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Sugar profiles and recommended portion sizes of geographical indication fruits in Southern Thailand

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Abstract

Fruits are well-known sources of vitamins, minerals, and phytochemicals which is associated with a wide range of potential health impacts. However, the high natural sugar contents of fruits indicate an association between fruit consumption and obesity. This study sought to determine the sugar profiles of well-known geographical indication fruits from Southern Thailand and provide recommended portion sizes for those fruits. The soluble sugar contents of mangosteen, rambutan, longkong, pomelo, and jackfruit collected from geographical indication areas were determined using Liquid Chromatography - Mass Spectrometry (LC-MS/MS). Fructose was found to have the highest sugar content of all the fruit samples, ranging from 0.8-30.6 g/100 g fresh weight (FW) (7.3-88.4% dried weight (DW)), followed by glucose (ranging from 2.2-23.9 g/100 g FW or 11.2-67.5% DW) and sucrose (ranging from 0.5-10.4 g/100 g FW or 2.6-58.2% DW). According to the Online Thai Food Composition Database and food exchange data, one serving or one edible portion of each fruit contains 15 g of carbohydrate. The recommended size for an edible portion is 3-4 pieces or 85 g of mangosteen, 5-7 pieces or 90 g of rambutan, 2-4 pieces or 177 g of pomelo, 6-9 pieces or 109 g of longkong, and 3-5 pieces or 58 g of jackfruit. These data should prove helpful in a health promotion campaign aimed at encouraging healthy people to limit their intake of fresh fruit in order to prevent obesity and promoting glycemic control among people with type 2 diabetes mellitus.

Keywords: Geographical indication fruits, One edible portion size, Fructose, Glucose, Sucrose

1. Introduction

Fruits are well-known sources of essential minerals, vitamins, and phytochemicals that exhibit a wide range of health benefits [1,2]. The World Health Organization (WHO) and the Food and Agriculture Organization of the United Nations (FAO) recommend eating at least five portions or 400 g of edible fruit and vegetables per day to help prevent non-communicable diseases (NCDs) and alleviate several micronutrient deficiencies [3]. Besides being a good source of vitamins, minerals, and phytochemicals, fruits also have high sugar contents [4]. Previous studies have found that the consumption of fruits and vegetables is strongly influenced by their flavor or sweetness [5,6]. The combination of fruit consumption patterns and the seasonal availability of fruits for particular meals can also affect the glycemic response [7]. Due to simple sugar being rapidly digested and absorbed, its consumption results in the blood sugar level being increased and further metabolized into energy and energy storage (i.e., the deposition of fat). The overconsumption of fruits containing simple sugars such as fructose, glucose, and sucrose results in the generation of more energy than is required per day and so has been reported to have adverse health outcomes, including overweight, obesity, and type 2 diabetes mellitus [8].

Furthermore, any excess simple sugar intake is converted into fat in the body, including triglycerides, very-low-density lipoprotein (VLDL), and low-density lipoprotein (LDL) [9]. In general, fructose and glucose metabolism occur in the liver and adipose tissue, respectively, where the fructose and glucose undergo fat biosynthesis. The fat produced from fructose is stored as visceral fat, whereas the fat produced from glucose is stored as subcutaneous fat [10]. Therefore, high sucrose and fructose consumption is strongly linked to obesity-related diseases such as insulin resistance [11]. Moreover, the consumption of tropical fruits with moderate and high glycemic indexes is associated with an increased risk of gestational diabetes mellitus [12].

The species richness of the fruits grown commercially in the tropical regions and climates of Thailand has been well established. In fact, fruits can be available all year round in Thailand; however, around 3–6 months growth is required for each seasonal fruit. Fruit crops grown in specific production areas associated with specific local factors (e.g., latitude, climate, storage conditions, soil, fertilizer, water) are classified as geographical indication fruits. Thus, a geographical indication fruit differs from the same type of fruit produced in another area. The geographical indication fruits of Southern Thailand, including mangosteen (Khiriwong Village), the Rong-rean variety of rambutan (Ban Na San District), and the Tubtim Siam variety of pomelo (Pak Phanang District), are year-round fruits in Thailand, the cultivation of which is linked to home-delivery, marketing, and logistics services [13]. During the coronavirus disease (COVID-19) pandemic, the consumption of fruits containing high levels of vitamins and minerals, especially vitamin C, vitamin E, and zinc, was recommended as a proactive dietary strategy for maintaining good health and reducing the risk of severe illness due to COVID-19 [14]. Recently, the sugar profiles (e.g., glucose, fructose, sucrose) and recommended portion sizes of geographical indication fruits from Southern Thailand have been unavailable online via the Thai Food Composition Database [15]. Yet, numerical information concerning the sugar contents of fresh fruits is necessary to ensure consumer awareness of the growing number of geographical indication fruits in the market system.

In the present study, the sugar profiles of five geographical indication fruits from Southern Thailand, namely mangosteen, rambutan (Rong-rean variety), longkong, pomelo (Tubtim Siam variety), and jackfruit (Jum-pa variety), were determined by means of a Liquid Chromatography - Mass Spectrometry (LC-MS/MS) analysis. The recommended portion sizes of the fruits were also compared. The knowledge gained from this study should help promote the consumption of geographical indication fruits as rich natural sources of sugar with potential health impacts, which following further investigation could lead to the prevention of obesity and an improvement in the glycemic control among people with type 2 diabetes mellitus.

2. Materials and methods

2.1 Fruit mterial and collection

Ripe fruit samples, namely mangosteen, rambutan (Rong-rean variety), longkong, pomelo (Tubtim Siam variety), and jackfruit (Jum-pa variety), from five geographical indication areas in Southern Thailand were harvested from orchards located in Khiriwong Village (latitude: 8° 25' 58.7" N; longitude: 99° 46' 57.8" E) during early August 2021, Ban Na San District (latitude: 8° 48' 03.1" N; longitude: 99° 21' 50.4" E) during early August 2021, Narathiwat Province (latitude: 6° 25' 50.4" N; longitude: 101° 48' 06.3" E) during late August 2021, Pak Phanang District (latitude: 8° 21' 29.3" N; longitude: 100° 12' 18.9" E) during early October 2021, and Satun Province (latitude: 6° 37' 26.8" N; longitude: 100° 04' 01.5" E) during late August 2021, respectively. From August to October each year, a temperate continental climate characterizes the region of interest. The mean annual rainfall is 1,200-4,500 mm, with lower totals being recorded on the leeward side and higher totals on the windward side, while the mean temperature is 27.5°C in the southern and coastal areas. At each geographical indication area, 9-12 kg of each fruit sample (3-4 kg/orchard) was sampled from three representative orchards. Each fruit was combined and mixed to form a composite sample. Subsequently, each fruit sample was picked, placed in a sampling box, and transported to the laboratory. The fruit samples were weighed and grouped into a interquartile range comprising samples with a small size (<first tertile [Q1]), samples with a medium size (Q1-3), and samples with a large size (>third tertile [Q3]). All the samples were washed with tap water, before the edible part was cut into small pieces. Each fruit sample was then stored at -80°C until required for further analysis.

2.2 Sample preparation and extraction

The soluble sugar extraction was performed according to the method described by Pan [16]. Briefly put, the fruit samples (stored at -80°C) were homogenized and diluted with an equal volume of ultrapure water. The solution was then subjected to sonication for 30 min. Following centrifugation at 12,000 rpm (4°C) for 30 min, the supernatant was filtered through a 0.22 µm syringe filter and transferred to a new tube. The samples were again stored at -80°C until required for further analysis.

2.3 Sugar concentration determination (LC-MS/MS)

The sugar concentrations of the samples were also determined according to the method described by Pan [16], albeit with some modifications. All the samples were diluted with ultrapure water (1:100), before 1 µL was injected into the LC-MS/MS analysis. The fructose, glucose, and sucrose standards were obtained from Sigma-Aldrich (Darmstadt, Germany). In terms of the LC-MS/MS method, a liquid chromatograph was coupled to a triple quadrupole mass spectrometer capable of negative ion mode electrospray ionization that was equipped with an ultra-performance liquid chromatography system (Agilent Technologies, Santa Clara, CA, USA). The fructose, glucose, and sucrose standards and the samples were separated using an Asahipak NH2P-50 Column (4.6 µm, 250 mm; Showa Denko America, Inc., New York, NY, USA). A mobile phase consisting of 80% 10 mM ammonium acetate and 20% acetonitrile at a flow rate of 0.2 mL/min was used. The column temperature was maintained at 28°C, while the injection volume was set at 10 µL. The mass spectrometer detector conditions were as follows: the capillary voltage was maintained at 4500 V, the nebulizer was set to 2 Bar, the drying heater was set to 200°C, and the drying gas flow was set to 8 L/min. The fructose, glucose, and sucrose concentrations were calculated using the following Equations (Eq. 1-3):

$$\text{Fructose (g/100g FW)} = \frac{\text{Area of sample x Dilution factor}}{\text{Slope of std of fructose x Weight of sample}} \text{ x } 100 \tag{1}$$

$$\text{Glucose (g/100g FW)} = \frac{\text{Area of sample x Dilution factor}}{\text{Slope of std of glucose x Weight of sample}} \text{ x } 100 \tag{2}$$

$$\text{Sucrose (g/100g FW)} = \frac{\text{Area of sample x Dilution factor}}{\text{Slope of std of sucrose x Weight of sample}} \text{ x } 100 \tag{3}$$

2.4 Sweetness index and total sweetness index

The sweetness index (SI) and the total sweetness index (TSI) were calculated using the following equations (Eq. 4-5) [17]:

$$\text{SI} = (1.00 \times [\text{glucose}]) + (2.30 \times [\text{fructose}]) + (1.35 \times [\text{sucrose}]) \tag{4}$$

$$\text{TSI} = (1.00 \times [\text{sucrose}]) + (0.76 \times [\text{glucose}]) + (1.50 \times [\text{fructose}]) \tag{5}$$

2.5 Sugar content of a portion size

Based on food exchange data, one serving, or one edible portion of each fruit was calculated on the basis of the total sugar content (fructose + glucose + sucrose). Then, the weight of each fruit required for one edible portion was calculated using the amount of carbohydrate available from Online Thai Food Composition Database [15]. The assumption was that one edible portion should provide 15 g of carbohydrate [18].

2.6 Statistical analysis

The data were statistically analyzed using statistical software (IBM® SPSS® Statistics for Version 20.0, IBM, Armonk, New York, USA) and then presented as means ± standard deviations. The differences between the samples' mean values were analyzed by means of a one-way analysis of variance (ANOVA) using Duncan's new multiple range test. The differences between the samples were accepted as being statistically significant at a level of $\alpha = 0.05$.

3. Results

Five fruits, namely mangosteen, rambutan, longkong, pomelo, and jackfruit, from well-known geographical indication areas in Southern Thailand were collected and their soluble sugar contents (fructose, glucose, and sucrose) were determined via an LC-MS/MS analysis. The fructose, glucose, and sucrose standards were eluted at 2.9 min, 3.4 min, and 4.3 min, respectively (Figure 1). The total sugar content (fructose + glucose + sucrose) of each fruit was calculated by comparing with the standard curves of the fructose, glucose, and sucrose (Figure 1). The results revealed that fructose was the most abundant sugar in the fruit samples, ranging from 0.8–30.6 g/100 g fresh weight (FW) (7.3–88.4% dried weight (DW)), followed by glucose (ranging from 2.2–23.9 g/100 g FW or 11.2–67.5% DW) and sucrose (ranging from 0.5–10.4 g/100 g FW or 2.6–58.2% DW). The jackfruit contained the highest average concentration of total sugar (59.3 g per 100 g FW or 167.1% DW), followed by longkong (26.2 g/100 g FW or 134.7% DW), rambutan (20.2 g/100 g FW or 112.3% DW), mangosteen (16.5

g/100 g FW or 84.1% DW), and pomelo (4.5 g/100 g FW or 44.8% DW) (Tables 1 and 2). The monosaccharides (fructose and glucose) were the major types of sugars detected in the longkong and jackfruit, whereas sucrose was the predominant sugar detected in the mangosteen, rambutan, and pomelo. With regard to the glucose-to-fructose ratio, the amount of fructose stored in the mangosteen and rambutan was approximately 1.5- and 2-fold higher than the amount of glucose, respectively.

Among the geographical indication fruits investigated in this study, pomelo was characterized by the lowest total fructose and glucose contents (below the detection limit), while sucrose was the main sugar component, contributing to 80–90% of its total sugar content. In terms of the sugar profiles of the small, medium, and large sample sizes, the fructose, glucose, and sucrose concentrations differed significantly among the different fruit sizes (Tables 1 and 2). The mean total sugar concentrations of the mangosteen and rambutan increased in parallel with the increasing sample size (Tables 1 and 2, Figure 2). However, the small, medium, and large sample sizes of the longkong and pomelo showed nearly the same value of total sugar. The SI and TSI were calculated as shown in Table 1. The medium sample size of jackfruit was found to have the highest SI and TSI, which were the result of sucrose and fructose concentrations of 1326.4 mg/g FW and 906.5 mg/g FW, respectively.

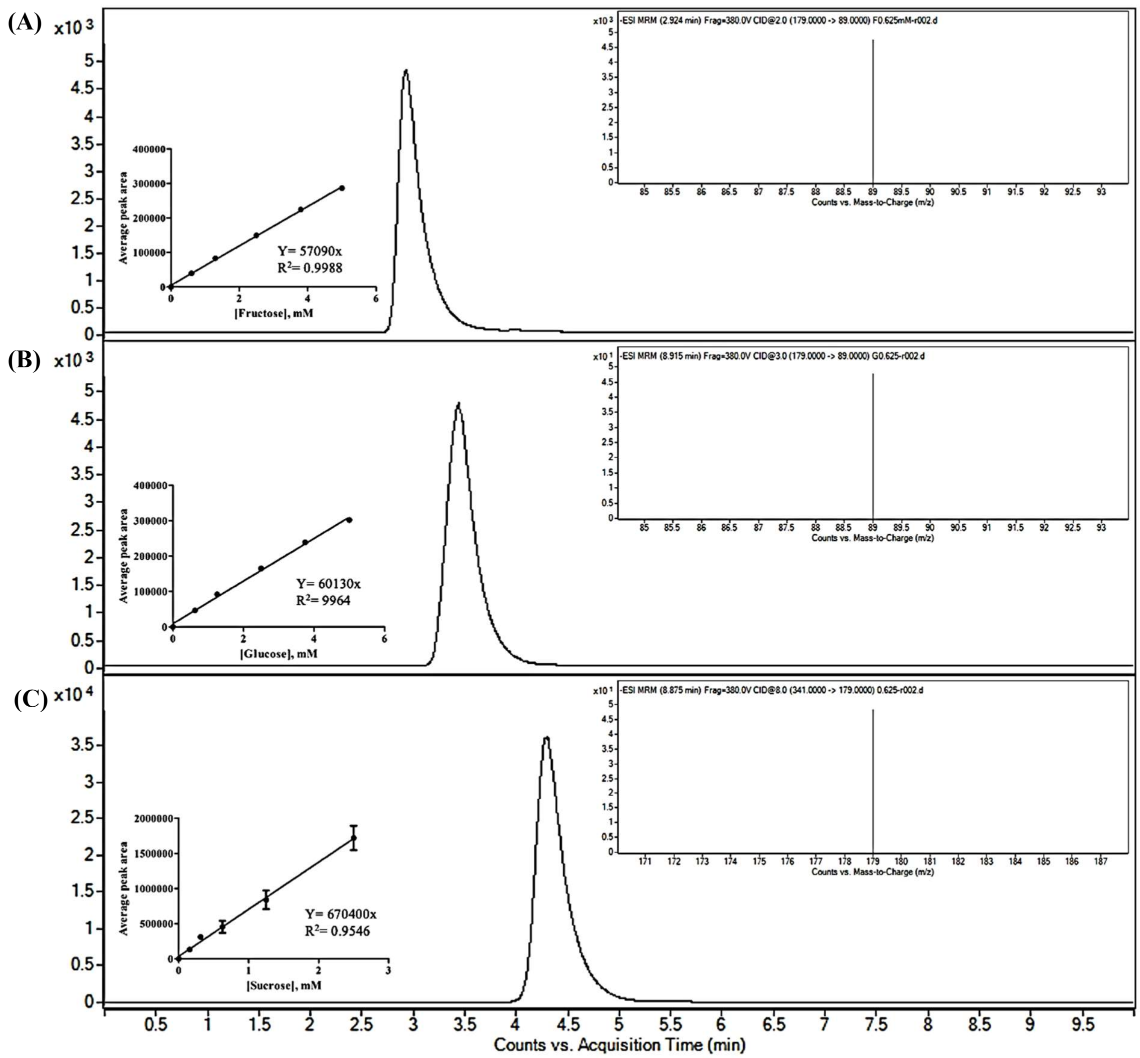

Figure 1 LC-MS/MS chromatogram of the fructose, glucose, and sucrose standard compounds. The fructose, glucose, and sucrose standard compounds were separated using an Asahipak NH2P-50 Column. Moreover, the fructose, glucose, and sucrose were eluted at 2.9 min (m/z 179→89) (A), 3.4 min (m/z 179→89) (B), and 4.3 min (m/z 341→179) (C), respectively.

Table 1 Sugar profiles of different sizes of fresh-weight geographical indication fruits from Southern Thailand.

Fruit item	Edible part Median (Q1, Q3)	Fructose (g/100 g FW)	Glucose (g/100 g FW)	Sucrose (g/100 g FW)	Total sugar (g/100 g FW)	SI (mg/g FW)	TSI (mg/g FW)
Mangosteen							
Small	21.0 (19.8, 22.0)	3.2±0.0^{c}	1.4±0.0^{c}	8.2±0.0^{b}	12.8	198.9	140.9
Medium	23.7 (22.8, 24.9)	5.1±0.0^{a}	2.8±0.0^{a}	11.0±0.1^{a}	18.9	294.3	208.1
Large	27.0 (26.0, 30.8)	4.8±0.0^{b}	2.4±0.0^{b}	10.6±0.0^{a}	17.8	278.1	196.6
Average		4.4±1.0	2.2±0.7	9.9±1.5	16.5	256.9	181.8
Rambutan, Rong-rean variety							
Small	13.0 (10.3, 13.8)	3.8±0.0^{c}	2.4±0.0^{c}	6.4±0.0^{c}	12.6	198.4	139.6
Medium	16.0 (15.0, 17.8)	6.0±0.1^{b}	4.0±0.0^{b}	10.5±0.0^{b}	20.5	319.3	225.2
Large	20.0 (19.0, 20.5)	8.0±1.1^{a}	5.1±0.1^{a}	14.4±1.5^{a}	27.4	428.4	302.1
Average		5.9±2.1	3.8±1.3	10.4±4.0	20.2	315.2	222.2
Pomelo, Tubtim Siam variety							
Small	50.0 (45.3, 69.8)	1.0±0.0^{b}	n.d.	4.2±0.6^{b}	5.2	80.8	57.8
Medium	70.0 (53.3, 83.5)	1.2±0.0^{a}	n.d.	4.5±0.8^{a}	5.6	87.1	62.2
Large	99.0 (92.3-113.3)	0.3±0.0^{b}	n.d.	4.2± 0.7^{b}	4.4	63.1	46.1
Average		0.8±0.4	n.d.	4.3±0.2	4.5	76.9	55.3
Longkong							
Small	11.0 (10.0, 13.0)	14.3±0.1^{c}	11.3±0.1^{a}	0.3±0.0^{c}	25.9	446.2	303.6
Medium	15.0 (14.0, 16.0)	15.0±0.6^{a}	11.2±0.1^{b}	0.8±0.0^{a}	27.0	468.5	318.6
Large	20.0 (18.5, 23.0)	14.6±0.0^{b}	10.5±0.0^{c}	0.4±0.0^{b}	25.6	447.2	303.5
Average		14.7±0.4	11.0±0.4	0.5±0.3	26.2	453.9	308.5
Jackfruit, Jum-pa variety							
Small	11.0 (9.5, 12.0)	20.2±0.3^{b}	14.6±0.1^{b}	7.2±0.1^{a}	41.9	707.0	485.4
Medium	15.0 (14.0, 15.0)	40.5±0.3^{a}	33.2±0.1^{a}	4.7±0.0^{a}	78.4	1326.4	906.5
Large	18.0 (17.3, 18.8)	31.2±0.3^{a}	24.0±0.1^{a}	2.3±0.0^{b}	57.5	989.0	673.6
Average		30.6±10.2	23.9±9.3	4.7±2.4	59.3	1007.4	688.5

$^{a, b, c}$Means within the same column with different superscripts are significantly different ($p \leq 0.05$).
n.d. = not detected; FW = fresh weight; SI = sweetness index; TSI = total sweetness index.

Table 2 Sugar profiles of different sizes of dried weight geographical indication fruits from Southern Thailand.

Fruit item	Fructose (g/100 g DW)	Glucose (g/100 g DW)	Sucrose (g/100 g DW)	Total sugar (g/100 g DW)
Mangosteen				
Small	15.2	6.6	38.9	60.7
Medium	25.8	14.1	55.6	95.5
Large	25.9	13.0	57.3	96.2
Average	22.3±6.2	11.2±4.0	50.6±10.2	84.1±20.3
Rambutan, Rong-rean variety				
Small	19.0	12.0	32.0	63.0
Medium	31.3	20.8	54.7	106.8
Large	48.8	31.1	87.8	167.1
Average	33.0±15.0	21.3±9.6	58.2±28.1	112.3±52.3
Pomelo, Tubtim Siam variety				
Small	8.4	n.d.	35.3	43.7
Medium	10.6	n.d.	39.8	49.6
Large	2.8	n.d.	39.3	41.1
Average	7.3±4.0	n.d.	38.1±2.5	44.8±4.3
Longkong				
Small	71.9	56.8	1.5	130.2
Medium	77.3	57.7	4.1	139.2
Large	76.8	55.3	2.1	134.7
Average	75.3±3.0	56.6±1.2	2.6±1.4	134.7±4.5
Jackfruit, Jum-pa variety				
Small	55.0	39.8	19.6	114.2
Medium	112.8	92.5	13.1	218.4
Large	91.5	70.4	6.7	168.6
Average	86.4±29.2	67.5±26.5	13.2±6.4	167.1±52.1

n.d. = not detected; DW = dried weight.

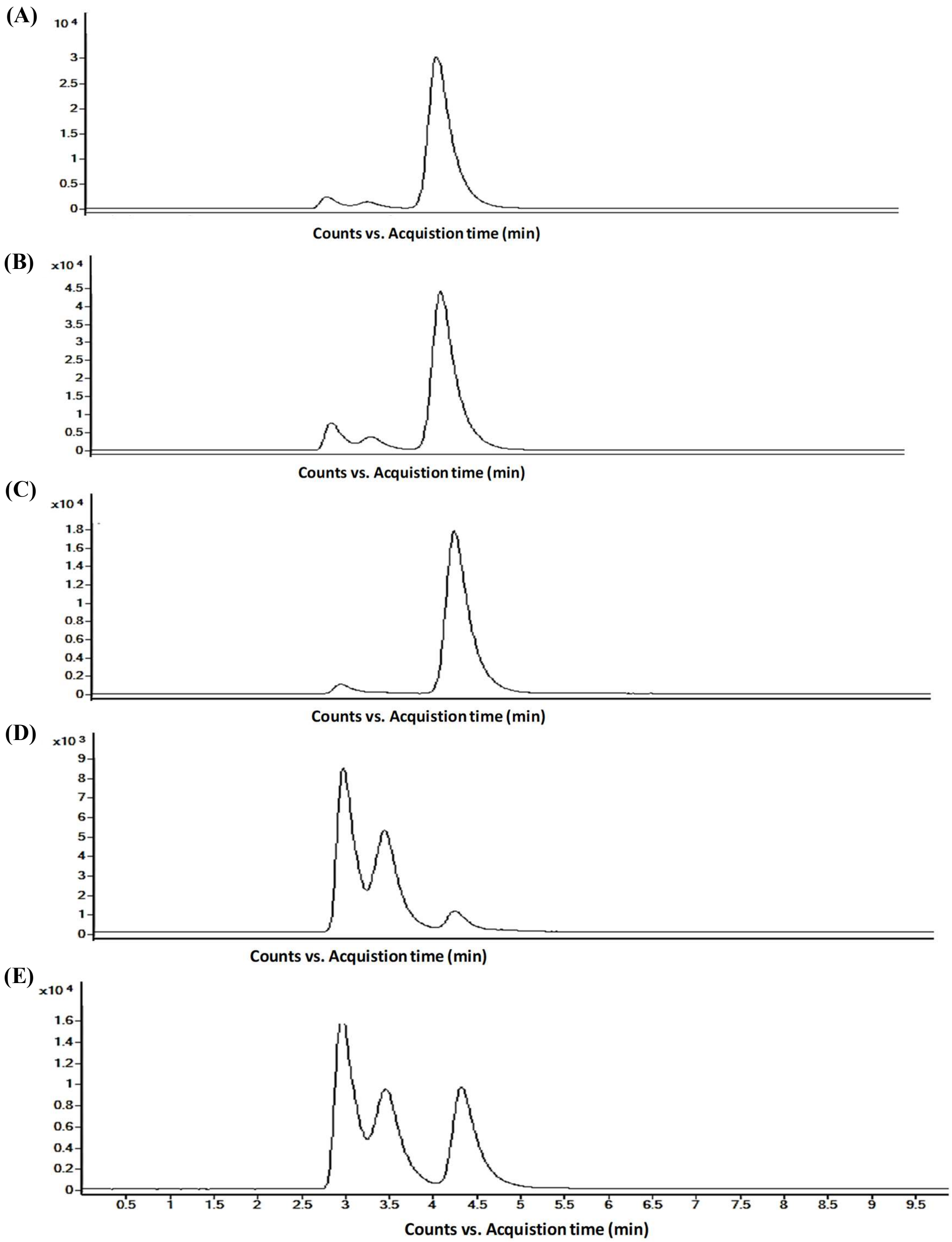

Figure 2 LC-MS/MS chromatogram of the sugar contents of the mangosteen (A), rambutan (Rong-rean variety) (B), pomelo (Tubtim Siam variety) (C), longkong (D), and jackfruit (Jum-pa variety) (E).

One edible portion size (carbohydrate = 15 g) of each fruit was calculated on the basis of food exchange data [18]. In (Table 3), the weight of each fruit that provides 15 g of carbohydrate (total amount of sugar) was calculated to one portion size according to the Online Thai Food Composition Database [15]. Eighty-five grams of mangosteen (3-4 pieces), 90 g of rambutan (5-7 pieces), 177 g of pomelo (2-4 pieces), 109 g of longkong (6-9 pieces), and 58 g of jackfruit (3-5 pieces), which all contained up to 15 g of carbohydrate, were accordingly recommended as the individual portion sizes for each fruit.

The determination of the various fruits revealed that one serving of large-sized pomelo (Tubtim Siam variety; approximately 177.0 g/ 2 pieces) contained the lowest fructose value of 0.5 g and a total sugar value of 7.8 g. By contrast, one serving of medium-sized jackfruit (Jum-pa variety) contained the highest amount of fructose (23.5

g), glucose (19.3 g), and total sugar content (45.5 g). Thus, it should be noted that the overconsumption of jackfruit (Jum-pa variety) will cause people to consume large amounts of fructose, glucose, and total sugar.

Table 3 Recommended amounts of different sizes of fresh-weight geographical indication fruits from Southern Thailand.

Fruit item	Edible part Median (Q1, Q3)	One edible portion[a]	Recommended amount (piece)	Fructose g/serving	Glucose g/serving	Sucrose g/serving	Total sugar g/serving
Mangosteen							
Small	21.0 (19.8, 22.0)	85	4	2.8	1.2	7.0	10.9
Medium	23.7 (22.8, 24.9)		4	4.4	2.4	9.4	16.1
Large	27.0 (26.0, 30.8)		3	4.1	2.1	9.0	15.1
Rambutan, Rong-rean variety							
Small	13.0 (10.3, 13.8)	90	7	3.4	2.2	5.7	11.3
Medium	16.0 (15.0, 17.8)		6	5.4	3.6	9.4	18.4
Large	20.0 (19.0, 20.5)		5	7.2	4.6	13.0	24.7
Pomelo, Tubtim Siam variety							
Small	50.0 (45.3, 69.8)	177	4	1.8	n.d.	7.5	9.2
Medium	70.0 (53.3, 83.5)		3	2.0	n.d.	8.0	9.9
Large	99.0 (92.3-113.3)		2	0.5	n.d.	7.4	7.8
Longkong							
Small	11.0 (10.0, 13.0)	109	9	15.6	12.3	0.4	28.2
Medium	15.0 (14.0, 16.0)		7	16.4	12.2	0.8	29.4
Large	20.0 (18.5, 23.0)		6	16.0	11.5	0.4	27.9
Jackfruit, Jum-pa variety							
Small	11.0 (9.5, 12.0)	58	5	11.7	8.5	4.2	24.3
Medium	15.0 (14.0, 15.0)		4	23.5	19.3	2.7	45.5

[a] One edible portion of each fruit (g) was based on food exchange data concerning the amount required to provide 15 g of carbohydrate [18]; the weight of one edible portion was calculated using the amount of carbohydrate in each kind of fruit available from the Online Thai Food Composition Database [15].

4. Discussion

Fruits are a good source of phytochemicals (e.g., flavonoids, terpenoids), vitamins, and minerals that are associated with a wide range of health benefits, including anti-inflammation, anti-oxidant, and anti-cancer activity. The level of fruit consumption is dependent on flavor, especially sweetness. Moreover, the sugar content (sucrose, glucose, and fructose) is a crucial indicator of a fruit's quality and economic traits [19]. Although previous studies have examined the sugar profiles of fruits, none have been conducted in relation to geographical indication fruits from Southern Thailand. In this study, pomelo (Tubtim Siam variety) was found to have a lower total sugar content (approximately 4.5 g/100 g FW or 44.8% DW), while the fructose and glucose contents were 0.8 g/100 g FW and lower detection limit, respectively. This finding is in line with the findings reported in Pan [16], where the sugar contents of 24 pomelos from subtropical areas of China were mainly composed of sucrose (1.9–5.5 g/100 g FW), followed by fructose (1.6–2.4 g/100 g FW), and glucose (1.6–2.4 g/100 g FW). However, a prior study involving different species of pomelos from Thailand (e.g., Khaonahmpeung variety and Tongdee variety) showed 2- to 3-fold higher sugar contents than found in this study [20].

Moreover, in this study, the accumulation of soluble sugars in mangosteen, rambutan, and longkong ranged from 16.5–26.2 g/100 g FW. These findings are comparable to those of Chareoansiri [20], which determined the sugar profiles of Thai market fruits and found the total sugar contents of mangosteen, rambutan, and longkong to be 17.5 g/100 g FW, 18.5 g/100 g FW, and 15.2 g/100 g FW, respectively. Among the samples tested in this study, the highest sugar profile was found for the jackfruit (Jum-pa variety; 59.3 g/100 g FW). In addition, fructose (30.6 g/100 g FW) and glucose (23.9 g/100 g FW) represented the main sugar contents of the jackfruit (Jum-pa variety). This finding is inconsistent with the finding of Lee [21], which indicated sucrose (approximately 20 g/100 ml) to be the main sugar content of Cempedak (Jum-pa variety), followed by glucose and fructose.

The present study is the first to report the sugar profiles and mean total sugar concentrations of different sizes of geographical indication fruits from Southern Thailand. The findings demonstrated that the accumulation of the sugar contents of mangosteen and rambutan increased in parallel with an increasing size (Tables 1 and 2, Figure 2). However, the longkong and pomelo samples showed nearly the same value of total sugar among the small, medium, and large sample sizes. It has been hypothesized that genetic factors might contribute to carbohydrate metabolism during fruit growth and ripening, thereby resulting in different qualities in terms of sugar production in the fruits [22]. Moreover, environmental factors, including the materials stored in the soil (e.g., organic carbon, minerals, water) of the geographical indication areas in Southern Thailand, might have influenced the sugar contents of the fruits included in this study. A similar finding was observed in McCray [23], which showed that the sugar yield of sugarcane was influenced by calcium and magnesium as well as the soil's organic matter content. In light of this, further studies are required to examine the different environmental factors, including the materials (e.g., organic matter, minerals, water) stored in the soil, climate change, and the latitude between the geographical indication region and other regions, that influence the sugar contents of fruits.

The daily recommended level of fruit and vegetable consumption is based on the individual's calorie requirements, as determined by the individual's age, sex, and physical activity level [24]. According to the Dietary Guidelines for Americans, 1.5-2 cups and 2-2.5 cups of fruit each day are the recommended portions for female and male adults, respectively, until they are 60 years old, at which point the recommendation becomes 2 cups [25]. In addition, according to Thailand's Department of Health, Thai people who require 2,000 Kcal/day are recommended to eat approximately 3-5 portions of fruit [26]. Importantly, fruit and vegetable consumption has been linked to a lower risk of chronic diseases as well as to improved weight control, although the exact mechanism involved remains uncertain [27].

In the present study, the recommended amount per individual edible portion (15 g of carbohydrate [18]) of different sizes of geographical indication fruits from Southern Thailand was found to be 3-4 pieces of mangosteen, 5-7 pieces of rambutan, 6-9 pieces of longkong, 2-4 pieces of pomelo, and 3-5 pieces of jackfruit. These findings are lower than those obtained with regard to rambutan and longkong in Chareoansiri [20], likely due to the different cultivars studied and the adverse microclimate. The overconsumption of fruits may add too much sugar to the diet, leading to the deposition of fat. Consequently, choosing and limiting the intake of fresh fruits could prevent hyperglycemia in people with type 2 diabetes, while consuming at least the recommended amount of fruit should provide health-promoting properties and enhance well-being [28]. Thus, it should be noted that the data concerning the sugar profiles of the investigated fruits are significant and can be used in relation to healthy people.

5. Conclusion

This study provided valuable information concerning the sugar profiles and recommended portions of five geographical indication fruits from Southern Thailand. Fructose and sucrose were found to be the major naturally occurring sugar contents found in the fruits, which resulted in them having a good flavor. The individual edible portion size for each fruit was found to be 85 g of mangosteen, 90 g of rambutan, 177 g of pomelo (Tubtim Siam variety), 109 g of longkong, and 58 g of jackfruit (Jum-pa variety). Recognizing the preferred types of geographical indication fruits from Southern Thailand may help physicians and dieticians to provide appropriate nutritional education or run campaigns recommending fruit intake for general people.

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