Some Characteristics and Antioxidant Activity of Commercial Sugars Produced in Thailand

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ABSTRACT

Seven commercial sugars produced in Thailand (cane sugar paste (S1), unrefined cane sugar (S2), brown cane sugar (S3), caramel crystal cane sugar (S4), refined white crystal cane sugar (S5), coconut sugar paste (S6) and palm sugar paste (S7)) were analyzed for chemical and physical properties as well as antioxidative activity. The pH values of all samples ranged from 5.17 to 5.57. S5 exhibited the highest L* value, whereas S1 showed the lowest L* value (p<0.05). Among sugars from sugar cane, S1 had the highest amount of Ca, Mg, Fe, K, and Na (p<0.05). Additionally, differences in total sugar and reducing sugar contents of all samples were observed (p<0.05). The intermediate browning products and browning intensity of all samples were also determined. S1 had the highest intermediate and browning products (p<0.05). Higher total phenolic content was observed in sample extract with water compared with that did with 95% methanol (p<0.05). Regardless of extraction solutions, S1 extract exhibited the highest total phenolic content (p<0.05). Antioxidant activities of both extracts were evaluated. S1 exhibited the highest DPPH and ABTS radical scavenging activities and ferric reducing power, compared with other samples (p<0.05). From the results, sugar with high browning products and total phenolic content contributed to their high antioxidant activities.

Keywords: sugar, browning intensity, total phenolic content, antioxidative activity

1. INTRODUCTION

Sugar as a basic food carbohydrate primarily comes from sugar cane and from sugar beet. It is a natural sweetener, and it has been intensively used in many food industries for example, candy, soft drinks and canned fruit. Sugar enhances the taste, texture, color, and aroma of many kinds of foods. Additionally, sugar is also used as traditional preservatives such as sugar syrup, sweetmeat and pickling etc. because sugar can function as antimicrobial preservative, which inhibit the growth of bacteria and fungi. In Thailand, sugar are manufactured from many type of plant, based on raw materials available in each local such as sugar palm from the sap of flowering stalks, coconut palm from the sap from coconut tree blossoms and juice from stem of sugar cane. There are various types of sugar categorized by their use and their characteristics such as size of the crystals, color and taste. In the production of sugar, syrup must heat until it is concentrated. During the heating process, physical and chemical changes occur which impart the unique color and flavor features. Major reactions occur during the process of heating, including the inversion reaction and non-enzymatic browning reactions (Maillard reaction and caramelization) [1]. Maillard reaction products and caramelization products have been found to exhibit antioxidative activity due to their radical scavenging activities and reducing power [2]. Sugars in form of powder granulate and paste can be found commercially. Although, studies on some characteristics and antioxidative activity of certain sugars have been mentioned but no information on characteristics and antioxidative activities of commercial sugars produced in Thailand has been systematically reported. Thus, this study aimed to investigate the chemical and physical properties as well as antioxidative activities of different commercial sugars produced in Thailand.

2. MATERIALS AND METHODS

2.1 Collection of commercial sugars

Cane sugar paste (S1) was procured from Chiangmai, Thailand. The manufactured sugars including unrefined cane sugar (S2), brown cane sugar (S3), caramel crystal cane sugar (S4), and refined white crystal cane sugar (S5) were purchased from supermarkets with the same manufacturer. Coconut sugar paste (S6) and palm sugar paste (S7) were obtained from Chumphon and Petchaburi, Thailand (Figure 1). Sugar samples
were vacuum packed in aluminum bag (500 g/bag) and kept at -20°C until used within 1 week.

Figure 1 Commercial sugars. Cane sugar paste (S1), unrefined cane sugar (S2), brown cane sugar (S3), caramel crystal cane sugar (S4), refined white crystal cane sugar (S5), coconut sugar paste (S6) and palm sugar paste (S7)

2.2 Physicochemical properties of commercial sugars

2.2.1 Determination of pH value

The pH of sugar was determined according to the method of Benjakul, Seymour, Morrissey and An [3]. Sample was homogenized with 10 volumes of distilled water (w/v), and the pH of the homogenate was measured using a pH meter (UB-10 UltraBasic, Denver, USA).

2.2.2 Determination of water activity (a_w) value

The aw of sugar was measured using a water activity meter (S40003131, AQUA LAB, USA)

2.2.3 Determination of color

Color of sugar was measured by Hunter lab (ColorFlex, Hunter, USA) and reported in CIE system, L*, a* and b* parameters indicate lightness, redness/greenness and yellowness/blueness, respectively.

2.2.4 Determination of total sugar and reducing sugar contents

Total sugar content was determined following the method of James [4] with a slight modification. Sample (1 g) was added with 10 ml of 1.5 M sulphuric acid and mixed well with a vortex. The mixture was incubated at 100°C for 20 min in water bath then cooled with ice and water for 5 min. Twelve milliliters sodium hydroxide solution (10%) was added and mixed with a vortex. The mixture was filtered through a Whatman No.4 filter paper into a 50 ml volumetric flask and made up to volume with distilled water. The filtrate (500 µl) was pipetted into a test tube and 500 µl of 3,5-dinitrosalicylic acid (DNS) solution was added and then mixed well. Distilled water (1 ml) was added and transferred to incubate at 100°C for 20 min then cooled with ice and water for 5 min. The total sugar content was measured absorbance at 540 nm by spectrophotometer. A D-glucose solution (0-1.5 mg/ml) was used as a standard for total sugar and expressed as mg glucose/g dry weight of sample.

The content of reducing sugar was determined according to the method of James [4] with a slight modification. Sample (5 g) was added with 50 ml distilled water and mixed well. The mixture was incubated with water bath at 70°C for 10 min. Then, the mixture was filtered with Whatman No.4 filter paper. The reducing sugar content in filtrate was measured as described in total sugar content determination.

2.2.5 Determination of mineral content

The minerals including, calcium, magnesium, iron, potassium, and sodium were determined by inductively coupled plasma emission spectrometer (Optima 3300 DV, Perkin-Elmer, United States) according to the AOAC [5]. Sample (150 mg) was mixed well with 4 ml nitric acid. The mixture was incubated at 40°C for 20 min then cooled with ice and water. The digested sample was transferred to a volumetric flask and the volume was made up to 50 ml with distilled water. The solution was subjected to inductively couple plasma-optical emission spectrometer (ICP-OES) analysis. Flow rates of argon to plasma, auxiliary and nebulizer were kept at 15, 0.2 and 0.8 l/min, respectively. Sample flow rate was set at 1.5 ml/min. The wavelengths for analysis of calcium, magnesium, iron, potassium, and sodium were 317.933, 285.213, 238.204, 766.490, and 589.592 nm, respectively.

2.2.6 Determination of intermediate browning product and browning intensity

The intermediate browning product and browning intensity of sugar was determined according to the modified the method of Ajandouz and Puigserver [6]. Sample was dissolved in distilled water (10% w/v). Prior to analysis, fifty-fold and five-fold dilutions made for determination of intermediate browning product and browning intensity, respectively using distilled water as the diluent. The intermediate browning product and browning intensity was measured at a wavelength of 285 nm and 420 nm, respectively using a spectrophotometer.

2.2.7 Determination of total phenolic content

Total phenolics content of sugar solution was determined by the Folin-Ciocalteu micro-method (Saeedeh and Asna [7]). Twenty microliters of sugar solution was mixed with 1.16 ml of distilled water and 100 µl of Folin-Ciocalteu reagent, followed by the addition of 300 µl of 20% Na₂CO₃ solution. Then, the mixture was incubated at 40°C in a shaking water bath (model D-91126, Memmert, Schwabach, Germany) with speed 6 for 30 min. The absorbance at 760 nm of the mixture was measured by spectrophotometer. Total phenolic content was calculated and expressed as mg gallic acid equivalent (GAE)/g dry weight of the sample.

2.3 Determination of antioxidat activities of sugars

2.3.1 Preparation of extracts from sugars

Solutions of sugar were prepared at 0.5% (dry weight/volume), dissolved in distilled water or
methanol using a stirrer for 2 h. Then, the mixture was filtered through a Whatman No.4 filter paper. The extracts were stored at 4°C in the dark until analyses.

2.3.2 Determination of 2,2-diphenyl-1-picrylhydrazyl (DPPH)-radical scavenging activity

DPPH-radical scavenging activity of sugar solution was determined according to the method of Yen and Hsieh [8] with a slight modification. Four hundred microliters of sugar solution was mixed with 2 ml of DPPH solution (0.12 mM in 95% methanol). The reaction mixture was mixed well and incubated at room temperature for 30 min. The absorbance of mixtures was measured at 517 nm by spectrophotometer. The control was prepared in the same manner, excepted that 80% methanol was used instead of sugar solution. The radical scavenging activity was measured as a decrease in the absorbance of DPPH-sample mixture. The percentage of DPPH radical scavenging activity was calculated as follows (Singh and Rajini [9])

\[
\text{Radical scavenging activity (\%)} = \left(1 - \frac{A_s}{A_c}\right) \times 100
\]

where:
- \(A_s\) is the absorbance at 517 nm of sample
- \(A_c\) is the absorbance at 517 nm of control

2.3.3 Determination of 2,2'-azino-bis (3-ethylbenzthiazoline -6-sulphonic acid) (ABTS)-radical scavenging activity

ABTS radical scavenging activity was determined as described by Re, Pellegrini, Proteggente, Pannala, Yang and Rice-Evans [10] with a slight modification by Khantaphant and Benjakul [11]. ABTS radical (ABTS\*+) was produced by reacting ABTS stock solution (7.4 mM) with 2.6 mM potassium persulphate at the ratio of 1:1 (v/v). The mixture was allowed to react in dark for 12 h at room temperature. Prior to assay, ABTS\*+ solution was diluted with methanol to obtain an absorbance of 1.1 (±0.02) at 734 nm. To initiate the reaction, sugar solution (150 µl) was mixed with 2850 µl of ABTS\*+ solution. The mixture was incubated at room temperature for 2 h (dark reaction). The absorbance was then read at 734 nm of the mixture was measured by spectrophotometer. A standard curve of Trolox ranging from 0-600 µM was prepared. The activity was expressed as µmol Trolox equivalents (TE)/g dry weight of the sample.

2.3.4 Determination of ferric reducing antioxidant power (FRAP)

Ferric reducing antioxidant power of sugar solution was determined following the method of Benzie and Strain [12]. Stock solutions contained 300 mM acetate buffer (pH 3.6), 10 mM 2, 4, 6-tripyridyl-s-triazine (TPTZ) solution in 40 mM HCl, and 20 mM FeCl\(_3\)·6H\(_2\)O. A working solution was prepared freshly by mixing 25 ml of acetate buffer, 2.5 ml of TPTZ solution and 2.5 ml of FeCl\(_3\)·6H\(_2\)O solution. The mixed solution was incubated at 37°C for 30 min and was referred to as FRAP solution. One hundred fifty microliters of sugar solution was mixed with 2850 µl of FRAP solution and kept for 30 min in the dark. The ferrous tripyridyltriazine complex (colored product) was measured by reading the absorbance at 593 nm. The standard curve was prepared using Trolox ranging from 0-600 µM. The activity was expressed as µmol Trolox equivalents (TE)/g dry weight of the sample.

2.4 Statistical analysis

The data was subjected to One-way Analysis of Variance (ANOVA) and the differences between means were evaluated by Duncan’s Multiple Range Test or Independent samples t-test (Steel and Torrie [13]).

3. RESULTS AND DISCUSSION

3.1 Physicochemical properties of commercial sugars

3.1.1 pH values

Table 1 shows the pH values of seven commercial sugars. Differences in pH values of commercial sugars were observed (p<0.05). In general, five commercial sugars produced from sugar cane used in this study are cane sugar paste, unrefined cane sugar, brown cane sugar, caramel crystal cane sugar and refined white crystal cane sugar. The pH values of those cane sugars were found in the ranges of 5.14 to 5.57. Cane sugar paste exhibited the highest pH value (5.57). Beside cane sugar sample, the pH values of coconut sugar paste and palm sugar paste were 5.50 and 5.27, respectively. Many researchers suggested that the pH of sugar can be used as an indicator for the product safety [1]. Furthermore, the pH value can be used to classify the food products into acid food and low acid food [14]. Guerra and Mujica [15] reported that the pH values of cane sugar “Panela” ranged from 5.58-6.90. Nakano et al [16] showed that the pH value of coconut sugar was 5.57. Nakano et al and Meenune [1] and Phichaivanman, Posri and Meenune [17] also reported the pH value of palm sugar which was in the ranges of 4.49-5.42 and 4.5-5.37, respectively. The pH value of the sugar is related to the quantity of lime used in the clarifying process of the juice during sugar preparation [15]. Also, Phichaivanman, Posri and Meenune [17] found that the organic acids, particularly lactic acid, produced by lactic acids bacteria were observed in palm sugar concentrate. Generally, the decrease in pH value of palm sap and coconut sap occurred during heating for palm sugar and coconut sugar productions [18]. In addition, the reduction of pH was probably due to the occurrence of organic acids such as formic and acetic acid via the Maillard reaction [19-21]. From the results, the differences in pH of sugar might be resulted from the different raw materials and processes used.
The highest total sugar and reducing sugar contents of seven commercial sugars were slightly different (p<0.05) (Fig.3). Commercial sugars had total sugar content between 761.96 - 841.23 mg/g dry weight. The highest total sugar content was found in caramel crystal cane sugar, followed by brown cane sugar, while coconut sugar paste had the lowest. A wide range of reducing sugar content of commercial sugars (0.15-122.07 mg/g dry weight) was noticeable. Cane sugar paste contained the highest reducing sugar content, followed by coconut sugar paste and palm sugar paste, respectively. Refined white crystal cane sugar had the lowest reducing sugar content. Martins, Jongen and Van Boekel [24] reported that during heating in the manufacturing process, especially at high temperature.
and long heating time, it could accelerate the hydrolysis of sucrose yielding reducing sugars. However, high reducing sugar content presented in sugar also influences the browning color of sugar afterward, due to the Maillard reaction [1]. Cane sugar paste, coconut sugar paste and palm sugar paste were traditional produced by evaporating the juice in a large opened pan under heating with the wood fired stove until the concentrated paste was obtained [25]. Those sugar pastes had higher reducing sugar content than other industrially manufactured sugars. Thus, low reducing sugar in refined white crystal cane sugar compared to cane sugar paste, coconut sugar paste and palm sugar paste may be due to the chemical refining process which can eliminate the reducing sugar. In addition, Phaichamnan, Posri and Meenune[17] reported that the difference of total sugar and reducing sugar contents might be due to the effect of contamination from micro-organisms in sugar. The microorganisms can convert sucrose to glucose and fructose (invert sugar) and finally to organic acids or alcohols [26].

![Figure 3](image3.png)

**Figure 3** Total sugar (A) and reducing sugar (B) contents in commercial sugars. Bars represent the standard deviations from triplicate determinations. Different letters in the same value the different samples indicate the significant differences (p<0.05). S1: cane sugar paste; S2: unrefined cane sugar; S3: brown cane sugar; S4: caramel crystal cane sugar; S5: refined white crystal cane sugar; S6: coconut sugar paste; S7: palm sugar paste.

### 3.1.5 Mineral contents

The mineral contents of seven commercial sugars are shown in Fig 4. Different commercial sugars contained different levels of minerals (p<0.05). The levels of Ca, Mg, Fe, K, and Na were found to be highest in cane sugar paste (p<0.05). The contents of Ca in brown cane sugar was similar to that in cane sugar paste. This was probably due to the molasses addition during brown cane sugar production [27]. The pattern of mineral level of sugars produce different level of minerals. Guerra and Mujica [15] found that different brands of granulated sugar “Panel” had different contents of Ca, Mg, Fe, and K. Olaiya [28] reported that Ca is highly implicated in the maintenance of firmness of fruits and it requirements in fruits are related to cell wall stability and membrane integrity. According to the nutrition, Ca, Mg, and K are elements in macronutrient for function of human body. Several factors have been reported to affect the amount of some minerals in sugar such as cane variety, climate, soil, crop, handling, level of juice extraction, clarifying method, lime purity and impurity removal efficiency in manufacturing process [1]. From the result, cane sugar paste was abundant in minerals.

![Figure 4](image4.png)

**Figure 4** Calcium (A), magnesium (B), iron (C), potassium (D), and sodium (E) contents in commercial sugars. Bars represent the standard deviations from triplicate determinations. Different letters in the same value the different samples indicate the significant differences (p<0.05).

#### 3.1.6 Intermediate browning product and browning intensity

Intermediate browning product and browning intensity of seven commercial sugars were significantly different (p<0.05) (Fig 5). Cane sugar paste exhibited the highest intermediate browning product and browning intensity, followed by brown cane sugar and palm sugar paste, respectively whereas refined white crystal cane sugar exhibited the lowest. UV absorbance at 285 nm was used to monitor the intermediate degradation product of non-enzymatic browning reaction in commercial sugars [6], [29]. The high absorbance at 285 nm suggested the formation of an uncoloured compound, which could be the precursor of the Maillard reaction [6], [30]. The intermediate degradation products via enolization known as color precursors include methylglyoxal, glyceraldehyde, hydroxymethylfururaldehyde, furfural and hydroxyacetylufuran [31-34]. Naknean, Meeneune and Roudaut [35] suggested that an intermediate product was converted to a brown polymer and brown pigments were formed proportionately with the intermediate products generated. The degree of browning, usually measured
using the absorbance value at 420 nm, is often used to
determine the browning intensity in final stages [6],
[36], [37]. From the study in the model system of
Ajandouz and Puigserver [6], Lerttitikul, Benjakul and
Tanaka [20], Benjakul, Visessanguan, Phongkanpai and
Tanaka [29], Benjakul, Lerttitikul and Bauer [30]
and Phongkanpai, Benjakul and Tanaka [34],
intermediate degradation products increased as the
heating time and pH increased. In addition, Benjakul,
Visessanguan, Phongkanpai and Tanaka [29] reported
that the browning of sugars was developed
increasingly with the increase in pH. From the results,
high absorbance at 285 nm and 420 nm of cane sugar
paste might correlate to pH values. Generally,
different intermediate browning products and
browning intensity depend on the heating time and
pH levels.

Figure 5 Intermediate browning product (A) and browning
intensity (B) in commercial sugars. Bars represent the
standard deviations from triplicate determinations.
Different letters in the same value indicate the
significant differences (p<0.05). S1: cane sugar
paste; S2: unrefined cane sugar; S3: brown cane sugar; S4:
caramel crystal cane sugar; S5: refined white crystal cane
sugar; S6: coconut sugar paste; S7: palm sugar paste

3.2 Total phenolic content

Total phenolic contents of seven commercial
sugars extracted with distilled water or 95% methanol
were investigated. Total phenolic content of
commercial sugars extracts were different (p<0.05).
Higher total phenolic content was observed in
commercial sugar extracted with distilled water. In
general, the solubility of phenolic compound depends
on polarity of solvent [38]. Regardless of extraction
solvent, cane sugar paste had the highest total
phenolic content, followed by brown cane sugar and
palm sugar paste, respectively, whereas the lowest
was found in refined white crystal cane sugar. Harish
Nayaka, Satishha, Manohar, Chandrashekar and Dharmesh [39]
reported that total phenolic content of
brown cane sugar, refined sugar and jaggery (palm
sugar) extracted with distilled water were 0.37, 0.03
and 3.84 mg GAE/g, respectively. Nakane and
Meenune [1] studied the phenolic content of palm
sugar syrup produced in southern Thailand. It was
found that the total phenolic content of distilled water
extract was 1.35–2.21 mg GAE/g. Phoichanman, Posri
and Meenune [17] reported that the phenolic
compound was naturally found in the palm sap itself
and some was dissolved from Kiam wood during the
palm sap collection. In addition, Harish Nayaka Satishha,
Manohar, Chandrashekar and Dharmesh [39] reported
that jaggery and brown sugar had higher phenolic
content compared to white and refined sugar. This
was probably due to the minimal chemical processing
in the manufacture of jaggery and brown sugar which
retains more polyphenols. The phenolic compounds
impact color as well as taste to the sugar and its
removal is an important problem associated with
sugar manufacture [40]. The different techniques used
in sugar processing to remove color and impurities
affect the amount of polyphenols in sugars and this
may explain the low phenolic content of white and
refined sugars. From the results, commercial sugar
pastes (cane sugar paste, coconut sugar paste and
palm sugar paste) and brown cane sugar exhibited
high total phenolics content. Most phenolic compounds
found in distilled water extract. Therefore, sugar
paste composed of higher total phenolic compounds
than granulated and powdered sugars.

Figure 6 Total phenolic content in sugar dissolved in
distilled water (A) and 95% methanol (B). Bars represent the
standard deviations from triplicate determinations.
Different letters in the same value indicate the
significant differences (p<0.05). S1: cane sugar
paste; S2: unrefined cane sugar; S3: brown cane sugar; S4:
caramel crystal cane sugar; S5: refined white crystal cane
sugar; S6: coconut sugar paste; S7: palm sugar paste

3.3 Antioxidative activities

3.3.1 DPPH-radical scavenging activity

DPPH-radical scavenging activities of seven
commercial sugars extracted with distilled water or 95%
methanol were elucidated. DPPH-radical scavenging
activities of commercial sugars extracts were different
(p<0.05) (Fig 7). Distilled water extracts had higher
DPPH-radical scavenging activity than methanol
extract. Regardless of extraction solvent, cane sugar
paste exhibited the highest percentage scavenging
activity, followed by brown cane sugar, palm sugar
paste and coconut sugar paste, respectively. Refined
white crystal cane sugar had the lowest percentage
scavenging activity. The higher percentage scavenging
activity of commercial sugars extracts was coincidental
with the higher reducing sugar, intermediate browning
product, browning intensity and total phenolic content.
DPPH is one of compounds that possess a proton free
radical with a characteristic absorption, which decreases
significantly on the exposure to proton radical
scavenging [41]. Lerttitikul, Benjakul and Tanaka [20]
and Benjakul, Visessanguan, Phongkanpai and
Tanaka [29] reported that Maillard reaction products
(MRPs) and caramelization products (CPs) from fructose showed the highest radical-scavenging activity, compared with glucose. The reduction of alcoholic DPPH solution in the presence of a hydrogen-donating antioxidant is due to the formation of the non-radical form, DPPH-H. When the DPPH-radical is scavenged by antioxidants through the donation of hydrogen to form a stable DPPH-H molecule, the color is changed from purple to yellow [42]. However, sugar consists primarily of sucrose containing glucose and fructose. Therefore, the higher the reducing sugar the greater the percentage scavenging activity was observed. In addition, Haghparast, Shabanpour, Kashirila Alipour and Sodagar [43] reported that intermediates or the final brown polymer could function as hydrogen donors. From the results, commercial sugars, especially cane sugar paste can function as antioxidant through the donation of hydrogen atom.

Figure 7 DPPH radical scavenging activity in sugar dissolved in distilled water (A) and 95% methanol (B). Bars represent the standard deviations from triplicate determinations. Different letters in the same value the different samples indicate the significant differences (p<0.05). S1: cane sugar paste; S2: unrefined cane sugar; S3: brown cane sugar; S4: caramel crystal cane sugar; S5: refined white crystal cane sugar; S6: coconut sugar paste; S7: palm sugar paste

3.3.2 ABTS-radical scavenging activity

The antioxidant activities of sugars, using the ABTS-radical scavenging activity assay are shown in Fig. 8. ABTS-radical scavenging activities of seven commercial sugars extracted with distilled water or 95% methanol were tested. ABTS-radical scavenging activity of commercial sugars extracts were different (p<0.05). The results showed that the ABTS-radical scavenging activity of distilled water extract was greater than that of methanol extract. Regardless of extraction solvent, cane sugar paste showed the highest ABTS-radical scavenging activity, compared with other sugars (p<0.05). ABTS-radical scavenging activity of water extract from cane sugar paste and refined white crystal cane sugar was 13.19 and 0.97 µmol Trolox/g dry weight, respectively whereas the water extract of cane sugar paste and refined white crystal cane sugar was 9.87 and 0.37 µmol Trolox/g dry weight, respectively. The results showed that higher ABTS-radical scavenging activity was in agreement with higher DPPH-radical scavenging. However, ABTS radical assay employed for measuring the relative radical scavenging activity of hydrogen-donating and chain breaking antioxidants [44], [45]. The decolorization assay method was to screen the antioxidative activity, and it is applicable to both lipophilic and hydrophilic antioxidants [10]. Thus, commercial sugars, especially cane sugar paste can act as hydrogen donating and chain breaking antioxidants. From the results, ABTS-radical scavenging activity correlated well with DPPH radical scavenging, intermediate browning product, browning intensity and total phenolic content.

Figure 8 ABTS radical scavenging activity in sugar dissolved in distilled water (A) and 95% methanol (B). Bars represent the standard deviations from triplicate determinations. Different letters in the same value the different samples indicate the significant differences (p<0.05). S1: cane sugar paste; S2: unrefined cane sugar; S3: brown cane sugar; S4: caramel crystal cane sugar; S5: refined white crystal cane sugar; S6: coconut sugar paste; S7: palm sugar paste

3.3.3 Ferric reducing antioxidant power

Ferric reducing antioxidant powers of seven commercial sugars extracted with water or 95% methanol are shown in Fig 9. Ferric reducing antioxidant powers of commercial sugars extracts were different (p<0.05). The results showed that the ferric reducing antioxidant power of commercial sugars extracted with distilled water was greater than that of commercial sugars extracted with methanol. Regardless of extraction solvent, the ferric reducing antioxidant power was found in the order of cane sugar paste>brown cane sugar>palm sugar paste>coconut sugar paste>caramel crystal cane sugar>unrefined cane sugar>refined white crystal cane sugar (p<0.05). Ferric reducing antioxidant powers of cane sugar paste were 19.87 and 10.82 µmol Trolox/g dry weight, when extracted with distilled water and methanol, respectively whereas, those of refined white crystal cane sugar extracted with distilled water and methanol of were 0.66 and 1.97 µmol Trolox/g dry weight, respectively. These results were in agreement with those obtained for the antioxidant activities determined by the DPPH and ABTS-radical scavenging activity assays. Generally, the correlation between ferric reducing antioxidant power with the DPPH-radical scavenging, ABTS-radical scavenging activity, intermediate browning
product, browning intensity and total phenolic content was noticeable.

Figure 9. FRAP in sugar dissolved in distilled water (A) and 95% methanol (B). Bars represent the standard deviations from triplicate determinations. Different letters in the same value the different samples indicate the significant differences (p<0.05). S1: cane sugar paste; S2: unrefined cane sugar; S3: brown cane sugar; S4: caramel crystal cane sugar; S5: refined white crystal cane sugar; S6: coconut sugar paste; S7: palm sugar paste

4. CONCLUSION

Seven commercial sugars showed different physicochemical properties and antioxidative activities. High reducing sugar and mineral contents (Fe, Na, and K) were found in cane sugar paste (S1). Also, cane sugar paste (S1) with high browning intensity exhibited the greatest antioxidative activity. Therefore, sugar particularly cane sugar paste could be used as a sweetener with antioxidative property for food production.

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