% glucose syrup, 0.03% salt, 0.01% calcium lactate and 22.45% water. Total soluble solids, pH, L*, a*, b*, titration acidity (citric acid), reducing sugar, vitamin C, beta-carotene and a_w were 46°B, 3.22, 66.63, 23.70, 45.24, 0.62 and 11.45%, 38.42 mg/100 g, 46.46 µg/100 g and 0.90, respectively. The product consisted of moisture, protein, total carbohydrate (not including dietary fiber), ash and dietary fiber in amounts of 52.10, 0.26, 45.61, 0, 0.51 and 1.52%, respectively. Interestingly, the jam had no fat at all. The average score for overall laboratory sensory evaluation was moderate preference. The results of consumer testing of the product with bread using 117 consumers from the general public aged from 19 to 65 years are shown at Fig. 4 and 5. The consumers liked the jam product with their reasons being: good flavor and color, low sweetness, high benefit and very strange jam product that was not found in Thai market, while reasons given

Table 1: Pearson correlation coefficients of sensory evaluation at probability levels of a Significant difference of ($p \leq 0.05$) (*) and ($p \leq 0.01$) (**)

	Color	Odor	Flavor	Spread ability	Overall
Color	1				
Odor	0.530**	1			
Flavor	0.498**	0.584**	1		
Spread ability	0.473**	0.386**	0.578**	1	
Overall	0.460**	0.440**	0.738**	0.627**	1

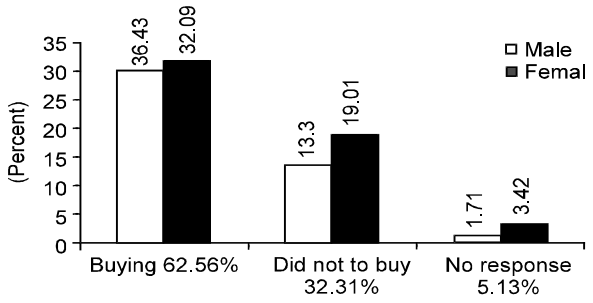

Fig. 5: Consumer buying percentage of developed jam product

by consumers for not liking it with their reasons being: low flavor, bad odor and very sour taste. Consumers wanting to buy it because it was a new product and a high benefit jam while the consumers who did not want to buy it because it had a bad smell. Some consumers (5.13%) did not reply to the questions asking whether they liked or would buy the jam.

Shelf-life of the developed jam product: Results of the monthly sensory evaluation by the panelists of the jam from the three storage methods are shown in Fig. 6. After the first to the fourth month of storage, all attributes of all three methods had scores that were not significantly different but after the fifth month, the scores for flavor of the C method were lower than those of the A method and after the sixth month, the scores for color and overall of the C method were lower than those of the A and B methods which suggested that the jam stored using the C method could be kept for only five months, while the jam from the two other storage methods could be kept for more than six months.) Titration acidity as citric acid (0.63-0.70%), pH (3.05-3.50), TSS (45.50-47.18°B) and a_w (0.88-0.92) were not significantly different among methods for every month and had not changed at the end of the storage period. The microbial organism levels of all methods of each month were the same results and still within the safe range set down for jam products (Ministry of Health, 2000) as $\leq$ (none) colony forming units per gram (cfu/g) for the total plate count (TPC) and yeast and mold, < 3 most probable numbers/g of coliform bacteria, none cfu/g for *Staphylococcus aureus* and *Bacillus cereus* and not detected for *Clostriduum perfringens*/0.1 g and *Salmonella* sp./25 g because the jam was stored in hermetically sealed jars and kept in a refrigerator in the A method and with the addition of 0.08% preservatives by weight in the B method. Thai FDA regulations specify that preservatives are not allowed to exceed 0.1% by weight (Ministry of Health, 2000). The C method involved steaming after filling which was sufficient to kill any microbial organisms that might have contaminated the jam during filling by hand.

Vitamin C or L-ascorbic acid or ascorbate is an essential nutrient for humans and it is water-soluble and a good free radical scavenger (Buettner *et al*., 1993). The vitamin C content is shown in Fig. 7. This jam had vitamin C from the papaya meat and lime juice with about 75.7-78.8 and 23.6-35.2 mg/100 g fresh, respectively (Diop *et al*., 1988). In all three storage methods, the amount of vitamin C decreased with increasing storage period with values of 33.57, 42.22 and 74.38% for the A, B and C method respectively. The A method had the highest value and the slowest level of decreasing because it was kept in the refrigerator at a lower temperature (about 4-7°C) than the others (30-38°C). The L-ascorbic acid content (53-58%) decreased in low-sugar bilberry jam after thermal processing and storage at 20°C (Poiana *et al*., 2012). It should be noted that the starting level was different in the three storage methods, especially in the C method where the starting level was lowest because the jam was steamed again after filling, followed by the B method that was kept at room temperature with added preservatives. Oxygen causes vitamin C to degrade, even though the oxygen content was low in the hot jam during filling; in addition, fructose can also cause vitamin C to break down but a higher level of citric acid can protect from vitamin C loss (Padayatty *et al*., 2003). The loss in vitamin C content during steaming of the C method and keeping at room temperature of the B and C method could be attributed to the fact that vitamin C is not stable at high temperature (Nagy and Smooth, 1977; Dewanto *et al*., 2002).

Beta-carotene, its role as a potent vitamin A precursor, gives vitamin A value of 1667 IU/mg (Johnson and Peterson, 1974). Fig. 8 shows the amount of beta-carotene from the papaya meat and under all three methods its level deceased with increasing storage period by 13.86, 31.75 and 20.77% for the A, B and C methods, respectively. This was similar to the decrease in the vitamin C content, especially under the C method. According to the decreasing of beta-carotene content in freeze-dried mangoes during storage (Harnkarnsujarit and Charoenrein, 2011). Harirutsaree and Keeratipibul (1995) found that there was a lower loss of stability of an extract of carotenoid stored at low temperature than at high temperature because heat and oxygen cause an oxidation reaction.

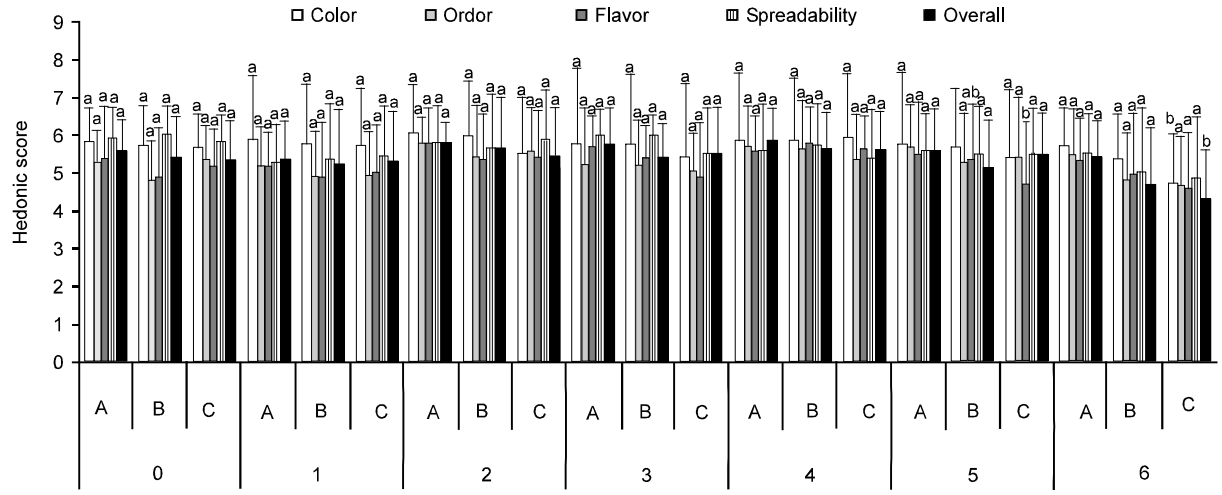

Fig. 6: Sensory evaluation quality of jam under different storage methods. For comparison between methods for each month, the different lower case letter above a bar indicates that such a mean value is significantly different ($p \leq 0.05$). (The error T bar indicates the upper range of the mean plus the standard deviation)

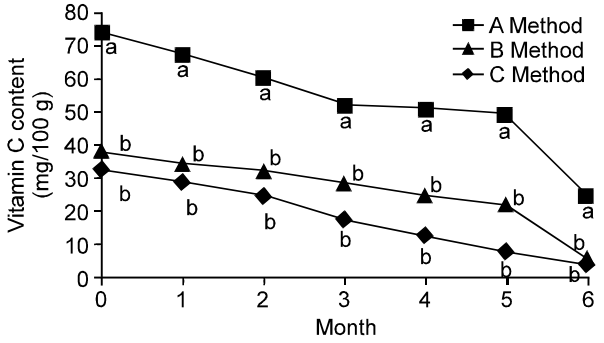

Fig. 7: Vitamin C content of jam under different storage methods. For comparison between methods for each month, the different lower case letter above a bar indicates that such a mean value is significantly different ($p \leq 0.05$). (The error T bar indicates the upper range of the mean plus the standard deviation)

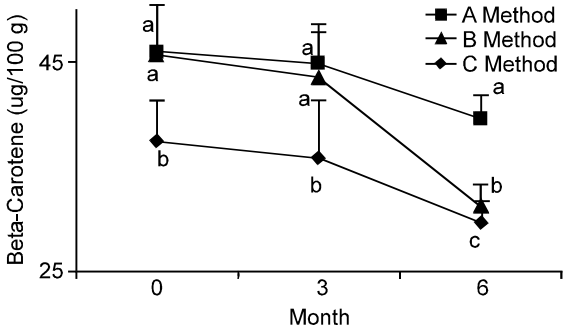

Fig. 8: Beta-carotene content of jam under different storage methods. For comparison between methods for each month, the different lower case letter above a bar indicates that such a mean value is significantly different ($p \leq 0.05$). (The error T bar indicates the upper range of the mean plus the standard deviation)

The reducing sugar content is shown in Fig. 9. It could be explained by a partial hydrolysis of sucrose during cooking (Pearson, 1976). The reducing sugars help to reduce the crystallization phenomenon of the jam because they have more affinity for water than sucrose (Cheftel and Cheftel, 1976). Mostly, there was an inversion of added disaccharide sucrose comprised of monosaccharides such as glucose and fructose by hydrolysis reaction with heating and this was accelerated by the citric acid from the lemon juice. Levels increased with all three storage methods with 71.60, 174.06 and 103.53% of A, B and C method, respectively. The increasing of reducing sugars of jams noted by after 60 days of storage, except for pineapple-banana jam and orange-banana jam (Singh *et al*., 2009).

For color, the a* value was the most important because this jam was a red color and a* was the only color that decreased (Fig. 10) in every method but there was no significant difference between methods. The decrease in the a* color may have been caused by the increase in the amount of reducing sugar that was combined with the available amino acids and produced browning products from a maillard reaction which provided the dark color to the jam. The L* (64.80-70.70) and b* (44.38-49.62) color values were not significantly different between methods in every month of storage and had not changed at the end of the study.

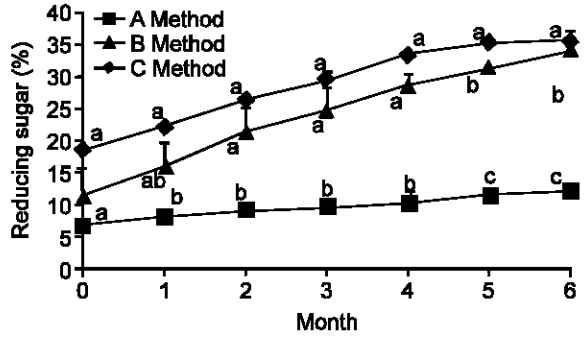

Fig. 9: Reducing sugar of jam under different storage methods. For comparison between methods for each month, the different lower case letter above a bar indicates that such a mean value is significantly different ($p \leq 0.05$). (The error T bar indicates the upper range of the mean plus the standard deviation)

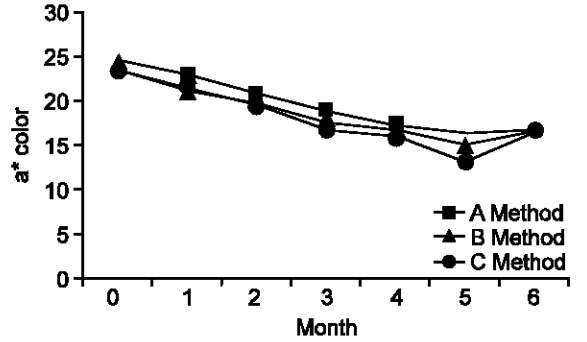

Fig. 10: The a* color of jam under different storage methods. For comparison between methods for each month, the different lower case letter above a bar indicates that such a mean value is significantly different ($p \leq 0.05$). The error T bar indicates the upper range of the mean plus the standard deviation

Conclusion: The developed low sugar jam made from papaya meat and lime juice was accepted from lab scale panelists and general consumers so it is interesting opportunity to produce for a commercial product in response to the health consumers.

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