Effects of Replacement of Sucrose by Maltitol on the Physicochemical and Sensorial Properties of Rose Apple Jam

Natthaporn Chatchavanthatri, Tiraporn Junyusen, Weerachai Arjharn, Pornpimol Moolkaew, and Siriporn Sornsomboonsuk
School of Agricultural Engineering, Institute of Engineering, Suranaree University of Technology, Nakhon Ratchasima, Thailand
Email: {chat.natthaporn, jaeminxiah, miwfullsiriporn}@gmail.com, tirapo@sut.ac.th, arjhan@g.sut.ac.th

***Abstract*—This study investigates the effects of replacement of sucrose by maltitol on the quality properties of rose apple jams. Three jam formulations were developed, the traditional jam formulation containing sucrose (T1, control), jam formulation prepared by partially (50%, T2) and fully (100%, T3) replacing sucrose with maltitol. The nutritional composition, antioxidant, color, texture, and sensory characteristics were determined. The finding revealed that total sugars and energy value of the T3 jam were significantly reduced compared with those of the T1 jam ($P<0.05$). The energy value of T3 jam was decreased by 35% in relative to T1 jam. The water activity (a_w) and total soluble solids (TSS) content of jams were in the range of 0.76-0.81, and 67-70 °Brix, respectively. Partially (T2) and fully (T3) replacing sucrose with maltitol in jams significantly increased the a_w ($P<0.05$). The use of maltitol significantly increased the lightness (L*) value and reduced the redness (a*) of the jams ($P<0.05$), but minimally altered jam's yellowness (b*). The antioxidant, texture, and sensorial properties showed slightly variations between the prepared jams. Overall, the experimental findings verify the prospects of maltitol as a sweetener in the jam product.**

***Index Terms*—rose apple, jam, maltitol, physicochemical properties, sensory evaluation**

I. Introduction

Jam is an intermediate moisture food, produced from fruit pulp, sugar, pectin, acid, and other ingredients (i.e., flavoring, coloring, and preservatives) [1]. According to CODEX [2], jam product typically should not contain less than 45% fruit, and more than 65% total soluble solids (TSS). Sucrose is one of the most popular sugar contributing to the physiochemical, and sensorial properties of the jam. Sucrose binds water inducing pectin gelatinization and lowering the water activity level close to 0.8 resulting in inhibition of microbial growth [3], [4]. However, high sugar level of jam product providing a high calorific value relates to diabetes and other illnesses such as obesity and hypertension [5], [6]. Reduction of sugar content strongly affects the quality properties and palatability of final jam products. Therefore, the use of non-/low caloric sweeteners (i.e., xylitol, sorbitol, aspartame, stevioside, and sucralose) has been considered as alternative to sucrose. Replacement of sugar by those sweeteners in jam could alter the color, texture, rheology, and consumer acceptance [1], [3]. Vilela *et al*. [3] found that replacement of sucrose by fructose, sorbitol, and fructo oligosaccharides (FOS) in strawberry, raspberry, and cherry jams significantly affected in the parameters measured.

Maltitol is a sugar alcohol (polyol) having a calorific value of 2.0-3.0 kcal/g and 90% of the sweetness of sucrose [7]. It provides very good mouth feel and taste in finished products including chewing gum, candies, chocolates and gumdrops [8], [9]. There is to date no statement on effect of maltitol consumption [7]. The study involving the effects of partial or full replacement of sucrose using maltitol of jam on the physicochemical and sensorial characteristics is still limited. This study thus investigates the effects of replacement of sucrose by maltitol at the level of 50% and 100% on the physicochemical properties of rose apple jams. In addition, sensory attributes (color, flavor, texture, spreadability, and overall acceptance) of rose apple jams were also evaluated.

II. Material and Methods

A. Material

Ripe rose apple (*Syzygium jambos*) fruit was acquired from Nakhon Ratchasima, Thailand. The fruit was washed thoroughly with clean water and cut into small sizes. The seeds were removed and the small pieces were blended and filtered to obtain the clear juice.

B. Preparation of Rose Apple Jam

In this study, three jam's formulations, jams with sucrose (control, T1), jam's with partially (50%) replacing sucrose with maltitol (T2), and jam's with fully (100%) replacing sucrose with maltitol (T3) were tested. Variations of sweetener content in the formulations showed in Table I.

Manuscript received February 20, 2019; revised June 1, 2019.

doi: 10.18178/ijfe.5.2.136-140

Rose apple juice previously heated to 85 ℃ was mixed with the sweeteners (Table I), low-methoxyl (LM) pectin, citric acid, and calcium chloride. The mixture was then heated to 85-90 ℃ for 15 min to obtain the TSS value of the jam more than 65 ºBrix as determined in previous experiments. Hot jams were poured into sterilized jam glass bottles with screw caps and cooled using 30 ℃ cleaned water. The jam samples were retained at 4 ℃ for further analysis.

TABLE I. SWEETENER CONTENT IN JAM'S FORMULATIONS

Treatment	Sucrose (%)	Maltitol (%)
T1	40	0
T2	20	20
T3	0	40

C. Analysis of Rose Apple jam

1) Physicochemical properties

Nutritional compositions of the jams were determined according to the methods described in Association of Official Analytical Chemists [10]. Moisture content was performed by drying sample at 105 ℃ until constant weight. Ash content was done using a muffle furnace at 550 ℃ until free of black coloration. Crude protein was determined by Kjeldahl method using 6.25 as the conversion factor. Crude fat was evaluated by the Soxhlet extraction method. Crude fiber was determined by sequential acid and alkali hydrolysis followed by oven drying. Total sugars were analyzed by 3,5-Dinitrosalicylic acid (DNS) colorimetric method of James [11]. Energy value was calculated by using the factors of 4 kcal/g of carbohydrates, 4 kcal/g of protein, and 9 kcal/g of fat [5]. Analyzes were performed in triplicate.

Water activity (a_w) and pH value of the jams were measured using a water activity meter (Aqualab CX-2, Decagon Devices, Inc., USA) and a pH meter (Oakton pH700, Oakton instruments, USA), respectively, at 25 ℃. Total soluble solids (TSS) expressed as ºBrix was determined using a hand refractometer (Master-80H, Atago, Tokyo, Japan). Triplicate measurements were performed.

2) Antioxidant activity

DPPH and ABTS radical scavenging activities of the jams were measured according to the method of Thaipong et al. [12]. The results were expressed in μM Trolox equivalents (μM TE/g dried sample).

Total phenolics content of the jams was determined by the Folin-Ciocalteu method following Mustafa *et al*. [13]. The results were expressed in gallic acid equivalents (mg GAE/g dried sample).

3) Color of the jams was measured by a colorimeter (ColorQuest® XE, Hunter Associates Laboratory, Inc., VA, USA) using the CIE L*a*b* scale. The L* is a measure of the lightness to darkness, a* varies from green (-) to red (+), and b* varies from blue (-) to yellow (+).

4) Texture analysis was carried out directly in the jam bottles using a Texture Analyzer (TA.XTPlus, Texture Technologies Corp. and Stable Micro Systems, Ltd., MA, USA) equipped with a 2 mm diameter cylindrical probe. In the analysis, the pre-test, test, and post-test speeds were 1, 0.5, and 5.0 mm/s, respectively. The compression distance and the trigger force were 5 mm, and 5 g, respectively. The jam texture parameters included gel strength (g), and adhesiveness (g.sec). All analyses were performed in six replications at 25 ℃.

5) Sensorial evaluation was performed by 50 untrained panelists chosen from staff and students of the Suranaree University of Technology. Each jam treatment in the glass bottle (coded with random 3-digit number) and sliced 4 x 4 cm bread were provided. The acceptance of the jams based on a hedonic scale of 9-point (1 = disliked extremely, 5 = neither like nor dislike, 9 = liked extremely). The sensory attributes of the jams were color, flavor, texture, spreadability, and overall acceptance. Water and unsalted crackers were served to neutralize the taste between the different samples evaluation.

D. Statictical Analysis

One-way analysis of variance (ANOVA) was used to determine differences among group means. Tukey-HSD multiple comparison was used to compare the means, given the 5% significance level ($P<0.05$). The statistical analysis was carried out using Minitab® 17 (Minitab Inc., USA).

III. RESULTS AND DISCUSSION

A. Effect of Sweetners on Physicochemical Properties of Rose Apple jam

1) Nutritional composition (protein, fat, total fibers, total sugars, and ash) and enegy value (kcal/g dry weight) of rose apple jams prepared with different sweeteners formulations are presented in Table II. The values of protein, fat, total fibers, and ash showed only slighly variation between the prepared jams.

TABLE II. CHEMICAL COMPOSITION (% DW) AND ENERGY VALUE OF ROSE APPLE JAMS

Parameters	Treatment *		
	T1	T2	T3
Protein	0.55±0.03	0.53±0.05	1.49±0.00
Fat	0.18±0.05	0.10±0.01	0.10±0.01
Ash	2.76±0.28	3.79±0.68	3.58±1.36
Total fibers	2.85±0.01	2.86±0.03	2.87±0.02
Total sugars	61.45±0.26^{a}	53.94±12.87^{ab}	39.01±1.99^{b}
Energy value (kcal/100 g)	253.46±1.04^{a}	218.80±10.80^{b}	162.90±7.96^{c}

* The values represent the means of triplicate ± standard deviations. The different letters in each row represent the difference among treatment at $P<0.05$.

Total sugars and energy values of the jams were in the range of 39.01-61.45%, and 162.90-253.46 kcal/100 g dry weight, respectively. The lowest total sugars and energy value were found in the jam prepared by fully replacing sucrose with maltitol (T3). It indicated that substitution of sucrose by maltitol resulted in 35% decrease of the energy value the jam. This is consistent with Belović *et al*. [14], who reported that the partially

(50%) replacing sucrose with natural sweeteners (stevioside and fructose) in jam product could reduce the energy value by 45%.

Moisture content, a_w, pH, and total soluble solids (TSS) values were given in Table III. The moisture content and a_w were significantly affected by sweeteners. Increasing the maltitol content significantly increased the moisture content, and a_w of the jams ($P<0.05$) from 21.39 to 25.76%, and from 0.76 to 0.81, respectively. According to Besbes *et al*. [15], the a_w of jam product is lower than 0.86, considering safe from the most bacteria growth. In this study, the results indicated that jams prepared by sucrose (T1) could be better inhibition of the bactiral growth than the jams prepared by partially (50%, T2) and fully (100%, T3) sucrose replacement by maltitol. This is consistent with Belovic *et al.* [14], who found that the substitution of sucrose with natural sweetener resulted in increase the a_w of the jam. On the other hand, the pH and TSS values of jams were not significantly influenced by the maltitol addition. The pH and TSS values were in the range of 2.98-3.15, and 67-70 °Brix, respectively, complying the recommended TSS for jams [2].

TABLE III. MOISTURE CONTENT, WATER ACTIVITY (A_w), PH, AND TOTAL SOLUBLE SOLIDS (TSS) OF ROSE APPLE JAM

Treatment *	Moisture content (%)	a_w	pH	TSS (°Brix)
T1	21.39 ±0.31^a	0.76 ±0.01^a	2.98 ±0.02	70.00 ±1.41
T2	24.95 ±0.2^{ab}	0.81 ±0.00^b	2.98 ±0.08	67.00 ±1.41
T3	25.76 ±1.50^b	0.81 ±0.02^b	3.15 ±0.03	67.00 ±1.41

* The values represent the means of triplicate ± standard deviations. The different letters in each column represent the difference among treatment at $P<0.05$.

TABLE IV. ANTIOXIDANT ACTIVITY OF ROSE APPLE JAM

Antioxidant activity	Treatment *		
	T1	T2	T3
DPPH (μM TE/g sample)	64.32 ±1.26	64.32 ±1.26	67.00 ±2.53
ABTS (μM TE/g sample)	76.80 ±0.35	76.86 ±0.62	76.93 ±0.35
Total phenolic content (mg GAE/g sample)	2.24 ±0.03	2.30 ±0.04	2.29 ±0.05

* The values represent the means of triplicate ± standard deviations.

2) In this study, DPPH and ABTS radical scavenging assays were used to evaluate the effect of stweeteners on antioxidant activity of jams. The total phenolics content was also evaluated as the results shown in Table IV. Antioxidant activity measured by DPPH assay was varied from 64.32-67.00 μM Trolox equavalent per g dry weight (μM TE/g dw). The TE values obtained by ABTS assay were in the range of 76.80-76.93 μM TE/g dw. The highest activities were found in T3 jam. In addition, the total phenolic contents were 2.24-2.30 mg gallic acid equivalent per g dry weight (mg GAE/g dw). The results revealed that replacing sucrose with maltitol slightly increased in antixodiant capacity. The phenolic compounds possibly contributed to radical scavenging activity [13].Vasco *et al.* [16] divided the level of phenolic compounds into three levels; high (10.10-21.67 mg GAE/g), intermediate (2.38-4.62 mg GAE/g), and low (0.26-0.91 mg GAE/g). These could be suggested that the total phenolic content in the jams was closed to an intermediate level as comparable to strawberry (2.64 mg GAE/g) and guava (1.70-3.45 mg GAE/g) [12], [16].

3) Color is one of the important parameters that influcences to the palatability of final jam products. Appearance, taste, flavor, color, texture and stability of jams are affected by the amount of sugar [3], [14]. In this study, the L*, a*, and b* values of the jams prepared with different sweeteners ratios are presented in Table V. Increasing proportion of maltiol in the jam formulation from 50% to 100% in relative to sucrose sigificantly significantly decrasae L* value ($P<0.05$). The jams prepared with sucrose (T1) was darker. It was probably due to interaction between sucrose and water contributing to Mailard and/or caramelization reaction [17], [18]. Similar results were found in Vilela et al. [3]. Decrease in sucrose content in the jams significantly reduced the a* value from 37.64 to 32.76. While, replacing sucrose with maltitol did not significantly affect the b* value ($P>0.05$).

TABLE V. COLOR CHARACTERISTIC OF ROSE APPLE JAM

Treatment	Color value *		
	L*	a*	b*
T1	44.73 ±0.33^a	37.64 ±0.13^a	41.36 ±1.51
T2	52.08 ±3.94^{ab}	34.98 ±0.86^{ab}	38.31 ±1.39
T3	53.74 ±0.36^b	32.76 ±0.71^b	38.63 ±1.83

* The values represent the means of triplicate ± standard deviations. The different letters in each column represent the difference among treatment at $P<0.05$.

TABLE VI. TEXTURE PROPERTIES OF ROSE APPLE JAM

Treatment	Gel strength (g)	Adhesiveness (g-sec)
T1	4.88 ±0.66	0.14 ±0.01
T2	4.64 ±0.48	0.13 ±0.01
T3	4.60 ±0.45	0.14 ±0.02

* The values represent the means of triplicate ± standard deviations.

4) Compression tests were performed to evaluate the influence of different sweeteners in the jams formulations on the texture properties included gel strength, and adhesiveness are given in Table VI. The gel strength represents the peak force to reach the preferred distance during penetration and adhesiveness is assessed as the negative peak force during the probe removal. The results showed that replacing sucrose by 50% and 100% with maltitol did not significantly affected on the texture profiles of jams. The gel strength values were slightly decreased as increased maltitol content. Similar result was also reported for gels prepared with natural sweentener [14]. This could be explained that sucrose induced pectin-pectin interaction forming pectin network [3], [14]. Abid *et al*. [17] reported that the texture parameters of jam were mainly affected by the pectin concentration relating to the number of juction zones forming the gel network. In addtion, it has been

established that the texture properties are mainly affected by the amount and type of sugar added, proportion and kind of gelling agent used [3].

B. Effect of Sweetners on Sensory Properties of Rose Apple Jam

Sensory properties of three different jam formulations are presented in spider plot (Fig. 1). The color scores varied between 5.6-7.6 ("neither liked nor disliked" to "liked moderately"). While, the flavor, texture, spreadability, and overall acceptance scores varied between 6.3-7.4 ("liked slightly" to "liked moderately"). The color and overall acceptance scores were slightly increased on the jam's produced by maltitol. According to Haniyeh *et al*. [19] and Gajar and Badrie [20] polyols provides a mounthfeel and taste in finished products. The results for color, texture, and spreadability obtained by sensory panel evaluation are in accordance with the results obtained by the color and texture measurements. Specifically, jams prepared by sucrose (T1) was darker than the jam's produced with partially (50%, T2) and fully (100%, T3) replacing sucrose with maltitol. In addtion, texture and spreadability could be related to the gel strength and adhesiveness obtained by the instrument analysis.

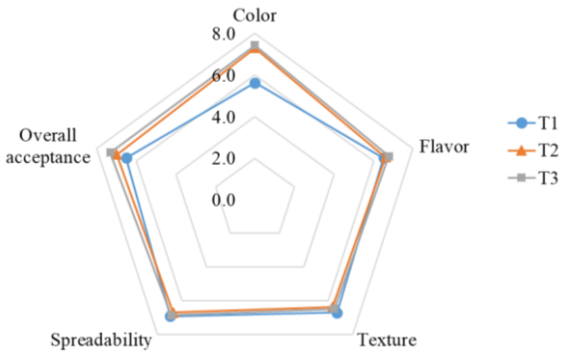

Figure 1. Sensory properties of rose apple jam.

IV. Conclusion

In this study, three rose apple jam formulations were developed; the jam formulation containing only sucrose (T1, control); jams prepared by partially (50%, T2) and fully (100%, T3) replacing sucrose with maltitol. The results revealed that T3 jam has the lowest energy value (162.90 kcal/100 g). Replacing sucrose with maltitol significantly increased a_w ($P<0.05$). In addition, the use of maltitol significantly increased the lightness (L*) value and reduced the redness (a*) of the jams ($P<0.05$). However, the antioxidant, texture, and sensorial properties showed small variations between the prepared jams. Essentially, maltitol is an effective alternative sweetener providing some physicochemical and sensorial properties of jams closely resembled those of sucrose.

Acknowledgment

The authors would like to extend sincere gratitude to Suranaree University of Technology (SUT) for the scholarship: External Grants and Scholarships for Graduate Students (OROG) and Technopolis, SUT for the research grant.

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Natthaporn Chatchavanthatri was born in Thailand. She received her B.Eng. (2015) and M.Eng. (2017) degree in Agricultural and Food Engineering, from Suranaree University of Technology, Thailand. Currently, she is a Ph.D. student in Mechanical and Process System Engineering Program, Suranaree University of Technology.

Tiraporn Junyusen was born in Thailand. She received her B.Sc. (2003), M.Sc. (2007), and Ph.D. (2014) degree in Food Science and Technology from Oregon State University, USA. She is a lecturer in School of Agricultural Engineering, Suranaree University of Technology, Thailand.

Weerachai Arjharn was born in Thailand. He received his B.Sc. (1994), M Eng. (1997), and Ph.D.(2001) degree in Agricultural Engineering from University of Tsukuba, Japan. He is an assistant professor, School of Agricultural Engineering, Suranaree University of Technology, Thailand**.**

Pornpimol Moolkaew was born in Thailand. She received her B.Eng. (2016) degree in Agricultural and Food Engineering, from Suranaree University of Technology. Currently, she is a master student in Mechanical and Process System Engineering Program, Suranaree University of Technology, Thailand.

Siriporn Sornsomboonsuk was born in Thailand. She received her B.Eng. (2017) degree in Agricultural and Food Engineering, from Suranaree University of Technology. Currently, she is a master student in Mechanical and Process System Engineering Program, Suranaree University of Technology, Thailand