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Physical property and antioxidant activity of spread product from Jerusalem artichoke (*Helianthus tuberosus L*.) tubers

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Abstract

Tubers of Jerusalem artichoke (Helianthus tuberosus L.) or Kaentawan (Thai name) are produced worldwide and mainly cultivated in North America, Northern Europe, Australia, China as well as Thailand. It contained high fructans (inulin and fructo-oligosaccharides), moderate protein and dietary fiber, and very low fat and sugar. Fructans are acts as two major functions as soluble dietary fiber and prebiotic. It has been increasingly used as a versatile ingredient in processed functional foods. This study aimed to develop Kaentawan spread product and to determine its physical properties and antioxidant activity. The developed spread product was made from different levels of Kaentawan tubers; 100% (F1), 75% (F2), and 50% (F3). The results showed that formula F1 and F2 found significantly higher water activity (a_w) than formula F3. The higher amount of Kaentawan tuber, the lower pH value was observed. For total soluble solid content, there were significantly increased when decreased the level of added Kaentawan tuber (F1<F2<F3). Brightness (L*) of spread products were decreased when decreased level of added Kaentawan tuber whereas values of redness (a^{*}) and yellowness (b^{*}) significantly increased. The viscosities measured by Bostwick consistomerter of all three formulas were very high. Total phenolic content in formula F1 had highest value (6.97 mgGAE/100g fresh weight, FW) and there were no significant differences between formulas F2 and F3 (5.31 and 5.42 mgGAE/100g FW respectively). In addition, antioxidant activity by oxygen radical absorbance capacity (ORAC) assay in formula F1 showed the highest value (16.53 µmolTE/g FW) compared to formulas F2 and F3 (13.11 and 10.02 µmolTE/g FW) respectively). The amount of Kaentawan in spread product of formula F3 was achieved acceptable to consumers. Thus, Kaentawan tubers had capability to be developed for the spread product and could become a commercial product.

Keywords: Kaentawan, spread product, physical property, antioxidant, total phenolic

Introduction

Jam is a product made from part of fruit components that may be as whole fruits, piece of fruit, fruit pulp, or fruit. The fruit was mixed with sugar or fruit juice or concentered fruit juice and viscous enough (Notification of the Ministry of Public Health, 2001. No.213). They are one of the most popular food products because of their low cost, all year long availability and organoleptic properties (Mohd et al. 2017). Jam can add various fruits such as strawberry, pineapple, lemonade etc.

Kaentawan or Jerusalem artichoke (*Helianthus tuberosus* L.) can grow under various climatic conditions, and its tubers can be produced world-wide, including Europe, North America, China, Korea, Australia, and New Zealand (Takeuchi & Nagashima, 2011; Li et al. 2015). Moreover, Kaentawan can be grown successfully in Thailand which it can be grown in two seasons including the early rainy season (May to September) and late-rainy season (September to December) (Puangbut et al. 2015).

For nutrient compositions, Kaentawan tuber contained high moisture, moderate protein, and very low fat. Carbohydrate content was the second main nutrient, which most carbohydrate was found in the form of fructans, dietary fiber, and some total sugar (Judprasong et al. 2018). The inulin-type fructans content of this tuber ranges from 7 to 30% of fresh weight or around 50% of dry weight basis (Kays & Nottingham, 2008). Fructans are a group of oligo- and polysaccharides which composed of fructose units connected with β -(2 \rightarrow 1) linkages, and frequently terminating in a glucosyl moiety. The shortest members of this structural classification are called oligofructose or FOS, and consisted of 2-9 units while fructans with 10 or more monomeric units are categorized as inulin. The number of units in a polysaccharide chain is also frequently referred to as degrees of polymerization (DP) (Mitmesser & Combs, 2017). Inulin-type fructan consists of linear $(2 \rightarrow 1)$ linked d-fructosyl units attached to the fructosyl moiety of sucrose. Moreover, inulin is widely used in the processed foods as a fat or sugar replacer or to impart desirable characteristics and it gives only 25-35% energy as compared to digestible carbohydrates. The sweetness level of inulin is about 10% of the sucrose. Inulin also being a distinctive food element, offers many important dietary benefits. Thus, inulin is an important health functional constituent and its use in food applications in term of fat or sugar replacer (Shoaib et al. 2016). Fructo-oligosaccharides (FOS) are composed of a mixture of Kestose (GF2), Nystose (GF3) and Fructosyl nystose (GF4), obtained from sucrose by enzymatic addition of fructosyl moieties, and are named as short-chain FOS. FOS also continue to exist in market as functional food ingredient for product formulations due to it used as prebiotic ingredients and fat replacers, for examples the uses of FOS in food formulations includes jam products, Ice cream, confectionery applications (Sridevi et al. 2014). Thus, Kaentawan was interested in developing a healthy food product. Therefore, this study aims to develop Kaentawan spread product and to determine its physical properties and antioxidant activity.

Materials and methods

Sample preparation

Kaentawan tubers were purchased from the local gardener in Nakhonpathom province. They were peeled by a knife and soaked with 0.3% (w/v) of salt solution and then washed again with deionized water. Then, they were steamed around 40 minute, cooled to room temperature and kept in refrigerator (4 °C) for further study.

Product development

Developed Kaentawan spread was made from different level of Kaentawan tubers (JA); 100% (F1), 75% (F2), and 50% (F3) of JA tubers. Then, they were added water, sugar, pectin, salt, and citric acid for all formulas (**Table 1**). All ingredients except water were mixed in an open stainless steel pan and stored 10 min at the temperature 80-85 °C. They were hot filled in closed glass jars and stored overnight at the refrigerator (4 °C) until analysis.

Table 1 Levels of Kaentawan tubers (JA) with ingredients.

Ingradiants (0/)	Formula				
Ingredients (76)	F 1	F2	F3		
Kaentawan tubers (JA)	100	75	50		
Water	50	50	50		
Sugar	44	44	44		
Citric acid	0.62	0.62	0.62		
Pectin	0.18	0.18	0.18		
Salt	0.90	0.90	0.90		

Physical properties analyses

All physical properties were determined in triplicates.

Water activity measurement

Water activities (a_w) were measured at 25±1 °C using a water activity meter (Novasina AG 8853 Lachen MS1 AW). Sample in a plastic container was placed in a chamber of the machine. Constant water activity at equilibrium was obtained.

pH measurement

pH values were determined using a pH meter (Mettler delta 340, Toledo Ltd) at 25 °C.

Total soluble solid measurement

Total soluble solid content (°brix) were measured with hand refractometer (ATAGO N-2, Brix 28-62 and N-3, Brix 58-90).

Viscosity measurement

Viscosity was measured at room temperature $(25\pm1^{\circ}C)$ using the Boswick consistometer. Total volume of sample for analysis was 40 g. The Boswick consistometer is used to determine sample consistency by measuring the distance in centimeters that a material flows under its own weight during a given time interval (5 min).

Texture analysis

Kaentawan spread formulations (at room temperature) were measured by back extrusion tests using a Texture Analyser. A cylindrical container of 95 mm height and 52 mm internal diameter, as well as a loose-fitting, flat-cylindrical plunger of 35 mm diameter were used for this study. Container was filled with Kaentawan spread, 90 g. The instrument working parameters were determined with the test mode compression, pre-test speed at 1.0 mm/s, test speed at 1.0 mm/s, post-test speed at 10.0 mm/s, distance 10.0 mm, and trigger force at 10.0 g. The data were analyzed firmness, consistency, cohesiveness, and viscosity in the samples. The results were analyzed in 5 replicates and report as the mean (Sesmero et al. 2006 & Kopjar et al. 2009).

Color measurement

The color of Kaentawan spread formulation was measured using spectro-colorimeter (ColorFlex EZ Spectrophotometer). The results were expressed as L^* , a^* , and b^* values. The maximum L^* value is 100, which represents the most light diffusion or lightness and the minimum L^* is 0, which represents to black color. The a^* and b^* values represented redness and yellowness respectively. Positive a^* value is red and negative one is green. Positive b^* value is yellow and negative one is blue.

Antioxidant activity analysis

Sample extraction

Each Kaentawan spread formula (5 g) was homogenized with 25 mL of 70% ethanol for 2 hours at 30 Hz. The mixture was incubated in the dark at room temperature for 48 hours. After that, the mixture was centrifuged at 13,000 g for 5 min at room temperature. Supernatant was collected and kept in a 2-mL microtube (Ainsworth and Gillespi, 2007). The extracted sample was used for determination of total phenolic content and antioxidant properties by ORAC method.

Total phenolic assay

The total phenolic content of each extracted sample was determined according to the method described by Ainsworth & Gillespie (2007) and measured with microplate reader. Briefly, 25 μ L of each extract was transferred into a 96 well microplate which it was mixed with 50 μ L of 10 % (v/v) solution of 2N Folin-Ciocalteau reagents in deionized water. After 5 minutes incubation, 200 μ L of 7.5% (w/v) Na₂CO₃ were added and after that incubated for 2 hours at room temperature in the dark. The absorbance at 760 nm was measured using a microplate reader (Synergy HT, Bio-Tek Instruments, Winooski, Vermont, USA). Gallic acid (10-200 μ g/mL) was used as a standard, and results were calculated as Gallic acid equivalent (mg GAE/g) (Ainsworth and Gillespi, 2007).

Oxygen radical absorbance capacity (ORAC) assay

ORAC Assay of each extracted sample was determined according to the method described by OU et al (2002). Trolox, a water-soluble analogue of vitamin E, was used as a control standard. The experiment was conducted at 37 °C under pH 7.4 condition with a blank sample in parallel. The analyzer was programmed to record the fluorescence of Fluorescein disodium every minute after addition of AAPH. All fluorescent measurements were expressed relative to the initial reading. The final results were calculated using the differences of areas under the Fluorescein disodium decay curves between the blank and a sample and were expressed as micromole Trolox equivalents (TE) per gram (µmol TE/g) (OU et al., 2002).

Sensory evaluation

Sensory evaluation of spread products were evaluated the acceptance test by 40 participants within the Institute of Nutrition, Mahidol University. Samples of each spread products were conducted in individual booths under white light in the Sensory Analysis Laboratory. Each participant evaluated the appearance, color, odor, spreadibility, taste, texture, and overall acceptability by 9-point hedonic scale (1 = disliked extremely, 2 = disliked a lot, 3 = disliked moderately, 4 = disliked slightly, 5 = neither liked nor disliked, 6 = liked slightly, 7 = liked moderately, 8 = liked a lot, 9 = liked extremely) was used for evaluation of products. Spreads were presented in three-digit coded containers, and the order of serving was determined by random permutation. Bread was used as carrier due to the spread is generally consumed with bread (Abdullah A. & Cheng T. C., 2001).

Statistical analysis

All physical, chemical, and sensory evaluation data were analyzed using the one-way ANOVA with Duncan new multiple range test (SPSS software, version 17). The result was express as mean \pm SD. The significance level at p \leq 0.05 was used throughout the study.

Results and discussion

Physical properties

Physical properties including water activity (a_w), pH, total soluble solid, viscosity, and color values of spread products are presented in **Table 2**. All of three spread formulas had high level of water activity ranged from 0.79 to 0.86 which were found in the same range of microbial growth. F1 and F2 formulas showed higher of water activity and were significantly different from the formula F3. The pH values of three spread formulas showed in range of 4.11-4.53 and there were significantly decreased (p<0.05) when they were decreased the level of added Kaentawan tubers. The type of acid food (pH<4.6) is a key factor that influences the extent of microbial inhibition. Therefore, this product is categorized as one of acid foods. For total soluble solid content, there were significantly increased when decreased the level of added Kaentawan tubers by total soluble solid content of F1, F2, and F3 were 49.67, 51.337, and 64.33 °brix, respectively. Viscosity of all Kaentawan spread formulas were expressed 0 cm that means they had very high viscosity.

The color values of all spread formulas were significantly different which brightness (L^*) of spread formulas were decreased, when decreased levels of added Kaentawan tubers (**Table 2**). While, values of redness (a^*) and yellowness (b^*) of the spread formulas were significantly increased. Formula F1 was found the most brightness and less redness and yellowness followed by F2 and F3, respectively. Caramelization of sugars and consequently formation of hydroxymethylfurfural (HMF) were often occurred as an intermediate product and were being able to undergo polymerization, producing melanin, darkening the product (Mamede et al. 2013).

Formula	Water activity	рН	Total soluble solid	Viscosity -	Color		
					L*	a*	b*
F1 (100% JA)	0.86±0.003 ^a	4.53±0.02 ^a	49.67±0.58°	0.00 ± 0.00	47.89±0.02 ^a	-1.08±0.01 ^c	18.65±0.02 ^c
F2 (75% JA)	0.86±0.001 ^a	$4.42{\pm}0.02^{b}$	51.33±0.58 ^b	0.00 ± 0.00	42.91±0.02 ^b	$0.20{\pm}0.02^{b}$	19.55±0.10 ^b
F3 (50% JA)	0.79 ± 0.003^{b}	4.11±0.02 ^c	64.33±0.58 ^a	0.00 ± 0.00	37.93±0.09 ^c	2.86±0.03 ^a	$24.51{\pm}0.07^{a}$

Table 2 Physical properties of Kaentawan tuber spreads¹.

¹values present as mean±SD from triplicate measurements.

Different superscript in the same column showed significantly different (p<0.05).

Texture parameters commonly desired characteristic of spread products is spreadibility which it was related with firmness. The firmness values were significantly different in all formulas by formula F1 (100% JA) showed higher texture than formula F3 (50% JA) and F2 (75% JA), respectively (**Table 3**). Thus, formula F1 had more difficult to spread than formula F3 and F2, respectively. Moreover, the result showed cohesiveness values were significantly different with formula F3 (50% JA) which it was higher than formula F1 and F2, respectively. There were no significantly different between formula F1 and F3 while formulas F2 and F3 showed no significantly different in consistency. The viscosity values were significantly higher value when decreased amount of Kaentawan tubers which there were significantly different with formula F3 by formula F3 had higher viscosity than formula F1 and F2. However, formation of gel from pectin affected texture of the products due to pectin was formed gel with sugars and acid. In general, pectin can form gel at different pH levels but it was stable at the pH of 2.5-4.5. The optimum gel is normally set in a pH range of 3.1-3.3. A pH level above 3.5, it was resulted in poor gel formation. Heat-stability of pectin is greatly improved when the water activity of the system is lowered through the addition of sugar (Flutto, 2003).

Table 3 Texture analysis of Kaentawan tuber spreads¹.

Formula —	Texture properties				
	Firmness (g)	Consistency (g-sec)	Cohesiveness (g)	Viscosity (g-sec)	
F1 (100% JA)	197.31±7.60 ^a	1256.94±34.10 ^a	137.85±9.84 ^b	126.11±1.19 ^b	
F2 (75% JA)	156.70±7.64 ^c	1092.75±28.71 ^b	123.36±6.52 ^b	121.09±5.65 ^b	
F3 (50% JA)	173.69±9.65 ^b	1171.35±72.63 ^{ab}	167.43±9.86 ^a	166.40±12.40 ^a	

¹ values present as mean±SD from triplicate measurements.

Different superscript in the same column showed significantly different (p<0.05).

Antioxidant activity

Total phenolic (TP) content of Kaentawan spreads showed different values ranging from 5.42 to 6.97 mgGAE/100g which formula F1 (100% JA) found higher TP content than F2 (75% JA) and F3 (50% JA), respectively (**Table 4**). There were significantly different which TP content in formula F1 (100% JA) was significantly decreased when decreased levels of Kaentawan tubers. Deliorman and Orhan (2016) studied TP content of Kaentawan tubers which they reported amount of TP content as 7.91±1.62 mgGAE/g. The TP content was decreased when Kaentawan tubers were processed into Kaentawan spreads by TP content decreased from 7.91 to 6.97 mgGAE/100g. This phenomenon is agreed well with the study of Öksüz et al. (2015) which they reported TP content in red beet jam. They found that TP content was decreased when red beets were processed into red beet jam. Similarly, Levaj et al. (2012) reported that TP content was decreased in strawberry jam samples during processing fruit into jams.

Oxygen radical absorbance capacity (ORAC) of three formulas was between 10.02 and 16.53 μ molTE/g FW (**Table 4**). There were significantly different in all formulas which formula F1 showed significantly higher than that of formula F2 and F3, respectively. ORAC values were significantly decreased when decreased amount of Kaentawan tubers. Formula F3 showed lowest ORAC value (10.02±0.212 μ molTE/g FW) while formula F1 showed highest ORAC value (16.53±0.509 μ molTE/g FW). In combination results of TP and ORAC, they showed the same trend of decreasing when decreased the levels of Kaentawan tuber into spread products.

Table 4 Total phenolic (TP) content and oxygen radical absorbance capacity (ORAC) assay of Kaentawan tuber spread formulas

Formula	TP (mgGAE/100g FW ¹)	ORAC (µmolTE/g FW ¹)
F1 (100% JA)	6.97±0.23 ^a	16.53±0.51 ^a
F2 (75% JA)	5.31±0.16 ^b	13.11±1.23 ^b
F3 (50% JA)	5.42±0.31 ^b	$10.02 \pm 0.21^{\circ}$

¹ values present as mean±SD from triplicate measurements.

Different superscript in the same column showed significantly different (p<0.05).

Sensory evaluation

There were no significantly different (p>0.05) in odor and taste between the different formulas of Kaentawan spreads (**Table 5**). There were also no significantly different (p>0.05) in color, spreadibility, and texture between formula F2 (75% JA) and F3 (50% JA) but significantly differences with formula F1 (100% JA). The appearance of formulas F1 and F2 were significantly different (p<0.05) from that of formula F3. There were no significantly different in overall acceptability with formulas F2 and F3 but significantly different (p<0.05) with formula F1. However, the highest scores of all attributes were showed in formula F3 (50% JA). Thus, the amount of Kaentawan in spread product was acceptable to consumers showed in F3 (50% JA).

Table 5 Sensory scores of Kaentawan tuber spread production
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	Sensory properties						
Formula	Appearance	Color	Odor	Spreadibility	Taste	Texture	overall acceptability
F1 (100% JA)	$5.94{\pm}1.58^{b}$	5.79±1.74 ^b	6.15±1.37 ^a	4.88±1.79 ^b	6.41±1.46 ^a	5.82±1.73 ^b	6.03±1.60 ^b
F2 (75% JA)	6.38±1.37 ^b	6.47±1.48 ^{ab}	6.38±1.13 ^a	7.24±1.26 ^a	6.88±1.23ª	6.85±1.52 ^a	7.00±1.35 ^a
F3 (50% JA)	7.29±1.40 ^a	7.18±1.53 ^a	6.56±1.60 ^a	7.68±1.39 ^a	7.09±1.76 ^a	7.56±1.65 ^a	7.29±1.77 ^a

¹values present as mean±SD from triplicate measurements.

Different superscript in the same column showed significantly different (p<0.05).

Conclusions

Kaentawan (JA) spread formulas F3 and F2, containing 50 and 75% JA respectively, showed good sensory acceptance for acceptability and spreadibility that was important parameter for described characteristic of spread products. Kaentawan spread containing 100% JA provided high water activity (a_w), pH, firmness and including total phenolic and ORAC contents. Whereas Kaentawan spread containing 50% JA had low water activity (a_w) and pH values. It had darker yellow than other formulas. In addition, it also high totals soluble solid (°brix), viscosity, consistency, and cohesiveness. However, it had lower total phenolic and ORAC contents than other formulas. In conclusion, the most suitable formula of Kaentawan spread product is the formula containing 50% Kaentawan. This formula could be further investigated for nutrient composition especially dietary fiber, fructans and total sugars. This product may be become a good choice for commercial industry and consumers.

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