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Comparative studies on chemical composition and antioxidant activity of corn silk from two varieties of sweet corn and purple waxy corn as influenced by drying methods

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Abstract

Characterization of chemical composition and antioxidant activities of two varieties of silk from sweet corn and purple waxy corn as influenced by different drying processes (freeze–dried and hot-air-dried) were investigated. Both corn silk had a high moisture (89.14–89.57%) ash (5.39–5.55%) and fiber content (52.08–53.49%). However, corn silk from sweet corn had the higher *L**– and *b**–values than those prepared from purple waxy corn (P<0.05). Purple waxy corn silk using freeze-dried (PCFD) showed the highest total phenolic content of 55.62 mg gallic acid equivalents/g samples. Nevertheless, PCFD had the higher in 2,2–diphenyl–1–picrylhydrazyl (DPPH), 2,2–azino–bis (3–ethylbenzothiazoline–6–sulfonic acid) (ABTS) radical scavenging activities and ferric reducing antioxidative power (FRAP) of 52.36, 728.82 and 352.92 μmoL TE/g sample than purple waxy corn using tray-dried (PCTD), sweet corn using freeze–dried (SCFD) and sweet corn using tray-dried (SCTD) (P<0.05). However, SCTD had the highest metal chelating activity of 35.51 μmoL EDTA/g sample. Types of corn silks and drying processes had no effect on the likeness of corn silk beverage. Results obtained indicated that corn silk extracts can be used as valuable bioactive source of natural antioxidants.

Keywords: Sweet corn, Purple waxy corn, Corn silk, Antioxidant activity, Drying method

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1. Introduction

Zea mays L., also known as maize or sweet corn is a cereal that is one of the most important edible grains in the world (Thoudam *et al.,* 2011). Maize is an important agricultural product and one of five major crops in Thailand. In addition to rice, sugarcane, cassava and rubber, maize occupies a major portion (about 33%) of Thai upland farmlands. In 2016, Thailand exported 4.06 million tons of maize and earned nearly US$ 191 million (OAE, 2017). However, purple waxy corn (*Zea mays* L. var. ceratina) is widely cultivated in Thailand, China, Vietnam, and Myanmar, and is harvested while immature and consumed on the cob as fresh food and whole grain food similar to sweet corn. Corns have been used extensively as foods, feeds and are processed to produce oil, starch and ethanol (Ekasingh *et al.,* 2004; Rahman & Rosli, 2014). During corn processing, a large amount of by-products including corn silk, husks and cob etc. is generated. Corn cobs and husks have been used as raw material for animal feed, charcoal, compost and handicraft (Padam *et al.,* 2014) whereas corn silk can be utilized commercially as an ingredient to produce a wide variety of value-added products such corn silk tea, snacks, cosmetics and medicines (Sarepoua *et al.,* 2015). Corn silks are scientifically referred to as Maydis stigma or Zea mays as they reflect the soft, fiber-like growth which accompanies the ear of the corn (Vijitha & Saranya, 2017). Its appearance is light green or yellow brown (sweet corn) and purple (waxy purple corn) strands or tassels called stigmas which found inside the husks of corn. They are relatively (20-30 cm) long with a mild sweetish taste (Archana, *et al.,* 2016). Corn silks contain many bioactive compounds such as proteins, vitamins, carbohydrates, calcium, potassium, sodium, magnesium, volatile oil compounds, steroid compounds namely sitosterol and stigmasterol, alkaloid, saponin, tannin, flavonoids and other phenolic compounds with beneficial effects on human health (Hasanudin *et al.,* 2012; Žilić *et al.,* 2016). Phenolic compounds present in corn silk are anthocyanins, *p*-coumaric acid, vanillic acid, protocatechuic acid, derivatives of hesperidin and quercetin, and bound hydroxycinnamic acid forms composed of *p*-coumaric and ferulic acid (Pedreschi & Cisneros-Zevallos, 2007). It is healthcare applications as a uricosuric, antilithiasic, antiseptic and diuretic and used for the treatment of edema as well as for gout, kidney, cystitis, nephritis, prostatitis and stones (Karami *et al.,* 2014). Other uses of corn silk include teas and supplements to treat urinary related problems (Karami *et al.,* 2014). Nevertheless, purple waxy corn is an important source of anthocyanins (Thiraphatthanavong *et al.,* 2014). The color range of waxy corn from white to black colors is correlated to phytochemical constituents and concentrations. Pigmented corn kernels had higher phytochemicals than did non-pigmented corn kernels. Cyanidin-3-glucoside is the major anthocyanin presented in these kernels almost 75% of total anthocyanins (Kokkaew, 2015). Anthocyanins have been extracted and

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isolated from purple corn silk for investigating their anticancer ability on colon cancers (Simla *et al.,* 2016), prevent heart ischemia–reperfusion injury and hyperlipidemia (Avramiuc, 2017), anti-inflammatory effects (Simla *et al.,* 2016) and prevent diabetes and obesity (Avramiuc, 2017). There are also reports about antioxidant activity of corn silk. The constituents in the volatile extract and, ethanol, water and petroleum ether extract of corn silk exhibited antioxidant activities (Ebrahimzadeh *et al.,* 2008). There are not enough records about antioxidant activity of corn silks extracts influenced by different drying methods. Therefore, this research was aimed to evaluate the effect of different drying methods on chemical composition and antioxidant activity of sweet and purple waxy corn silk extracts.

2. Materials and Methods

2.1 Chemicals

The compounds 2,2–diphenyl–1–picrylhydrazyl (DPPH), 2,2′–azinobis (3–thylbenzo thiazoline–6–sulphonic acid) (ABTS), 2, 4, 6-tripyridyltriazine (TPTZ), 3–(2–pyridyl)–5,6–di phenyl–1,2,4–triazine–4′,4′′–disulphonic acid sodium salt (ferrozine), ethylenediaminetetra acetic acid (EDTA), ferric chloride, gallic, folin–ciocalteu, acid and 6–hydroxy–2,5,7,8–tetra methyl–chroman–2–carboxylic acid (Trolox) were procured from Sigma–Aldrich, Inc. (St. Louis,MO., U.S.A.). Methanol, ethanol, chloroform, petroleum ether, hydrochloric acid, sulfuric acid potassium persulphate and ammonium thiocyanate were purchased from Lab–Scan (Bangkok, Thailand).

2.2 Preparation and chemical characterization of corn silks from sweet and purple waxy corns

Sweet corn and purple waxy corn were harvested from cornfields at Maejo University, Chiang Mai province, Thailand, and transported to the division of Food Science and Technology, Faculty of Engineering and Agro–Industry, Maejo University, with in 30 min. Upon arrival, Corn silk samples were separated from corn stalks and peels. The corn silk samples were washed with tap water, followed by drying with air–blown for 12 h at room condition (27 ± 2°C). The silks were placed in polyethylene bag and kept in 4°C before analyses.

2.2.1 Proximate analysis

Corn silk samples were analyzed for moisture, ash, fat, fiber and protein contents according to the method of AOAC (2000). Carbohydrate content was determined as the difference between 100 and the sum of moisture, protein, fat and ash contents. The values were expressed as % (wet weight basis).

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2.2.2 Color determination

Color value of corn silk from sweet and purple waxy corns was measured using a colorimeter (Hunter Lab, Model color Flex, Reston, VIRG, USA) with the port size of 0.50 inch. The determination of color was done on ten different samples. Standardization of the instrument was done using a black and white Minolta calibration plate. The values were reported in the CIE color profile system as L^*–value (lightness), a^*–value (redness/ greenness), and b^* value (yellowness / blueness).

2.3 Preparation of the silks from sweet and purple waxy corns as influenced by different dryings

The silk from sweet and purple waxy corns were subjected to different drying methods. To prepared hot air dried silks, two variety of silks were dried in cabinet tray dryer (Binder FED115, Tuttlingen, Germany). The corn silk samples were placed on stainless steel trays (80 cm length x 40 cm width and 1.37 kg weight) and experiments were conducted at 60°C for 6 h. For freeze dried silk, the samples were lyophilized using a SCANVAC CoolSafe™ freeze–dryer (CoolSafe 55, ScanLaf A/S, Lynge, Denmark). For the condition of Freeze dried, corn silk samples (–20°C) were introduced in the freeze–dryer on a pre-cooled heating shelf fixed at –50°C. For corn silk samples investigated, the temperature inside the freeze–dryer chamber was set at –17°C. The pressure inside the freeze–dryer chamber was kept at 18.4 Pa. The sweet and purple corn silk powders prepared using tray dried were referred to as “SCTD” and “PCTD”, respectively, while the sweet and purple corn silk powders prepared using freeze dried were referred to as “SCFD” and “PCFD” respectively. The different dried silks were then ground to obtain the particle size of 1.0–2.0 mm. Ground corn silks were placed in polyethylene bag and stored at –18°C until use, but not longer than 2 months.

2.4. Preparation of corn silk extracts

Sweet and purple waxy corn silk samples using tray–dried and freeze–dried were extracted according to the method of Buamard and Benjakul (2015) with a slight modification. The tray–dried and freeze–dried corn silk powders (10 g) were mixed with 350 mL of ethanol at concentrations of 80 % (v/v). The extraction was performed at room temperature (28–30 °C) for 3 h by stirring the mixture continuously at low speed using a magnetic stirrer (IKA-Werke, Staufen, Germany). Thereafter, the mixtures were centrifuged at 5000 x g for 30 min at room temperature using an RC–5B plus centrifuge (Beckman, JE–AVANTI, Fullerton, CA, USA) and the supernatant was then filtered through a Whatman filter paper No.1 (Whatman International Ltd., Maidstone, UK). The filtrates were evaporated at 40°C using an Eyela rotary evaporator (Tokyo Rikakikai, Co. Ltd., Tokyo, Japan) and purged with nitrogen gas to remove the residual

ethanol. The extracts were then dried using freeze dried to obtain the dry extract. The samples were kept in an amber bottle and stored in freezer at −18 °C until use or analysis.

2.4.1 Determination of total phenolic content

Total phenolic content of tray−dried and freeze−dried corn silk samples was determined using Folin−Ciocalteau Reagent (FCR) as described by Buamard and Benjakul (2015) with a slight modification. Corn silk extract (100 µL) was mixed with 0.75 mL of FCR, which was prediluted 10−fold with distilled water. After 5 min, the reaction was added with 0.75 mL of 6% (v/v) sodium carbonate. The solution was mixed and allowed to stand for 1 h at room temperature. The absorbance at 760 nm was read using UV−1601 spectrophotometer (Shimadzu, Kyoto, Japan). Standard solutions of gallic acid (0−600 ppm) were used for standard curve preparation. The phenolic content was expressed as mg gallic acid equivalents (GAE) per g dry weight of corn silk.

2.4.2 Determination of antioxidative activities

2.4.2.1 DPPH radical scavenging activity

DPPH radical scavenging activity was determined as described by Wu et al. (2003) with a slight modification. Tray−dried and freeze−dried corn silk samples (5 mg/mL) were dissolved in distilled water. Sample (1.5 mL) was added with 1.5 mL of 0.15 mM DPPH in 95% methanol. The mixture was mixed vigorously and allowed to stand at room temperature in the dark for 30 min. The absorbance of the resulting solution was measured at 517 nm using a spectrophotometer (UV−1800, Shimadzu, Kyoto, Japan). The blank was prepared in the same manner, except that distilled water was used instead of the sample. A standard curve was prepared using Trolox in the range of 10−60 µM. The activity was expressed as µmoL Trolox equivalents (TE)/g sample.

2.4.2.2 ABTS radical scavenging activity

ABTS radical scavenging activity was determined as described by Senphan and Benjakul (2014). The stock solutions included 7.4 mM ABTS solution and 2.6 mM potassium persulphate solution. The working solution was prepared by mixing two stock solutions in equal quantities and allowing them to react for 12 h at room temperature in dark. The solution was then diluted by mixing 1 mL of ABTS solution with 50 mL of methanol in order to obtain A_{734} of 1.1 ± 0.02 using a spectrophotometer. Fresh ABTS solution was prepared daily. Tray−dried and freeze−dried corn silk samples (1 mg/mL) were dissolved in distilled water. Sample (150 µL) was mixed with 2850 µL of ABTS solution and the mixture was left at room temperature for 2 h in dark. The absorbance was then measured at 734 nm using a spectrophotometer. A standard curve of Trolox ranging from 50 to 600 µM was prepared. The activity was expressed as µmol Trolox equivalents (TE)/g sample.

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2.4.2.3 Ferric reducing antioxidant power (FRAP)

FRAP was assayed according to Benzie and Strain (1996). Stock solutions included 300 mM acetate buffer (pH 3.6), 10 mM TPTZ (2,4,6−tripyridyl−*s*−triazine) solution in 40 mMHCl, and 20 mM $FeCl_3 \cdot 6H_2O$ solution. A working solution was prepared freshly by mixing 25 mL of acetate buffer, 2.5 mL of TPTZ solution and 2.5 mL of $FeCl_3 \cdot 6H_2O$ solution. The mixed solution was incubated at 37°C for 30 min and was referred to as FRAP solution. Tray−dried and freeze−dried corn silk samples (10 mg/mL) were dissolved in distilled water. Sample (150 µL) was mixed with 2850 µL of FRAP solution and kept for 30 min in the dark. The ferrous tripyridyltriazine complex (coloured product) was measured by reading the absorbance at 593 nm. The standard curve was prepared using Trolox ranging from 50 to 600 µM. The activity was expressed as µmoLTrolox equivalents (TE)/g sample.

2.4.2.4 Chelating activity towards Fe^{2+}

Chelating activity towards Fe^{2+} was measured as according to Senphan and Benjakul (2014). Tray−dried and freeze−dried corn silk samples (10 mg/mL) were dissolved in distilled water. The sample was mixed with 0.1 mL of 2 M $FeCl_2$ and 0.2 mL of 5 M ferrozine. The reaction mixture was allowed to stand for 20 min at room temperature (26−28°C). The absorbance was then read at 562 nm using a spectrophotometer. The blank was prepared in the same manner except that distilled water was used instead of the sample. The Fe^{2+} chelating activity was expressed as EDTA equivalents (EE)/g sample. A standard curve of 0–50 µM EDTA was prepared.

2.5 Sensory analysis

The sensory evaluation of tray−dried and freeze−dried corn silk beverages was performed by 65 untrained panelists, who were the students in Food Science and Technology program with the age of 20−22 years and were familiar with corn silk beverage consumption. The corn silk beverage samples (3 g) were infused with boiling water at 95°C (100 mL) followed by stand at ambient temperature for 5 min to cool down temperature. The corn silk beverages were poured in glasses and were covered with aluminum foil (Kılıç *et al.,* 2002). Corn silk beverages were drained and samples were allowed to cool to room temperature (25−28ºC) prior to evaluation. Panelists were asked to evaluate for color, odor, taste, texture, appearance and overall likeness of corn silk beverages using a 9−point hedonic scale (Mailgaad *et al*., 1999): 1, dislike extremely; 2, dislike very much; 3, dislike moderately; 4, dislike slightly; 5, neither like nor dislike; 6, like slightly; 7, like moderately; 8, like very much; 9, like extremely.

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2.6 Statistical analysis

Experiments were run in triplicate using three different lots of samples. Data were subjected to analysis of variance (ANOVA). Comparison of means was carried out by Duncan's multiple range test (Steel & Torrie, 1980). Statistical analysis was performed using the Statistical Package for Social Science (SPSS 11.0 for windows, SPSS Inc., Chicago, IL, USA).

3. Results and discussion

3.1 Chemical compositions and color

Sweet and purple waxy corn silks contained moisture, ash, protein, lipid, carbohydrate and fiber contents ranging from 89.14–89.57%, 5.39–5.55%, 3.74–4.01%, 0.89–0.12-0.97%, 0.06–0.68% and 52.08–53.49%, respectively. Rahman and Rosli (2014) report that immature silks contained higher moisture (89.31%) (wet basis), lipid (1.27%) and protein (12.96%) content than the mature silk. Mature silks contained higher composition of ash (5.51%), carbohydrate (29.74%) and total dietary fiber (51.25 g/100 g), than the immature silk (Rahman & Rosli, 2014). High fiber content in both corn silks was observed because it contains high levels of soluble dietary such as fiber; pectin, β–glucan, glucomanan, etc. and insoluble dietary fiber such as cellulose, hemicellulose and lignin (Kulapichitr, *et al.,* 2015). Variations in chemical composition are influenced by several factors, such as differences in varieties, the climate where it grows, soil fertility, the care of the plant and the treatment method (Haslina *et al.,* 2017).

Purple waxy corn silk was dark purple in color with L^*–value of 9.63, a^*–value of 8.29 and b^*–value of 1.26. L^* and b^* values of sweet corn silk were higher than purple corn silk ($P<0.05$). Higher a^* values in corn silk suggested that anthocyanin was high extent. Anthocyanins are polyphenolic pigments that belong to the flavonoid group and are responsible for many of the red–orange to blue–violet colors present in plant organs such as fruits, stalk, flowers, and leaves (Wallace & Giusti, 2015). Purple waxy corn has high anthocyanin accumulation (Harakotr *et al.,* 2014; Sarepoua *et al.,* 2015) as there are derivatives unique among flavonoids and phenolic compounds as their structures undergo reversible transformation at different pHs in aqueous solution (Harakotr, *et al.,* 2014). Anthocyanin also accumulate in other parts of corn such as in silk, leaves and seeds (Sarepoua *et al.,* 2015). Genotype and maturity stage were the important sources of variation in anthocyanin content in waxy corn (Harakotr *et al.,* 2014). The results indicated that silk of purple waxy corn is a rich source of anthocyanin.

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Table 1 Chemical compositions and color of corn silks from sweet and purple waxy corns

Composition (% wet weight)	Sweet corn silk	Purple waxy corns silk
Moisture	*89.57*±1.01 *a**	89.14±0.41 a
Ash	5.39±0.11 a	5.55±0.11 a
Protein	4.01±0.25 a	3.74±0.22 a
Fat	0.97±0.31 a	0.89±0.12 a
Carbohydrate	0.06±0.03 b	0.68±0.24 a
Total dietary fiber (g/100 g)	53.49±0.52 a	52.08±0.64 b
Color		
*L**	35.11±2.16 a	9.63±0.24 b
*a**	5.60±0.28 b	*8.29±0.42* a
*b**	16.89±1.16 a	1.26±0.24 b

* Values are given as means ± SD from triplicate determinations.

** Different superscripts in the same row indicate significant differences (P<0.05).

3.2 Total phenolic content (TPC)

Total phenolic content of corn silk extracts from sweet and purple waxy corns using tray dried and freeze dried condition is shown in Fig 1. The phenolic compound contents, ranked the samples in descending order, as follows: PCFD, PCTD, SCFD and SCTD the values of which were 55.62 ± 1.80, 53.36 ± 2.49, 37.53 ± 1.38 and 36.36 ± 2.15 mg gallic acid equivalents/g sample, respectively. PCFD had the highest content of phenolic compounds, while their lowest content was found in SCTD (P<0.05). The total phenolic content was not significantly different between PCFD and PCTD (P>0.05). However, different drying methods affected on total phenolic contents in corn silks. Sarepoua *et al.,* (2015) reported that corn silk from upper parts of ears (dark brown) had higher amounts of total phenolics, total anthraquinones and total flavonoids than the lower parts of ears (light yellow). Freeze–drying preserved more phenolic compounds than tray–dried which may destroy anthocyanins, and leads to decrease in TPC (P>0.05). Nurhanan *et al.,* (2012) extracted antioxidant components from corn silk by using methanol and water with a number of polyphenols in the extracts of methanol and water respectively were 272.81 mg GAE/100 g and 256.36 mg GAE/100 mg (dry). Phenolic compound is substances which have an aromatic ring with one or more hydroxyl groups so its nature is easily soluble in polar solvents. A polar solvent capable of

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dissolving the phenol is better so that the level of total phenols and flavonoids in the extract becomes high (Haslina & Eva, 2017). Phenol compounds on the corn silks which are polar include flavonoids, tannins, and saponins. Alkaloids and triterpenoids are semi–polar compounds and non-polar compounds are steroids (Ebrahimzadeh *et al.,* 2008; Haslina & Eva, 2017).

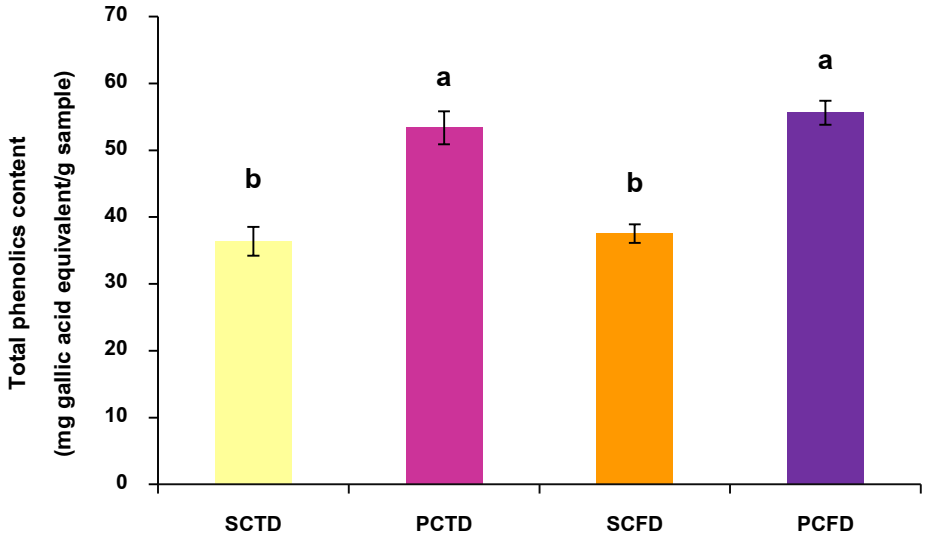

Fig 1 Total phenolic content of corn silk extracts from sweet and purple waxy corns using tray dried and freeze dried condition.

3.3 DPPH radical scavenging activity

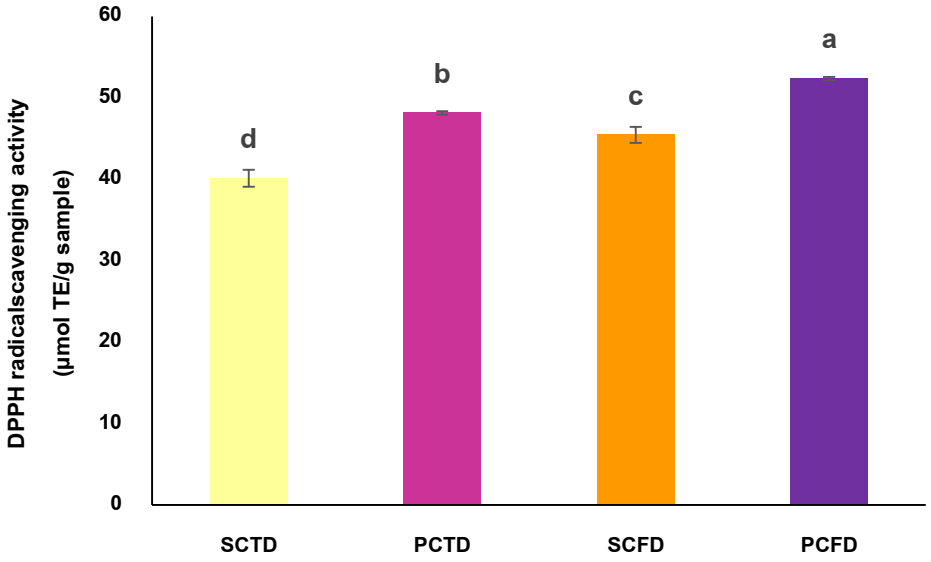

Fig 2 DPPH radical scavenging activity of corn silk extracts from sweet and purple waxy corns using tray dried and freeze dried condition.

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DPPH radical scavenging activities of corn silk extracts from sweet and purple waxy corns using tray dried and freeze dried condition are depicted in Fig 2. DPPH radical scavenging activities of corn silk samples ranged from 40.13 to 52.36 µmoL TE/g sample. The highest DPPH radical scavenging activities was found in PCFD, which had 52.36 ± 0.20 µmol TE/g sample.; on the other hand, SCTD had the lowest (40.13 ± 1.04 µmol TE/g sample) ($P<0.05$). Drying type showed a significant influence on DPPH scavenging activity in both con silk extracts. Freeze-drying preserved higher DPPH radical scavenging activity than tray-dried. However, antioxidant of the corn silk also depends on the type of corn, the variety, and the maturity at the time of harvest (Ku *et al.,* 2009). Nurhanan *et al.,* (2012) reported that corn silk extracted with methanol exhibited higher level of DPPH scavenging activity (81.7% at 1000 µg/mL) compared to the water extract (63.5%) at the same concentration. Nevertheless, corn silk of purple waxy corn has high anthocyanin content and is a good source of bioactive compounds which had a high extent antioxidant (Sarepoua *et al.,* 2015). DPPH is a stable free radical that shows maximal absorbance at 517 nm in ethanol. When DPPH encounters a hydrogen atom-donating substance, such as an antioxidant, the radical is scavenged. The colour is changed from purple to yellow and the absorbance is reduced (Mao *et al.,* 2006). Therefore, corn silk samples could donate hydrogen atom to free radicals and become more stable diamagnetic molecule, leading to the termination of the radical chain reaction (Haslina & Eva, 2017). High potential of free radical scavenging abilities in DPPH assays were correlated with the phytochemicals and TPC (Thapphasaraphong *et al.,* 2016)

3.3 ABTS radical scavenging activity

ABTS radical scavenging activities of corn silk extracts from sweet and purple waxy corns using tray dried and freeze dried condition are shown in Fig 3. ABTS radical scavenging activities, ranked the samples in descending order, as follows: PCFD, PCTD, SCTD and SCFD the values of which were 728.82, 701.49, 443.96 and 424.40 µmoL TE/g sample, respectively. However, PCFD has the highest ABTS radical scavenging activities with an amount of 728.82 ± 9.89 µmoL TE/g sample and the lowest value obtained is for SCFD, which is 424.40 ± 4.06 µmoL TE/g sample. Different drying methods demonstrate a significant impact on ABTS scavenging activity in all treatment of corn silk extracts. PCFD and PCTD preserved higher ABTS radical scavenging activity than SCFD and SCTD. Ku *et al.,* (2009) reported that dried corn silk powders at different of 199.17, 178.27, 85.48, 27.4 and 20.97 µm had ABTS radical scavenging activities of 2.36 µmoL TE/g dried weigh, 2.81, 3.20, 3.36 and 3.44 µmoL Trolox/g dried weight, respectively. The ABTS radical scavenging activity assay can be applied to both lipophilic and hydrophilic compounds (Miliauskas *et al.,* 2004). ABTS radical scavenging activity is based on the ability of antioxidants to donate a hydrogen atom or an electron to

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stabilize radicals, by converting it to the non-radical species (Senphan & Benjakul, 2014). The pre-formed radical monocation of $ABTS^{+}$ is generated by oxidation of ABTS with potassium persulphate and is reduced in the presence of hydrogen-donating antioxidants and chain breaking antioxidants (Tachakittirungrod *et al.,* 2007).

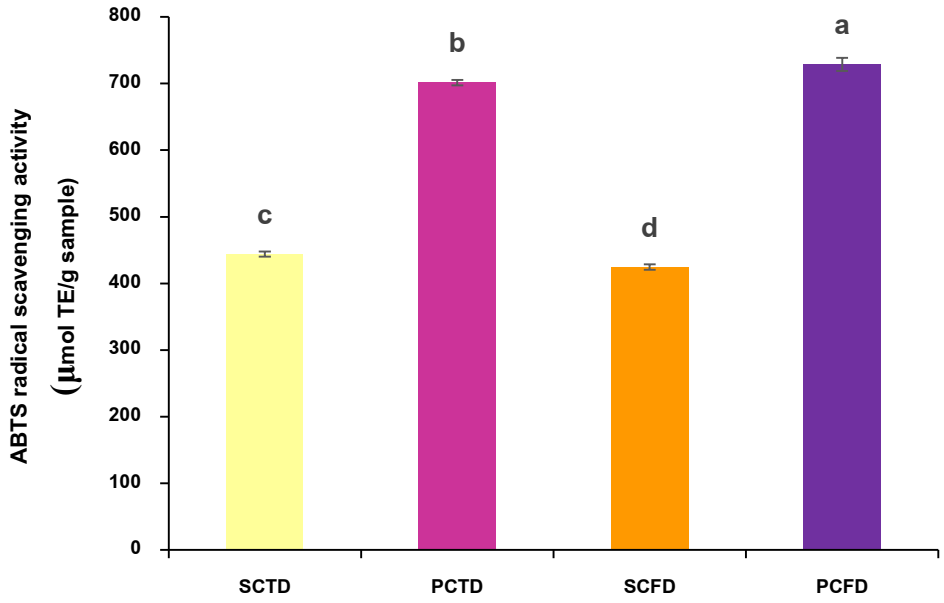

Fig 3 ABTS radical scavenging activity of corn silk extracts from sweet and purple waxy corns using tray dried and freeze dried condition.

3.4 Ferric reducing antioxidant power (FRAP)

As displayed in Fig 4, the FRAP values for investigated corn silk extracts varied in a wide range between 1240.71 and 352.92 µmoL TE/g sample. The FRAP in corn silk extracts were similar trend with TPC. Freeze-drying and tray-dried process effect on FRAP in purple con silk extract which had higher FRAP than tray-dried process. Nurhanan and Wan Rosli (2013) reported that the methanol extract of the dried corn silk powder had the highest reducing power activity (56.41%) compared to the ethanol (51.16%) and water extract (35.01%). Meanwhile, the lowest activity was showed by the ethyl acetate extract (27.21%). Purple waxy corn *(Zea mays L. ceritina Kulesh., PC)* extracted with ethanol gave the potential of ferric ion reducing rate was equal to 185.82 ± 0.79 mg Fe(II)/g sample (Olugbami *et al.,* 2014). From FRAP assay, the reducing potential of the corn silk extracts was determined based on the reduction of the Fe^{3+} to Fe^{2+} which subsequently from an intense blue Fe^{2+}-TPTZ complex (Senphan & Benjakul, 2014). Therefore, PCFD increased FRAP of the resulting corn silks via the enhancement of reducing power towards free radicals. As a result, propagation step could be terminated.

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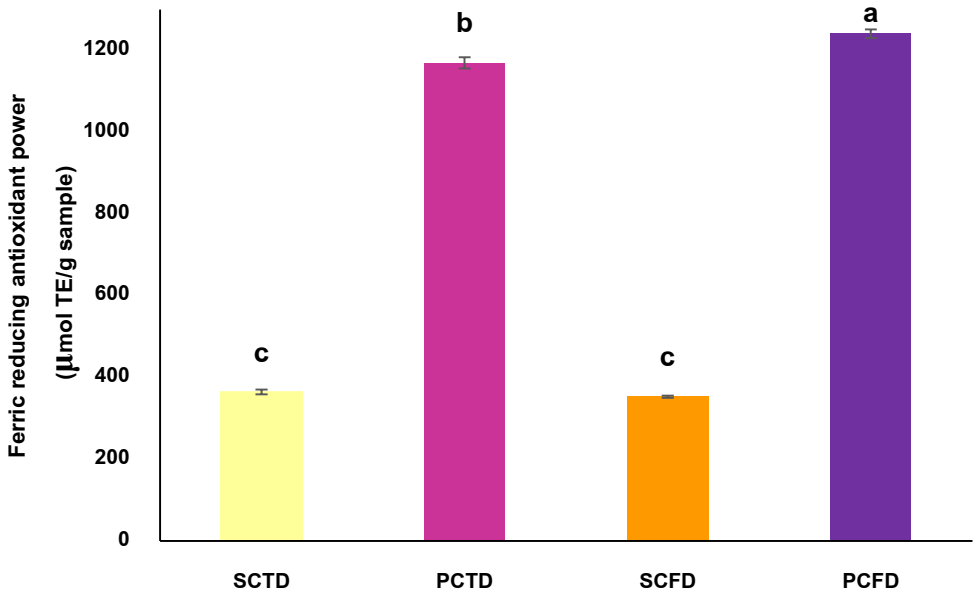

Fig 4 Ferric reducing antioxidant power (FRAP) of corn silk extracts from sweet and purple waxy corns using tray dried and freeze dried condition.

3.5 Chelating activity towards Fe^{2+}

Different metal-chelating activities were observed for corn silk extracts from sweet and purple waxy corns prepared using 80% ethanol and using tray dried and freeze dried condition (Fig 5). The highest metal-chelating activity was found in SCTD, followed by SCFD, PCTD and PCFD (35.51, 20.85, 16.10 and 14.44 µmoL EDTA/g sample), respectively ($P<0.05$). Kan, *et al.* (2011) reported that ethanolic extract from Z. mays var. indurata was the highest iron chelating capacity (63%) at concentration of 500, 1,000 and 2,000 µg/mL. Corn silk extracts can react with Fe^{2+} and ferrozine complex formation and interfere with the formation of ferrous and ferrozine complex, suggesting that it has chelating activity, and captures ferrous ion before ferrozine (Ebrahimzadeh *et al.,* 2008). Thus, corn silk extracts could act as the secondary antioxidant, which could scavenge prooxidative metal ions.

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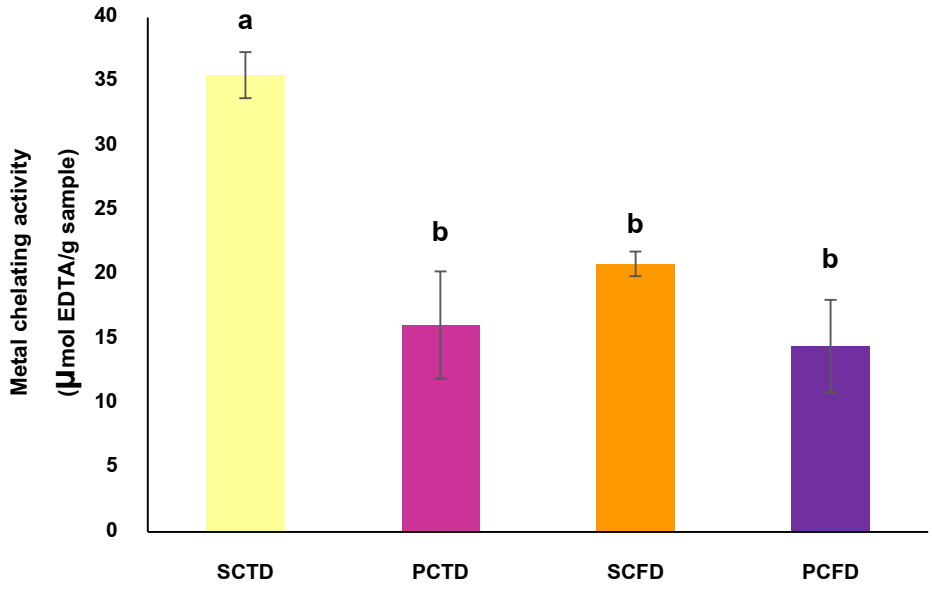

Fig 5 Metal chelating activity of corn silk extracts from sweet and purple waxy corns using tray dried and freeze dried condition.

3.6 Likeness score

Likeness score of corn silk beverage from sweet and purple waxy corns using tray dried and freeze dried condition is shown in Table 2. There was no difference in likeness score for all attributes including appearance, color, aroma, flavor, taste and overall amongst all samples ($P>0.05$). This result indicated that types of corn silks and drying methods had no effect on the likeness of corn silk beverage. All samples had likeness score of approximately 5.5 for all attributes, suggesting the moderate likeness of corn silk beverage, regardless of types of corn silks and drying methods ($P>0.05$). Thus, corn silks from sweet and purple waxy corns and drying condition can enhance antioxidative activity of resulting corn silks beverage without the negative effect on sensory property.

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Table 2 Likeness score of corn silk beverage from sweet and purple waxy corns using tray dried and freeze dried condition.

Sample	Appearance^{ns}	Color^{ns}	Flavour^{ns}	Taste^{ns}	Overall^{ns}
SCTD	6.18±1.58*	6.35±1.66	5.83±1.96	5.23±2.05	6.00±1.65
PCTD	5.02±1.85	5.05±1.88	4.93±1.85	4.55±1.79	5.00±1.56
SCFD	5.92±2.02	6.17±1.74	5.10±1.92	5.20±1.86	5.65±1.73
PCFD	5.17±1.83	4.82±1.87	4.52±1.64	4.40±1.81	4.78±1.43

*Values represent the mean ± SD (n=3).

^{ns} non-significant differences ($P < 0.05$) between values in the same column

**Different lowercase superscripts in the same column indicate significant differences ($P<0.05$)

4. Conclusions

The purple waxy corn is abundant of total phenolic compound, which are strong free radical scavengers. Freeze-drying preserved higher antioxidant capacity than tray-drying. Therefore, corn silks could be used as an alternative antioxidant, which was used as supplement in foods or drinks, particularly corn silk beverage.

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