FORMULATION OF JERUSALEM ARTICHOKE (*Helianthus tuberosus* L.) JUICE

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Abstract
Jerusalem artichoke (*Heliantus tuberosus* L.) is an interested functional food because its tuber has a high content of dietary fiber namely inulin and fructo-oligosaccharides. Therefore Jerusalem artichoke juice is developed as an alternative drink for people who are at risk for less dietary fiber consumption, especially the elderly. In-house sensory evaluation including a hedonic test and a just-about-right test were used in the process of juice formulation. The final juice formula consists of a tuber to water ratio of 1 to 3 (w/w), total soluble solid at 11°Brix, 0.23% (w/w) salt, 0.15% (w/w) citric acid and 0.06% (w/w) guar gum. The score of over acceptability after testing was 5.8 (out of 7) which means "like moderately". Color, sweetness and sourness of the juice were "just right" while texture was evaluated as too thick in body. It is noted that Jerusalem artichoke juice in this study is an excellent source of dietary fiber since one serving (200 ml) provided 35% of the Thai Recommended Daily Intake.

Keywords: Jerusalem artichoke, juice, inulin, fructo-oligosaccharides

Introduction

Jerusalem artichoke (*Heliantus tuberosus* L.) or Kaen-ta-wan is a tuberous annual crop originating from North America. It is presently cultivated in Europe, Australia and Asia (Baldini et al. 2004; Paseephol et al. 2007). Its tuber contains high amount of dietary fiber namely inulin and fructo-oligosaccharides (15.28 and 5.96 g/100 g fresh weight, respectively) (Tanjor et al. 2012). Jerusalem artichoke tuber as food is consumed in the form of both fresh and cooked in many recipes. However, for Thailand, using Jerusalem artichoke tuber as a food ingredient is not commonly used even it has many advantages for health.

Inulin and fructo-oligosaccharides are plant carbohydrate contribute 1.5 kcal/g of energy (Kleessen et al. 1997). The structure of inulin is both linear and branch fructose polymers, usually has a glucose unit at the end of the chain. Inulin has a degree of polymerization between 2-60 and each monosaccharide unit links together by β-(1-2) glycosidic bond. Fructo-oligosaccharides or oligofructose is a partial degraded product of inulin. It contains less than 10 units of fructose. Since human intestine have not had enzyme for inulin and fructo-oligosaccharides digestion, therefore when inulin and fructo-oligosaccharides reach the colon they serve as prebiotic substrate for growth of probiotic bacteria (Roberfroid et al. 1998). This prebiotic benefit helps decline pathogenic bacteria, improve an immune system of the body (Lourens-Hattingh and Viljoen 2011), reduce serum cholesterol level, and enhance the absorption of mineral (Williams 1999; Abrams et al. 2007). In addition, inulin and fructo-oligosaccharides help increase stool weight and decrease fetal pH caused by the production of short-chain fatty acids (Kleessen et al. 1997; Gibson et al. 1995).

According to the Thailand Population Health Examination Survey IV during 2008-2009, there was only 53.3% of the elderly with less than twenty functional teeth (Ministry of Public Health 2010). It renders these elderly have the problem in masticating. They cannot consume some foods that are difficult to chew. High fiber food such as fruits and vegetable are hardly to chew and the elderly may not get enough fiber. An appropriated consumption of fiber is decline leading to a risk of many diseases such as colon cancer, cardiovascular disease and diabetes. Therefore, in this study Jerusalem artichoke juice is selected to develop as a healthy food choice for people who are at risk for less dietary fiber consumption.

Methodology

Jerusalem artichoke sample

Jerusalem artichoke (variety HEL65) tubers were obtained from Khon Kaen University, Khon Kaen, Thailand. They were stored in a cold room at 4°C. Before use, the tubers were peeled and boiled in water at a ratio of 1 to 2 (w/w).

Formulation of Jerusalem artichoke juice

Carrot juice production was used as a reference for the formulation of Jerusalem artichoke juice. Cooked artichoke tubers were blended with water, sugar, salt, citric acid and guar gum in a blender until homogenous. A tuber to water ratio of 1 to 2 and 1 to 3 (w/w) was used. Jerusalem artichoke juice was formulated to six formulas (A-F) by varying total soluble solid (10, 11 and 12°Brix) which adjusted by adding sugar and amount of guar gum (0.06 and 0.08% (w/w)) as shown in Table 1. Salt and citric acid contents were kept constant at 0.23 and 0.15% (w/w), respectively. The juice was pasteurized by direct heating at 85°C for 20 seconds, followed by hot-filling in plastic bottles. The bottles were immediately cooled by soaking in running tap water. After cooling, Jerusalem artichoke juice was stored at 4°C for sensory test, and chemical and physical analysis.

Table 1 Varied ingredient of Jerusalem artichoke juice formulas A-F

Formula	Tuber to water ratio (w/w)	Total soluble solid (°Brix)	Guar gum (%)
A	1: 2	10	0.06
B	1: 2	12	0.06
C	1: 2	10	0.08
D	1: 2	12	0.08
E	1: 3	12	0.06
F	1: 3	11	0.06

Sensory evaluation

A randomized complete block design was conducted for in-house sensory test. Thirty panelists who recruited from staffs and graduate students of the Institute of Nutrition, Mahidol University were asked to evaluate general appearance before testing and overall acceptability after testing using a seven-point hedonic scale (7 = like very much, 4 = neither like nor dislike, 1 = dislike very much). Appropriateness of color, sweetness, sourness and texture (body) was evaluated using a five-point just-about-right scale (5 = much too strong, 3 = just about right, 1 = much too weak) (Stone and Sidel 2004). A formula with the overall acceptability score more than 5 (like slightly) was considered for acceptability.

Determination of chemical properties

The pH of Jerusalem artichoke juice was measured using a pH meter at 25°C. Total acid content was determined by the titratable acidity method (AOAC 942.15, 2005). The juice sample was titrated with 0.1N sodium hydroxide solution. Phenopthalene was used as an indicator. Total acidity was calculated based on the reaction ratio between sodium hydroxide and citric acid by the following equation.

$$\text{Total acidity (\%)} = \frac{\text{Volume of NaOH x Normality of NaOH x 192.14 x 100}}{\text{Weight of sample x 3 x 1000}}$$

Determination of physical properties

Total soluble solid of Jerusalem artichoke juice at 25°C was measured using a refractometer. The result was expressed as °Brix.

Color value of the juice sample was determined by a spectro-colorimeter model JS555 (Color Techno System Corporation, Japan). The value was expressed as L*, a* and b*. The maximum L* value is 100, which represents the most diffusion while the minimum value is 0, which represents the black color. Positive a* value represents redness and negative value represents greenness. Positive and negative b* values represent yellowness and blueness, respectively.

Viscosity was examined using a Brookfield digital viscometer model RVT DV-II (Brookfield Engineering Laboratories, Inc., MA, U.S.A.). All measurements were performed at room temperature (approximately 25°C), using the spindle no. 1 at speed at 100 rpm. The value was expressed in centipoise (cps) unit.

Nutrients analysis

Nutritive values including moisture, protein, total fat, ash, soluble fiber, insoluble fiber, and sugar of boiled Jerusalem artichoke tubers were determined according to the method of Association of Office Analytical Chemists (AOAC 2005). Inulin and fructo-oligosaccharides were analyzed according to the method of Joye and Hoebregs (2000). Carbohydrate was calculated from deducted one hundred percent by the sum of the percentage of moisture, protein, total fat and ash. Energy was the result from the total amount (gram) of protein, carbohydrate and fat multiply by 4, 4 and 9, respectively.

The nutritive values of Jerusalem artichoke juice were calculated based on the nutritive values of the tubers from the analysis except for sugar and sodium, which calculated from the added sugar and salt.

Statistical analysis

All treatments were conducted with three replications. Data was reported as mean±standard deviation. For the just-about-right test, mean of each characteristic was evaluated by One-Sample t-test using the statistical program, SPSS™ software (SPSS Inc., Illinois, U.S.A.). Significant difference was assessed at 5% level of probability.

Results and Discussion

The sensory scores of Jerusalem artichoke juice A-F are presented in Table 2. The results showed that B had the overall acceptability score after testing more than 5 (5.5; between "like slightly" to "like moderately"). However, when compared the score of texture with score of

3 (just-about-right score), the result showed that the score of texture of B (3.6) was significantly different from score of 3. This indicated that the juice sample B was "too thick" in body. Therefore, texture characteristic needed to be improved.

Table 2 Sensory scores of Jerusalem artichoke juice formulas A-F[1]

Formula	General appearance[2]	Overall acceptability[2]	Color[3]	Sweetness[3]	Sourness[3]	Texture (body)[3]
A	4.9±1.2	5.0±1.3	3.2±0.6	2.8±0.6	2.9±0.9	3.3±0.8*
B	5.2±1.2	5.5±1.2	3.1±0.4	3.0±0.6	2.8±0.8	3.6±0.7*
C	5.0±1.2	4.9±1.4	3.2±0.5*	2.8±0.8	3.0±0.7	3.6±0.9*
D	4.9±1.2	5.0±1.6	3.1±0.6	2.7±0.7*	2.8±0.8	3.3±1.0
E	4.9±1.2	5.3±1.4	3.1±0.8	3.4±0.8*	2.6±0.7*	3.4±0.8*
F	5.0±0.8	5.8±1.2	2.9±0.5	3.0±0.5	3.0±0.7	3.3±0.6*

[1]Results are mean±SD, n=30.
[2]Seven-point hedonic scale (7 = like very much, 4 = neither like nor dislike, 1 = dislike very much)
[3]Five-point just-about-right scale (5 = much too strong, 3 = just about right, 1 = much too weak)
*Significant difference from the score of 3 (just-about-right score) ($p \leq 0.05$)

To adjust the too thick body of B, a tuber to water ratio of 1 to 3 (w/w) was used in E, while total soluble solid and the amounts of other ingredients were the same. The results of sensory test in Table 2 show that E had the overall acceptability score after testing more than five (5.3; between "like slightly" to "like moderately"). The scores of sweetness (3.4) and sourness (2.6) were significantly different from score of 3. The "too sweet" characteristic of E was due to the decreased amount of tubers that in turn decreased total soluble solid of juice before adding sugar (-1.60°Brix compared to that of B). Therefore, more sugar was added to make the final total soluble solid of 12°Brix. A taste of "not sour enough" may be due to an imbalance between sweet and sour taste. Even though the score of texture of E (3.4) was numerical lower than that of formula B (3.6), a significantly different from score of 3 was observed.

Juice F was formulated to reduce the too sweet taste of E. Results of the just-about-right test in Table 2 show that color, sweetness and sourness were "just right". Although the panelists evaluated the body of Jerusalem artichoke juice F as "too thick" (score of 3.4 which is significant difference from score of 3), this characteristic may help preventing choke on water in the elderly where further study need to be conducted. According to the overall acceptability score after testing of 5.8 ("like moderately"), Jerusalem artichoke juice F is chosen as a suitable formula.

Chemical and physical properties of the juice samples are shown in Table 3. For A-F, pH values ranged between 3.9 to 4.1, and total acidity ranged from 0.16 to 0.19%. Color values implied that the Jerusalem artichoke juice had light brown color. It was noticed that viscosity of juice B was the highest (119 cps) which in agreement with "too thick" body in the sensory evaluation.

Table 3 Chemical and physical properties of Jerusalem artichoke juice formulas A-F[1]

Formula	pH	Acidity (%)	Color value			Viscosity[2] (cps)
			L*	a*	b*	
A	4.03±0.02	0.19±0.03	44.09±0.76	-2.76±0.06	4.27±0.62	78.1
B	4.10±0.02	0.19±0.00	46.44±0.26	-2.91±0.02	4.06±0.40	119.0[3]
C	4.11±0.02	0.19±0.00	44.86±0.89	-2.67±0.09	3.19±0.40	98.8
D	4.05±0.02	0.18±0.00	45.61±0.74	-2.76±0.09	3.17±0.70	96.0
E	3.87±0.05	0.16±0.00	42.38±0.41	-2.09±0.06	-0.78±0.40	56.1
F	3.90±0.40	0.17±0.00	42.94±0.04	-2.11±0.03	-0.40±0.18	50.7

[1]Results are mean±SD of three replications.
[2]Viscosity value came from a pooled sample of three replications.
[3]Viscosity measurement was performed at 50 rpm because at 100 rpm the value was off scale.

The results of nutrients analysis of boiled Jerusalem artichoke tubers presented in Table 4 show that the tubers contain high amount of inulin and fructo-oligosaccharides. The amount of inulin and fructo-oligosaccharides in boiled tubers in this study (14.1 g/100 g) was lower than that of the fresh one (21.2 g/100 g) (Tanjor et al. 2012). This loss may be due to leaching of inulin and fructo-oligosaccharides with water during boiling. Nutritive values of Jerusalem artichoke juice F were calculated based on the nutrients of boied tubers (Figure 1). One serving of Jerusalem artichoke juice (200 ml) contains 9 g of dietary fiber, which provided 35% of the Thai Recommended Daily Intake. According to the Ministry of Public Health Notification No. 182, product with an excellent source of dietary fiber must contain dietary fiber per one serving at equal or more than 20% of the Thai Recommended Daily Intakes (25 g) (Notification of the Ministry of public Health (no. 182) 1998). Therefore The Jerusalem artichoke juice formulated in this study can be nutrient claimed as an excellent source of dietary fiber.

Table 4 Nutritive values of boiled Jerusalem artichoke[1]

Nutrient	Amount per 100 g
Energy (kcal)	79
Moisture (g)	79.6
Protein (g)	1.2
Total fat (g)	Not detected
Carbohydrate (g)	18.6
Soluble dietary fiber (g)	3.8
Insoluble dietary fiber (g)	1.2
Ash (g)	0.6
Fructose (g)	0.7
Glucose (g)	0.4
Sucrose (g)	1.2
Inulin and fructo-oligosaccharides (g)	14.1

[1]Results are mean of duplicate analyses.

Nutrition Information

Serving size : 200 ml
Serving (s) per bottom : 1

Amount Per Serving		
Calories 100	Calories from Fat 0	
		% Thai RDI*
Total Fat	0 g	**0** %
Saturated Fat	0 g	**0** %
Cholesterol	0 mg	**0** %
Protein	<1 g	
Total Carbohydrate	25 g	**8** %
Dietary Fiber**	9 g	**35** %
Sugars	16 g	
Sodium	0 mg	**<5** %

* Percent Thai Recommended Dairy Intakes for population over 6 years of age are based on a 2,000 Kcal diet

Total Fat	Less than	65 g
Saturated Fat	Less than	20 g
Cholesterol	Less than	300 mg
Total Carbohydrate		300 g
Dietary Fiber		25 g
Sodium	Less than	2,400 mg

Calories per gram
Fat 9 Carbohydrate 4 Protein 4

**Inulin and fructo-oligosaccharides	6.4 g
Insoluble dietary fiber	0.5 g
Soluble dietary fiber	1.7 g

Figure 1 Nutrition information of Jerusalem artichoke juice

When compared to the commercial vegetable and fruit juice products which have been content claimed as a high fiber juice, the Jerusalem artichoke juice has higher amount of dietary fiber per serving (Table 5). Moreover, most of dietary fiber from Jerusalem artichoke juice comes from inulin and fructo-oligosaccharides which act as prebiotic (Roberfroid et al. 1998), enhance the immune system (Lourens-Hattingh and Viljoen 2011), reduce lactose intolerance (Gilliland 1990), and diminish serum cholesterol level and blood pressure (Williams 1999). The amount of sugar per one serving of the Jerusalem artichoke juice is less than those of the commercial juice products. When compared to the commercial Brand A juice product which has the same serving size and energy (100 kcal), the JA juice is more nutritious because of high dietary fiber content and low sugar content.

Table 5 Nutritive values of Jerusalem artichoke juice compared to three commercial vegetable and fruit juice products

Product	Serving size (ml)	Amount per serving size		
		Energy (kcal)	Dietary fiber (g)	Sugar (g)
Jerusalem artichoke juice	200	100	9 (35%)	16
Commercial Brand A	200	100	5 (20%)	24
Commercial Brand B	300	140	5 (20%)	28
Commercial Brand C	300	150	8 (32%)	27

Conclusions

Jerusalem artichoke juice formulated in this study contains 9 g of dietary fiber per serving which account for 35% of the Thai Recommended Daily Intakes. Jerusalem artichoke juice would give an opportunity for people who are at risk for less dietary fiber consumption, especially the elderly.

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Acknowledgements

This research was funded by the Office of the Higher Education Commission (OHEC). The authors thank all panelists who participated in the sensory test.