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Proximate compositions, Physicochemical properties, Polyphenolic content and antioxidant activity of spray-dried Melon Manis Terengganu peel

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Melon Manis Terengganu (MMT) or also known as *Cucumis melo* var. Inodorus cv. Manis Terengganu 1, which originates from Terengganu, Malaysia, is composed of 28-30% inedible peels and discarded as waste. The purpose of this study was to evaluate the proximate compositions, physicochemical properties, polyphenolic content, and antioxidant activity of MMT peel. The MMT aqueous extract was spray-dried by using maltodextrins (MD) as a coating agent. Folin-Ciocalteau (F-C) and aluminum chloride assay were used to estimate the total phenolic and flavonoid contents, respectively. Antioxidant activity was determined by using 1,1-diphenyl-2-picrylhydrazyl (DPPH) and 2,2-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt (ABTS) assay. The proximate analyses revealed that MMT peel aqueous extract contained high carbohydrate (79.81%) and low moisture content (7.55%). As for physicochemical properties, the spray-dried yield was 12.01%. It was slightly acidic (pH = 5.63) with a sweet taste (°Brix = 8.00) and had fair water solubility (49.12%). The resultant displayed low water activity (0.40) and was yellow (b* = 11.58). The results revealed that the total phenolic content was 4.85 (0.12) µg GAE/mg, while the total flavonoid content was 1.03 (0.02) µg QE/mg. The IC_{50} values of DPPH and ABTS assay were 520.05 (4.91) mg/ml and 214.98 (4.26) mg/ml, respectively. These outcomes signify that the spray-dried MMT peel aqueous extract is a weak antioxidant with negligible bioactive compounds. Hence, the spray drying parameters should be modified or other drying methods should be incorporated to yield high-quality powder with potent antioxidant activity.

Keywords: antioxidant, Melon Manis Terengganu peel, physicochemical properties, polyphenols, proximate compositions, spray-drying

INTRODUCTION

The market of functional foods and beverages has expanded tremendously worldwide following the escalating demand for functional foods attributed to raising health awareness (Das et al. 2016) and skyrocketing healthcare cost (Lau et al. 2012). As a result, Malaysians have begun changing their lifestyle by taking care of their physical health (Lau et al. 2012). Functional foods with added bioactive ingredients are essential as they have beneficial health effects (Das et al. 2016). Numerous methods have been proposed to formulate functional foods and beverages, including application of microorganism functionality, optimization of the production and formulation of functional beverages, utilization of prebiotics and synbiotics, exploitation and processing of natural ingredients, as well as application of by-products of fruit and food industries as functional ingredients (Corbo et al. 2014).

Use of wasted inedible fruit parts, such as peels and seeds, appears to be an ideal approach that upholds sustainability by reducing the adverse effects of accumulated wastes on the environment. High melon consumption has been observed globally due to its exquisite taste and smell. Undeniably, waste reduction is of great concern due to the huge production of melon by-products (Seabra and Rolim 2020). Melon Manis Terengganu (MMT) or also known as *Cucumis melo* var. Inodorus cv. Manis Terengganu 1, is a type of melon that originates from Terengganu, Malaysia, is composed of 36-42% of inedible peels (28-30%) and seeds (8-12%), which are discarded as waste. Waste derived from whole immature MMT accounts for 83% due to the underlying cultivation method (Ong et al. 2020). Having those said, the previous literature demonstrated the antioxidant activities exhibited by melon peel due to the presence of various phenolic compounds and flavonoids (Ong et al. 2019), which may serve as a potential therapy to mitigate several diseases, such as osteoarthritis (OA), in near future following scoping review (Ong et al*.* 2020).

The potential to design a functional food ingredient from MMT peel is indeed high. Spray drying is one of the most widely used drying techniques to produce fruit powders (Lascano et al. 2020). Thus, it is indeed imperative to assess the proximate compositions, physicochemical properties, polyphenolic content, and antioxidant activity of powder to ensure the production of high quality functional food ingredient. However, studies on spray-dried *Cucumis melo* L. powder appear to be in scarcity and under-explored. As such, this study aimed to produce a powdered functional food ingredient derived from MMT peel, besides assessing its proximate compositions, physicochemical properties, polyphenolic content, and antioxidant activity.

MATERIALS AND METHODS

Chemicals

The chemicals used in this study were of analytical grade. Ethanol, methanol, aluminum chloride, sodium acetate, Folin-Ciocalteau (F–C) phenol reagent were obtained from Merck (Darmstadt, Germany). High Performance Liquid Chromatography (HPLC) grade methanol was bought from O & E Technology (Malaysia). Gallic acid and quercetin standards were purchased from Acros Organics (NJ, USA). Next, 1,1-diphenyl-2-picrylhydrazyl (DPPH), 2,2-azino-bis (3-ethylben-zothiazoline-6-sulfonic acid) diammonium salt (ABTS), Trolox standard, potassium persulfate, and sodium carbonate were obtained from Sigma-Aldrich (St Louis, USA). EGCG standard was purchased from Chemfaces (China). Distilled water was purified using Sartorius water purification system (Germany).

Preparation of MMT Peel Aqueous Extract

The MMT at uniform maturity stage (65 days after seeding) was collected from Mega Fertigation Farm, Kampung Telaga Papan, Setiu, Terengganu, with ± 0.5 cm thick peel cut. One kg of MMT peel was crushed and extracted with 30 L of distilled water, which was later heated at 50 °C for 3 hrs. The extract was filtered using centrifuge cloth filter (muslin cloth). Next, the filtered extract was centrifuged using a disc stack centrifuge separator to discard fine sediments. The extraction process was carried out twice at the Institute of Bioproduct Development (IBD) located in Universiti Teknologi Malaysia (UTM).

Spray Drying

The resulting MMT peel aqueous extract was mixed with 1% (w/v) maltodextrin (MD) (dextrose equivalent = 9-12). Next, the slurry was fed into an industrial-scale model Prici Spray Dryer at the IBD. The spray dryer was operated at the following conditions: inlet temperature at 185 °C, outlet temperature at 110 °C, atomization air flow rate at 10, 000 rpm, liquid feed pump rate at 35 L/hr, main drying air flow rate at 35 Hz, and feed solution temperature at 40 °C. The resulting powder was collected at the bottom of the cyclone and sealed in aluminum foil bags at ambient temperature for further proximate and physicochemical analyses.

Proximate Analyses

The chemical composition of the spray-dried MMT peel aqueous extract was determined at the

IBD based on the outlined documented method. Oven drying (AOAC 934.01), Kjeldahl's (AOAC 988.05 and 981.10), Soxhlet (BS ISO 8262-3:2005), dry ashing (AOAC 923.03), and gravimetric (AOAC 962.09) methods were performed to determine moisture, crude protein, crude fat, ash, and crude fiber contents, respectively. Carbohydrate content was calculated by using the following formula: Carbohydrate (%) = 100% - % (moisture + crude protein + ash + crude fat). Meanwhile, calorie was determined by multiplying the total of crude protein, crude fat, and carbohydrate by the factor value, as follows: energy (kcal) = (crude protein × 4) + (carbohydrate × 4) + (crude fat × 9) (FAO 2002).

Physicochemical Properties

Yield

The yield of the spray drying process was determined by dividing the total solid content of the feed sample (Fs) by the weight of the final dry powder (Wp) and multiplied by 100% (Niveadhitha et al. 2018).

Yield (%) = Wp/Fs x 100%

pH Determination

The spray-dried MMT peel aqueous extract was prepared with 10% solution (w/v) 1 g:10 ml (Lascano et al. 2020). 10 ml of the solution was dispensed into a beaker and the pH was determined by employing the potentiometric method using a pH meter (Thermo Scientific, Singapore). The pH meter was calibrated using buffer solutions of 4.0 and 7.0 pH values.

Total Titratable Acidity (TTA) Determination

The spray-dried MMT peel aqueous extract was prepared with 10% solution (w/v) (Lascano et al. 2020). Between two to three drops of phenolphthalein indicator was added and 5 ml of solution was titrated against 0.10 N sodium hydroxide (NaOH) to achieve pH 8.1. TTA was expressed as citric acid equivalent and calculated using the following formula (Saikia et al. 2015):

TTA (%) = [volume of titrant (ml) x 0.1 N NaOH (0.1019) x Eq. wt. citric acid (64.04)]/[sample volume (ml) x sample weight (g) x 10]

Total Soluble Solids (TSS) Determination

The spray-dried MMT peel aqueous extract was prepared with 10% solution (w/v). (Lascano et al. 2020). The TSS content of the solution was measured in °Brix using an Atago Palette PR-101 refractometer (Tokyo, Japan).

Color

The color characteristics of the MMT powders and the solutions, when the powders had been reconstituted in water, were examined using a CR-400 Minolta Chroma Meter (Konica Minolta Ltd., Japan) calibrated with a white standard tile. Two grams of powder was mixed with 20 mL of distilled water and centrifuged at 4000 rpm for 15 min to assess the color of the supernatant (Yousefi et al. 2011). The color brightness coordinate (L*) measures the whiteness value of a color, and ranges from black (0–50) to white (51-100). The chromaticity coordinate (a*) measures red (+60) and green (-60), while the chromaticity coordinate (b*) measures yellow (+60) and blue (-60). Chroma and hue angle (H°) were calculated from a* and b* using Eqs.(1) and (2), respectively. The negative values of H° were changed to positive values by adding 180°, to ensure that it could fall into the 90-180°quadrant. Chroma refers to color saturation or vividness. Increased chromaticity results in more intense color and vice versa. Meanwhile, H° denotes the foundation of color unit (red, yellow, green, blue, etc.) that may be elucidated as 0° (red) and 90° (yellow) (Itle and Kabelka 2009).

$$\text{Chroma} = \sqrt{(a^*)^2 + (b^*)^2} \quad (1)$$

$$\text{Hue} = \tan^{-1}(b^*/a^*) \quad (2)$$

Solubility

Solubility was determined based on the method prescribed by Cano-chauca et al. (2005) with some modifications. One gram of sample powder was mixed with 100 ml of distilled water at room temperature, and stirred using a magnetic stirrer at 600 rpm for 5 minutes. Next, 20 ml of supernatant was placed in pre-weighed petri dishes and oven dried at 70 °C until a constant weight was attained. Solubility was determined by calculating the ratio of the final weight of supernatant after drying (Wf) to sample weight (S).

Solubility (%) = Wf/S x 100%

Bulk Density

Bulk density refers to the weight of a given volume of powder, which is examined by using the tapping method with some modifications. Approximately 0.5 g of the powder was loosely transferred to a 5 ml measuring cylinder. The cylinder was tapped on a flat surface by hand until a constant volume was achieved. Bulk density was determined as the ratio of sample weight to the volume occupied in the cylinder and expressed as g/ml (Niveadhitha et al. 2018).

True Density

The ratio of sample mass to true volume is defined as true density, which is determined by the toluene displacement method, as described by Niveadhitha et al. (2018). One gram of the sample powder was immersed in 10 ml of toluene in a measuring cylinder. The increase in liquid volume due to pouring of the sample was considered as the true volume of the sample, which was then used to identify the true density of the sample (g/ml).

Water Activity (a_w)

a_w was determined by using a Dew Point water activity meter.

Antioxidant Activities

Determination of Total Phenolic Content (TPC)

The TPC in MMT peel aqueous extract was quantified by using the F-C method (Chang et al. 2002). Standard solutions of gallic acid at 10-80 µg/ml concentration were prepared in water. About 50 µl of extract (5 mg/ml) or standard solution was added to 50 µl of distilled water. Next, 50 µl of 10% F–C phenol reagent and 50 µl of 1 M sodium carbonate solution were added to the mixture in a 96-well plate. Distilled water was used as blank. Reactions were incubated for 60 min at room temperature and protected from light. The absorbance was measured at 750 nm with a Microplate Reader (Thermo Scientific, USA). The TPC was expressed as µg Gallic Acid Equivalents (GAE) per mg of dry MMT peel extract.

Determination of Total Flavonoid Content (TFC)

The TFC was estimated by using aluminum chloride colorimetric assay (Chatatikun and Chiabchalard 2013). Standard solutions of quercetin at 20–80 µg/ml concentration were prepared in 80% ethanol. Next, 50 µl of extract (5 mg/ml) or standard solution was added to 10 µl of 10% aluminum chloride solution and followed by 150 µl of 95% ethanol. After that, 10 µl of 1 M sodium acetate was added to the mixture in a 96-well plate. 80% ethanol was used as reagent blank. All reagents were mixed and incubated for 40 min at room temperature and protected from light. The absorbance was measured at 415 nm with a Microplate Reader (Thermo Scientific, USA). The TFC was expressed as µg Quercetin Equivalents (QE) per mg dry MMT peel extract.

DPPH Assay

The free-radical scavenging antioxidant activity of the MMT peel aqueous extract was investigated by using DPPH assay, as described by Elisha et al. (2016). The stock solution of extract or the standard solution of quercetin was prepared in methanol. The extract with different concentrations (100-800 mg/mL) and the standard solution of quercetin with varied concentrations (10-80 µg/ml) were added in a 96-well microliter plate with a volume of 40 µl. Then, 160 µl of DPPH solution (prepared as 0.04 mg/ml in methanol) was added to each well. A blank solution that served as control was prepared consisting of the same volume of methanol and DPPH. The plate was shaken gently and placed in the dark for 30 minutes at 37 °C. The absorbance was measured at 515 nm using a Microplate Reader (Thermo Scientific, USA). Triplicate measurements were carried out and the percentage of DPPH scavenging activity was determined as follows: [1 - (absorbance of sample/absorbance of blank)] x 100. The MMT peel aqueous extract concentration for 50% inhibition (IC_{50}) was identified by the dose-response curve.

ABTS Assay

The procedure was performed as prescribed by Khatua et al. (2017), and Wang et al. (2018). First, ABTS was dissolved in water to prepare 7 mM concentrated solutions. Next, ABTS radical cation (ABTS•+) was generated by reacting the stock solution (3 ml) with 2.45 mM of potassium persulfate (3 ml), and followed by incubation in the dark at room temperature for 16 hr before use and used within two days. After 16 hr, 2 ml of ABTS•+solution was diluted with 98 ml of distilled water to an absorbance of 0.7±0.02 at 734 nm. The stock solution of extract or the standard solution of quercetin was prepared with 80% of ethanol. The procedure is given as follows: 200 µl ABTS working solution was added into a 96-well plate. Next, 10 µl of 80% ethanol was added into blank control wells. After that, 10 µl of previously prepared Trolox standard solutions at varied concentrations (30-100 µg/ml) had been added into standard curve wells. About 10 µl extract with varied concentrations (100-900 mg/ml) was added into the sample wells. The mixture was slightly stirred to attain evenly mixed solutions. The plate was incubated at room temperature for 5 min, and the absorbance values were measured at a wavelength of 734 nm using a Microplate Reader (Thermo Scientific, USA). Triplicate measurements were carried out and the percentage of ABTS scavenging activity was identified as follows: [1 - (absorbance of sample/absorbance of blank)] x 100. The MMT peel aqueous extract concentration for 50% inhibition (IC_{50}) was identified based on the dose-response curve.

HPLC Analysis

The MMT peel aqueous extract was dissolved in HPLC grade methanol (500 mg/ml) and filtered through a polypropylene filter unit (0.45 µm) before subjected to HPLC analysis with adherence to the method reported previously with EGCG as the standard (Ong et al. 2020).

Statistical Analysis

The research data were analyzed using IBM SPSS for Windows version 21.0. The data were assessed via descriptive analysis and presented as mean and standard deviation. Independent t-test was performed to identify the difference in color analysis between spray-dried MMT peel aqueous extract and reconstituted powder in solution. The level of significance was set at $P \leq 0.05$.

RESULTS AND DISCUSSION

Proximate Analyses

The proximate composition of MMT peel aqueous extract is tabulated in Table 1. Interestingly, the carbohydrate content of 79.81 (0.04)% accounted for the greatest amount among other nutrients. Apparently, the energy content of the MMT peel aqueous extract (353.31 kcal/100g) derived mostly from the carbohydrate. Another interesting point to highlight refers to the low moisture content at 7.55 (0.04)%. Moisture content, which indicates the water composition in each food system, implies product stability and shelf life during storage (Susantikarn and Donlao 2016; Yamashita et al. 2017). Low moisture content is cost-effective for manufacturers in terms of reduction of shipping fees due to lower total product weight contributed by water weight (Lascano et al. 2020). High inlet and outlet air temperatures increased the rate of heat transfer to the particles, and subsequently, generated a greater driving force for moisture evaporation. As a result, the powder had lower moisture content (Krishnaiah et al. 2014).

Physicochemical Properties

Referring to Table 2, the spray-dried yield was 12.01%. The MMT peel aqueous extract was slightly acidic (pH = 5.63) and a hint of taste sweet (°Brix = 8.00). It was also fairly soluble in water (49.12%) and had low a_w (0.40). Table 3 compares the results of color analyses between MMT peel aqueous extract in powder and solution form. Significant differences were observed in L*, b*, chroma, and H°, which indicated that the powder form was whiter, yellower, and developed more intense color than did the solution form. Besides, both powder and solution forms were greenish in color.

The physicochemical properties of powders generated from the spray drying method were influenced by numerous factors, including inlet air temperature, feed flow rate, content of coating agents, and type of coating agents (Bhusari et al. 2014; Susantikarn and Donlao 2016). Since the spray drying parameter in this study was differed from other studies (Papoutsis et al. 2018; Saikia et al. 2015; Yousefi et al. 2011), no comparison of physicochemical properties was performed. A study claimed that the average spray drying yield ranged from 20% to 70% (Krishnaiah et al. 2014). However, lower drying yield of 12% was observed in this study. This discrepancy is ascribed to the factors mentioned earlier.

The pH of the spray-dried MMT peel aqueous extract was acidic. This is beneficial in expanding its shelf life as the rate of microorganism growth is minimized in acidic medium, thus lowering the rate of product spoilage. pH values that range between 3.0 and 4.1 are desirable to retard microbial growth (Sodipo and Oluwajuyitan 2019). Furthermore, a_w refers to the free water quantity in a food system available for microbial growth, as well as enzymatic and biochemical reactions, which may serve as a measure of food stability and shelf life (Susantikarn and Donlao 2016; Yamashita et al. 2017). Typically, a product with $a_w < 0.6$ is microbiologically stable. Deterioration, if any, is caused by chemical reactions instead of by microorganisms (Susantikarn and Donlao 2016). In this present study, the a_w of spray-dried MMT peel aqueous extract was 0.4, which is lower than the critical a_w, denoting that this product is safe in terms of growth of pathogenic bacteria (Lascano et al. 2020).

Table 1: Proximate analyses of spray-dried MMT peel aqueous extract (n = 3)

Proximate analyses	Readings
Moisture content (%)	7.55 (0.04)
Crude protein content (%)	7.01 (0.08)
Crude fat content (%)	0.67 (0.00)
Ash content (%)	4.96 (0.00)
Crude fiber content (%)	0.00 (0.00)
Carbohydrate content (%)	79.81 (0.04)
Energy content (kcal/100g)	353.31 (0.13)

Data are reported as mean (SD).

Table 2: Physicochemical properties of spray-dried MMT peel aqueous extract (n = 3)

Physicochemical properties	Readings
Yield (%)	12.01
pH	5.63 (0.03)
Total Titratable Acidity (%)	0.13 (0.01)
Total Soluble Solid (°Brix)	8.00 (1.00)
Solubility (%)	49.12 (0.61)
Bulk density (g/ml)	0.43 (0.02)
True density (g/ml)	1.04 (0.07)
Water activity (a_w)	0.40 (0.01)

Data are reported as mean (SD) except yield.

Table 3: Color analyses of spray-dried MMT peel aqueous extract (n = 3)

Color analyses	Powder	Solution	*P*-value[a]
L*	54.78 (1.03)	35.55 (1.15)	< 0.001
a*	-1.18 (0.01)	-1.24 (0.16)	0.596
b*	11.58 (0.06)	7.82 (0.70)	0.011
Chroma	11.64 (0.06)	7.92 (0.72)	0.012
H°	95.82 (0.06)	98.97 (0.35)	< 0.001

Data are reported as mean (SD).
[a]Independent t-test was applied.

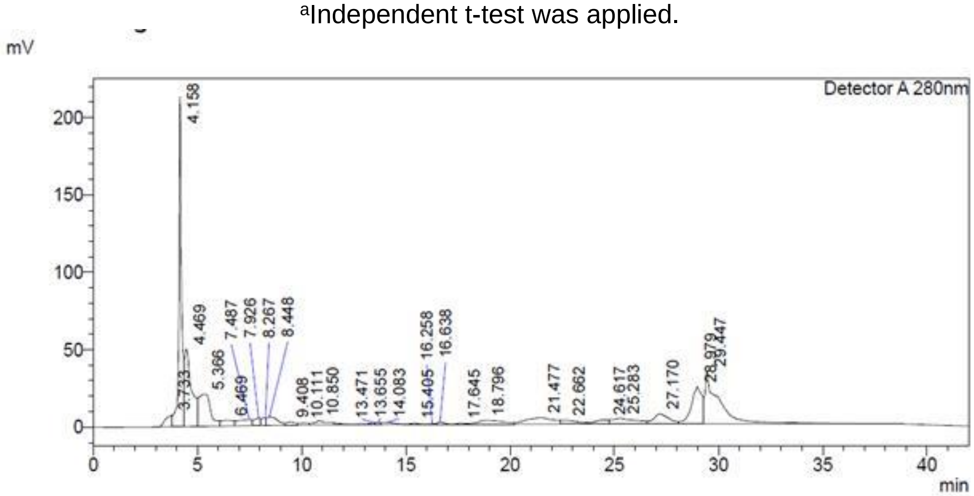

Figure 1: HPLC chromatogram of spray-dried MMT peel aqueous extract

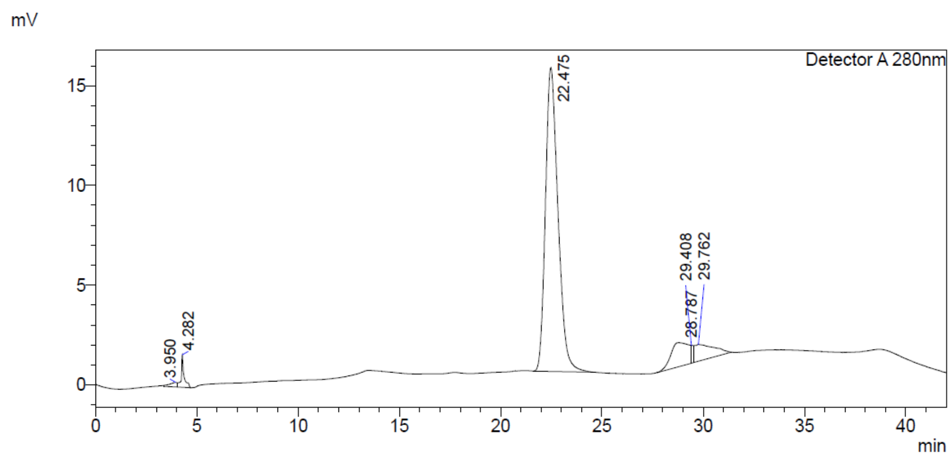

Figure 2: HPLC chromatogram of EGCG standard (50 µg/ml)

Solubility refers to powder practicality for dissolution in water (Susantikarn and Donlao 2016). This aspect is affected by the type of coating agent, in which higher soluble powder was observed when MD was used as the coating agent mainly because MD contains high water solubility (Krishnaiah et al. 2014). In this present study, the MMT peel aqueous extract displayed fair solubility in water due to its low sugar concentration (Sousa et al. 2008). It is noteworthy to emphasize that the color of food is one the main quality attributes in dried food products (Susantikarn and Donlao 2016). In this present study, yellow product was observed, which is attributed to the presence of carotenoid (Karanjalker et al. 2018) found in the MMT peel. Carotenoid is an essential pigment that dictates the color of the fruit peel (Karanjalker et al. 2018). A study on fruit juice and reconstituted powder reported that reconstituted powder appeared yellower than did the solution form (fruit juice) (Saikia et al. 2015).

Polyphenolic Content and Antioxidant Activity of spray-dried MMT Peel

The TPC of spray-dried MMT peel aqueous extract was 4.85 (0.12) µg GAE/mg, as identified from a linear gallic acid standard curve ($y = 0.0099x + 0.0506$, $R^2 = 0.9818$). Meanwhile, the quercetin standard curve with $y = 0.0071x – 0.0037$ and $R^2 = 0.9786$ was used to determine the TFC of 1.03 (0.02) µg QE/mg. Next, the antioxidant activity of MMT peel aqueous extract was determined based on DPPH and ABTS assay in terms of IC_{50} with 520.05 (4.91) mg/ml and 214.98 (4.26) mg/ml, respectively. As a result, no significant correlation was established among TPC, TFC, DPPH, and ABTS (data not shown).

In this present study, the MMT peel aqueous extract seemed to contain low TPC and TFC. Normally, these outcomes contribute to the antioxidant activity of the extract (Bouaziz et al. 2020). For instance, a study reported that the concentration of polyphenols and flavonoids correlated well with antioxidant activity (Aouachriaa et al. 2017). Unsurprisingly, the antioxidant activity of MMT peel aqueous extract assessed using DPPH and ABTS assay, which was expressed in IC_{50}, revealed that this extract is an inactive antioxidant, which is in agreement with that reported by Muhtadi and Wikantyasning (2016). The classification of antioxidants based on IC_{50} is as follows: < 50 µg/mL (very active), 500-100 µg/mL (active), 100-200 µg/mL (quite active), and > 200 µg/mL (inactive) (Muhtadi and Wikantyasning 2016).

HPLC Quantification of EGCG

Figure 1 illustrates the chromatogram of MMT peel aqueous extract. The retention time for EGCG standard was 22.475 minutes (see Figure 2). Referring to Figures 1 and 2, EGCG was found in negligible amount or even absent in MMT peel aqueous extract. This finding verified the TPC and TFC results. However, a recent study on freeze-dried MMT peel aqueous extract using similar chromatographic condition discovered the presence of EGCG and higher amount of bioactive compounds, when compared to this present investigation (Ong et al. 2020).

These findings were unexpected and a possible explanation for this is attributable to the spray drying process. Commonly, the presence and the amount of biologically active compounds are affected by spray drying due to the Maillard reaction, the drying processes, and the parameters applied to the food powder (Michalska et al. 2017). Turning to this present study, high inlet temperature at 185 °C and outlet temperature at 110 °C were applied during the spray drying process. Generally, phenolic compounds are highly sensitive to temperature. Upon exposure to high heat, their chemical structure undergoes alteration and results in structural breakage, as well as transformation into different compounds (Mishra et al. 2014).

Thermal processing leads to thermal and oxidative destruction, as well as a notable loss of antioxidant compounds (Do and Nguyen 2018). This deteriorates the capacity of the antioxidant. Such phenomenon has been reported in several other studies that involved spray-dried mulberry juice powder (Do and Nguyen 2018), spray-dried amla juice powder (Mishra et al. 2014), spray-dried blackberry powder (Ferrari et al. 2013), and spray-dried Gac fruit powder (Kha et al. 2010). The literature depicts that EGCG is degraded when the temperature exceeds 80 °C (Hsieh et al. 2018; Saklar et al. 2015).

CONCLUSION

This study has confirmed that MMT peel aqueous extract contains high carbohydrate and low moisture content. Besides, it is slightly acidic with a sweet taste, displays fair water solubility, yellow in color, and has low water activity. However, the MMT peel aqueous extract is a weak antioxidant with negligible bioactive compounds. This signifies that the spray drying method with the respective parameters is unsuitable to generate MMT peel aqueous extract powder. Therefore, the spray drying operation should be modified and optimized, or even other drying methods should be considered, in order to yield a good quality product with potent antioxidant activity by retaining most of its bioactive compounds.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

SH, MRS, NS and HH supervised the research process and provided critical feedback. YQO performed experiments, designed experiments, data analysis, wrote the manuscript and reviewed the manuscript. All authors read and approved the final version.

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