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Evaluation of nutritional compositions, Physical properties, functional characteristics and Biochemical properties of formulated Melon Manis Terengganu peel powder

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Melon seeds and peels are common by-products generated by the fruit processing industry. Melon Manis Terengganu (MMT) contained 28-30% of the peel which remained underutilized for their efficient valorization. Hence, this study aimed to develop formulated MMT peel powder besides evaluating its nutritional composition and physicochemical properties. The MMT peel was formulated with other ingredients such as sweetener, carboxy methyl cellulose, citric acid, and orange flavoring. Two formulations were produced, namely Formulation 0 (100% MMT peel powder) and Formulation 3 (40% MMT peel powder), which were subjected to several analyses performed according to standard methods. The analyses were proximate compositions, total dietary fiber, vitamins, minerals, physical properties, functional characteristics, and biochemical properties. The difference between the two formulations was compared using an independent t-test. The results demonstrated that Formulation 0 had significantly higher nutritional composition compared to Formulation 3 except for carbohydrate content. Besides, significantly greater water activity, functional properties, and acidity were observed in Formulation 0. In contrast, Formulation 3 had significantly higher total soluble solids than Formulation 0. In conclusion, Formulation 0 had superior nutritional composition and physicochemical properties compared to Formulation 3, except for carbohydrate content. The findings might be important in delivering health benefits to consumers upon consumption of the different formulated MMT peel powders.

Keywords: nutritional compositions, physical properties, functional characteristics, biochemical properties, Melon Manis Terengganu peel

INTRODUCTION

Consumption of *Cucumis melo* L. can bring nutritional health benefits with bioactive characteristics (Vishwakarma et al. 2017). The production of the *Cucumis melo* L. variety of melon has been promoted in many regions worldwide due to its high economic value (Khalid et al. 2021). However, high production rates and inappropriate handling techniques caused a large part of the fruit to be discarded and not used besides their good nutritional value (Hussain et al. 2020; Soni and Saxena, 2020). Melon seeds and peels are common by-products generated by the fruit processing industry (Gómez-García et al. 2021). Surprisingly, up to half of all cultivated fruits and vegetables are wasted before they are consumed (Elik et al. 2019; Sagar et al. 2018).

A recent study on Melon Manis Terengganu (MMT), specifically named as *Cucumis melo* var. Inodorus cv. Manis Terengganu 1 (Aisyah Athirah et al. 2018), was observed to contain 28-30% of peel (Ong et al. 2021a). Various research demonstrated that melon by-products exhibited biological activities such as anti-diabetic, antioxidant, anti-inflammatory, and anti-cancer properties (Horax et al. 2010; Ong et al. 2019). Lately, there has been a great interest in utilizing the by-products as food additives for dietary purposes, attributed to their health benefits such as blood glucose control, lipid metabolism, and diabetes prevention (Masci et al. 2018). The beneficial health effects were probably attributed to the dietary fiber content (Atef et al. 2013). Hence, this study aimed to develop formulated MMT peel powder besides evaluating its nutritional composition and physicochemical properties.

MATERIALS AND METHODS

Development of Formulated MMT Peel Powder

The MMT peel powder was produced according to the method described in the previous study (Ong et al. 2021a). Various trials were carried out to formulate the MMT peel powder. Finally, the MMT peel powder was formulated with different monk fruit sweetener ratios as shown in Table 1 below (Djarot and Badar, 2017). Carboxymethyl cellulose (CMC), citric acid, and orange flavoring were added to the formulations and mixed thoroughly for uniform distribution of ingredients. Formulation 0 and Formulation 3 represented 100% MMT peel powder and 40% MMT peel powder, respectively. The formulated MMT peel powder was then kept in an airtight container in a freezer (-21 °C) for further analysis.

Table 1: Formulation of MMT peel powder

Ingredients (%w/w)	Formulation 0	Formulation 3
MMT peel powder	95	38
Monk fruit sweetener	0	57
CMC	1	1
Citric acid	2	2
Orange flavoring	2	2

Analysis of Nutritional Composition

The proximate compositions of the formulated MMT peel powder were determined based on the outlined documented method. Moisture, crude protein, crude fat, ash, crude fiber and total dietary fiber content were quantified using the AOAC official method namely 950.46, 981.10, 991.36, 923.03, 962.09, and 991.43 respectively. Carbohydrate content was determined by using the following formula: Carbohydrate (%) = 100% - % (moisture + crude protein + ash + crude fat). Meanwhile, calories were calculated by multiplying the sum of crude protein, crude fat, and carbohydrates by the factor value, as follows: energy (kcal) = (crude protein × 4) + (carbohydrate × 4) + (crude fat × 9). Meanwhile, vitamins (A, D, E, K, and C) and minerals (calcium, magnesium, iron, zinc, selenium, manganese, and copper) were determined according to the procedure as mentioned previously (Ong et al. 2021a).

Physicochemical Properties

Some of the analyses below were conducted according to the method described (Ong et al. 2021b).

Analysis of Physical Properties

Color

The color characteristics of the sample were evaluated using a CR-400 Minolta Chroma Meter (Konica Minolta, Tokyo, Japan) calibrated with a white standard tile. The color brightness coordinate (L*) is a scale that indicates a color's whiteness value, ranging from black (0–50) to white (51-100). The chromaticity coordinate (a*) measures red (+60) and green (-60), whereas the chromaticity coordinate (b*) measures yellow (+60) and blue (-60). Chroma and hue angle (H°) were computed from a* and b* using Equation (1) and Equation (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).

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

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

Water Activity

The water activity (a_w) of the sample was determined using a Dew Point water activity meter (Decagon Devices, WA, USA) at 25 °C. Approximately, 0.5 g of formulated MMT peel powder was evenly spread into plastic cells and allowed to equilibrate within the sealed chamber headspace. The reading was taken when the equilibrium was reached.

Analysis of Functional Properties

Water Holding Capacity (WHC)

The water holding capacity (WHC) was determined by a method (Wanlapa et al. 2015) with slight modifications. 10 mL of distilled water was added to formulated MMT peel powder (500 mg) in a pre-weighed centrifuge tube, then shaken using an IKA MS1 mini shaker vortexer (Sigma Aldrich, Missouri, USA) for 2 minutes and left at ambient temperature for 30 minutes. After centrifuging at 3000 g speed for 20 min, the supernatants were decanted, each centrifuge tube was weighed then the WHC was calculated and expressed as a g of water per g of dry matter (g of water / g of dm). The WHC was computed using the equation below:

$$\text{WHC, g of water/ g of dry matter} = \frac{(W3 - W2) - W1}{W1}$$

Where: W1 = Weight of sample (g)
W2 = Weight of pre-dried centrifuge tube (g)
W3 = Weight of centrifuge tube + sample after supernatant was decanted (g)

*O*il Holding Capacity (OHC)

The oil holding capacity (OHC) was determined using the commercial corn oil (density = 0.920 g/mL) according to the method as mentioned in Section WHC with the exception that the OHC was expressed as a g of oil per g of dry matter (g of oil/ g of dm).

Swelling Capacity (SC)

Swelling capacity (SC) can be defined as the resulting volume of the sample after hydration. SC was obtained by suspending 200 mg of the sample with distilled water (10 mL) in a foil-covered graduated test tube. The suspensions were manually stirred with a glass tube to avoid agglomerations. After 24 hour at 25 °C, the volume of the precipitate was achieved. SC was calculated using the following equation:

SC, mL/g = VP/WS

Where: VP = Volume of the precipitate obtained after hydration (mL)
WS = Weight of sample (g)

Analysis of Biochemical Properties

Formulated MMT peel powder was weighed (1 g) and added to 10 mL of distilled water. The mixture was mixed in vortex method to obtain the slurry of the sample.

pH

The pH of samples was determined using a pH meter (Thermo Fisher Scientific, Massachusetts, USA). Buffer solutions of pH 4.0, 7.0, and 10.0 were used to calibrate the pH meter before analysis.

Total Titratable Acidity (TTA)

Total titratable acidity (TTA) was determined as described by AOAC Official Method 924.15 (AOAC, 1990) with slight modification. A 5 mL of sample was added with 2-3 drops of phenolphthalein indicator and titrated against 0.1 N sodium hydroxide (NaOH) solution until the mixture turns pink. The titer volume was recorded and the TTA was expressed as a percentage of citric acid equivalent.

The TTA value of formulated MMT peel powder was calculated using the formula:

$$\text{TTA, \%} = \left(\frac{N \times V \times F}{S}\right) \times 100$$

Where: N = Normality of standard NaOH solution used for titration (0.1019 N)
V = Volume of standard NaOH solution used for titration (ml)
F = Milliequivalent of citric acid factor (0.064)
S = Sample size (mL)

Total Soluble Solids (TSS)

Total soluble solids (TSS) of the sample were measured using a hand-held Atago Palette PR-101 refractometer (Tokyo, Japan) with a scale of 0-20 °Brix. The value of TSS was expressed in the °Brix. The instrument was calibrated using distilled water before analysis.

Statistical Analysis

The research data were examined using IBM SPSS for Windows version 21.0. The data were evaluated by descriptive analysis and reported as mean and standard deviation. An independent t-test was applied to compare the differences between Formulation 0 and Formulation 3 at a significant level of $p \leq 0.05$.

RESULTS AND DISCUSSION

Nutritional Compositions

The comparison of the proximate compositions, vitamins and minerals content between Formulation 0 and Formulation 3 are highlighted in Table 2. Formulation 0 had significant greater moisture, crude protein, crude fat, crude fiber, ash, total dietary fiber, energy, vitamins and minerals content than Formulation 3. This might be attributed to the greater amount of MMT peel powder in Formulation 0. This result seems to be consistent with other research that found that higher proximate composition, total dietary fiber, vitamins and minerals content were observed with the addition of ingredients of interest into the formulations such as hug plum in instant soft drink powder (Alam et al. 2020) and apple pomace flour in cookies (Zlatanović et al. 2019). Surprisingly, a greater carbohydrate content was observed in Formulation 3 than Formulation 0. This finding can be explained by the presence of sweetener in Formulation 3 which is absent in Formulation 0. These findings match those observed in the earlier study which reported that higher hug plum powder incorporation in the formulation resulted in lower carbohydrate and energy content (Alam et al. 2020). However, a lower energy content was observed in Formulation 3 due to the low calorie of the sweetener used with 0.02 kcal/g. The difference in the energy content of formulated MMT peel powder can be attributed to the variations in the macronutrient compositions such as total carbohydrate, crude protein and crude fat contents.

Moisture content is a crucial parameter in the drying process that indicates food quality and long-term stability (Rolim et al. 2018) because greater moisture content accelerates the growth of microorganisms and eventually deteriorates the food quality which leads to spoilage (Sodipo and Oluwajuyitan, 2019). Low moisture content is necessary for food industry application to produce products with a longer shelf life that are less likely subject to microbiological contamination (Rolim et al. 2018). Moisture content of less than 8% can prevent microbes growth whereas a level higher than 18% promote the growth of some microorganisms (Akther et al. 2020). In this study, Formulation 3 with a moisture content of 7.85 (0.01) can be considered more microbiologically stable than Formulation 0 (15.42 (0.00)).

Table 2: Nutritional Compositions of Formulated MMT Peel Powder

Proximate Compositions (g/100 g)	Formulated MMT Peel Powder[1]			
	Formulation 0	Nutrient content claim	Formulation 3	Nutrient content claim
Moisture content (%)	15.42 (0.00)[a]	N/A	7.85 (0.01)[b]	N/A
Crude protein	9.52 (0.02)[a]	Source of	3.99 (0.21)[b]	Not meet
Crude fat	1.46 (0.01)[a]	Low	0.69 (0.01)[b]	Low
Crude fiber	15.19 (0.08)[a]	N/A	5.11 (0.18)[b]	N/A
Ash	9.80 (0.04)[a]	N/A	4.22 (0.08)[b]	N/A
Carbohydrate[2]	63.81 (0.07)[a]	N/A	83.27 (0.28)[b]	N/A
Energy (kcal/100 g)[3]	306.40 (0.13)[a]	N/A	128.67 (0.33)[b]	N/A
Total dietary fiber	33.92 (0.20)[a]	High	13.89 (0.47)[b]	High
Vitamins (mg/100 g)	Formulation 0	Nutrient content claim	Formulation 3	Nutrient content claim
Vitamin A (β-carotene)	0.31 (0.00)[a]	High	0.13 (0.00)[b]	Source of
Vitamin D	0.55 (0.01)[a]	High	0.22 (0.00)[b]	High
Vitamin E (α-tocopherol)	0.38 (0.00)[a]	Not meet	0.15 (0.00)[b]	Not meet
Vitamin K	0.07 (0.01)[a]	N/A	0.03 (0.00)[b]	N/A
Vitamin C	5.32 (0.34)[a]	Not meet	2.13 (0.13)[b]	Not meet
Minerals (mg/100 g)	Formulation 0	Nutrient content claim	Formulation 3	Nutrient content claim
Calcium	348.00 (12.04)[a]	High	139.20 (4.82)[b]	Source of
Magnesium	435.78 (6.38)[a]	High	174.31 (2.55)[b]	High
Zinc	2.17 (0.06)[a]	Not meet	0.87 (0.02)[b]	Not meet
Selenium	0.29 (0.06)[a]	N/A	0.12 (0.03)[b]	N/A
Iron	7.42 (0.20)[a]	High	2.97 (0.08)[b]	Source of
Copper	0.40 (0.02)[a]	N/A	0.16 (0.01)[b]	N/A
Manganese	2.28 (0.08)[a]	N/A	0.91 (0.03)[b]	N/A

The presented results are indicated as means values (standard deviation) (n = 3).
Values with different superscript letters within a row indicate statistically significant among the group at level $p \leq 0.05$.
[1]Formulation 0: MMT peel powder without sweetener; Formulation 3: MMT peel powder with 60% sweetener
[2]Result obtained by calculation
[3]Result obtained by multiplying
N/A: Not applicable

Table 3: Physical Properties of Formulated MMT Peel Powder

Parameters	Formulated MMT Peel Powder[1]	
	Formulation 0	Formulation 3
Water activity	0.57 (0.01)[a]	0.52 (0.00)[b]
Color L*	54.57 (0.29)[a]	58.56 (0.41)[b]
Color a*	-1.86 (0.03)[a]	-1.83 (0.05)[a]
Color b*	23.05 (0.95)[a]	21.65 (0.32)[a]
Chroma	23.13 (0.95)[a]	21.72 (0.32)[a]
Hue angle	94.63 (0.23)[a]	94.84 (0.16)[a]

The presented results are indicated as means values (standard deviation) (n = 3).
Values with different superscript letters within a row indicate statistically significant among the group at level $p \leq 0.05$.
[1]Formulation 0: MMT peel powder without sweetener; Formulation 3: MMT peel powder with 60% sweetener

Table 4: Functional Properties of Formulated MMT Peel Powder

Parameters	Formulated MMT Peel Powder[1]	
	Formulation 0	Formulation 3
Water holding capacity (g of water/g of the dry sample)	4.61 (0.14)[a]	1.94 (0.03)[b]
Oil holding capacity (g of oil/g of the dry sample)	2.55 (0.10)[a]	2.38 (0.17)[a]
Swelling capacity (mL/g)	4.50 (0.50)[a]	2.33 (0.29)[b]

The presented results are indicated as means values (standard deviation) (n = 3).
Values with different superscript letters within a row indicate statistically significant among the group at level $p \leq 0.05$.
[1]Formulation 0: MMT peel powder without sweetener; Formulation 3: MMT peel powder with 60% sweetener

Table 5: Biochemical Properties of Formulated MMT Peel Powder

Parameters	Formulated MMT Peel Powder[1]	
	Formulation 0	Formulation 3
pH	4.71 (0.04)^a	5.60 (0.06)^b
Total titratable acidity (%)	0.78 (0.02)^a	0.41 (0.02)^b
Total soluble solid (°Brix)	5.03 (0.06)^a	6.47 (0.06)^b

The presented results are indicated as means values (standard deviation) (n = 3).
Values with different superscript letters within a row indicate statistically significant among the group at level $p \leq 0.05$.
[1]Formulation 0: MMT peel powder without sweetener; Formulation 3: MMT peel powder with 60% sweetener.

Another evidence also claimed that moisture content below 10% is vital to prevent microbial growth (Zambrano et al. 2019). This is supported by a study that reported that moisture content below 10% is ideal for dried food products such as instant drinks powder (El Wakeel, 2007). Similar findings were also observed in several studies which reported moisture content of < 10% observed in beverage powder (Akhter et al. 2010; Errazuriz et al. 2017; Farzana et al. 2017; Lascano et al. 2020; Masoud and El-Hadidy, 2017; Mohammed et al. 2017; Obilana et al. 2018; Vera Zambrano et al. 2019; Zlatanović et al. 2019).Usually, a preservative such as citric acid is added to prevent microbial growth.

Fat is considered a concentrated energy source that is stored in the body and utilized when the carbohydrate source is diminished. Also, fat is a cushion that can protect the internal organs such as the heart, lungs, kidney and intestine (Mohammed et al. 2017). Next, ash refers to an incombustible solid component in which 5%-6% indicates a good source of various minerals and micronutrients to soil (Errazuriz et al. 2017). A study also reported that higher ash content indicates better minerals sources (Asaolu et al. 2012). Apart from that, crude fiber is one type of dietary fiber that primarily consisted of cellulose, hemicelluloses and lignin contents which represents the components that are insoluble when subjected to standardized laboratory treatment with dilute acid and alkali (Akubor and John Ike, 2012). This typically aimed about distinguishing the composition of animal feed (Phillips et al. 2019). The treatment will dissolve all the soluble fiber and some of the insoluble fiber in food. Therefore, crude fiber content may underestimate the actual dietary fiber content in food by at least 50% (The National Academies Press, 1989). In short, the proximate analysis of the formulated MMT peel powder implies that it is beneficial for human consumption. Proximate analysis is very vital in commercial food manufacturing procedures in companies to ensure their products meet the standard laws and legal requirements as well as the safety and nutritional aspects of the end products. It is the only way to maintain and monitor the quality and shelf life of food products (Akther et al. 2020). According to the nutrient content claim in *Malaysian Dietary Guidelines* (2020), Formulation 0 is a source of protein, with low fat, high dietary fiber, vitamin A, vitamin D, calcium, magnesium, and iron content. Meanwhile, Formulation 3 is food with low fat, high dietary fiber, vitamin D, and magnesium as well as a source of vitamin A, calcium, and iron.

Physical Properties

Table 3 compares the physical properties of different formulated MMT peel powder namely Formulation 0 and Formulation 3. a_w determines the availability of water for biological activities and mathematically refers to the ratio of the vapor pressure of water in food to the vapor pressure of pure water (Vera Zambrano et al. 2019). It is apparent from this table that Formulation 0 had a significantly higher a_w than Formulation 3 (p = 0.004). This phenomenon can be explained by the presence of sweetener in Formulation 3. The sweetener exhibited hydrophilic properties which caused high hygroscopicity in which the food powder absorbs water from the environment with relative humidity higher than that of equilibrium (Ribeiro et al. 2016). The hygroscopicity is attributed to the formation of hydrogen bonds with water which reduces the amount of free water and leads to low a_w so that no water is available for microbial growth (Sayuti et al. 2017). A study also claimed that the addition of solutes such as sugar can control the quality of the food product by lowering its a_w (Ijabadeniyi and Pillay, 2017). Evidence claimed that a_w should be lower than 0.6-0.65 to avoid microbial growth (Mercer and Peng, 2008). Similarly, it is supported by a study that demonstrated 0.6 is the minimum a_w for microbial growth and no food spoilage will take place below this value at microbiological nature (Erkmen and Bozoglu, 2016). Thus, it can be concluded that the formulated MMT peel powder produced in this study is considered safe as no microbial proliferation would take place when stored properly (Sagrin and Chong, 2013).

The color of food is one of the most crucial sensory measures of general product acceptance by consumers (Yikmiş, 2020). This is because the consumers will perceive and use color changes as a tool to reject or accept dried samples (Ghanem et al. 2012). It is also a vital physical quality as it may cause alteration in food quality due to food processing and storage (Aziah and Komathi, 2009). The color parameters namely lightness (denoted by L*), redness (denoted by a*), and yellowness (denoted by b*) have been commonly used to highlight color changes during food processing and storage (Di Scala et al. 2011). According to Table 3, a significant lower L* value was observed in Formulation 0 which indicated that it had a darker color than Formulation 3 ($p < 0.001$) with a nearly similar value for the rest of the color parameters such as a*, b*, chroma, and H° ($p > 0.05$). A trend can be observed according to the findings of this study whereby the a* value decreases and the b* value increases with the increasing percentage of MMT peel powder in the formulations. These parameters have been associated with the types and quantities of components present or formed in the product (Di Scala et al. 2011). Usually, alterations in the color are induced by the reactions that occur in the food product such as pigment degradation (particularly carotenoids and chlorophyll pigments) and non-enzymatic browning (Maillard reaction) as well as oxidation of certain components such as ascorbic acid, lipids and polyphenols (Reihani et al. 2014; Tan et al. 2015). So, food coloring is sometimes added to enhance or preserve the color quality in food product.

Functional Properties

The comparison of functional properties between Formulation 0 and Formulation 3 is displayed in Table 4. The independent t-test revealed that Formulation 0 had a significantly greater WHC and SC with $p = 0.001$ and $p = 0.003$ respectively than Formulation 3. However, no significant difference was found in OHC even though a higher value was observed in Formulation 0 ($p = 0.194$). The evidence stated that citrus fruit peel contained carbohydrates, pectin and fiber which can provide better functional properties such as viscosity, water and oil absorption capacity in the food systems that can serve as the possible explanation for the findings obtained in this study (Abou-arab et al. 2017). These results match those observed in the earlier study (Rwubatse et al. 2014). Therefore, it is indicated that the capacity of water and oil retention, as well as SC, is directly associated with the fiber content present in the food (Abou-arab et al. 2017; Milek Dos Santos et al. 2015).

Functional properties are strongly correlated with the quality of the peels (Mallek-Ayadi et al. 2016) which can be affected by the chemical structure of the plant polysaccharides and protein (Jamsazzadeh Kermani et al. 2015). The dehydration process can exert an impact on the structure. So, the drying process greatly influences the physicochemical properties of food products which subsequently alter the functional properties (Abou-arab et al. 2017). WHC and OHC refer to the respective amount of water and oil retained by a set dry weight of food products in specific conditions of temperature, soaking time, duration, and speed of centrifugation (Mudgil and Barak, 2013). The structural properties and chemical compositions of the fiber (its water affinity of components) modulate the kinetics of water uptake whereby the water may be trapped in the capillary structure of the fiber due to surface tension strength which leads to subsequent hydrogen bonding or dipole interactions with the molecular structure of fiber (Yi et al. 2014). Similar findings were supported by previous research (Akubor & John Ike, 2012; Rafiq et al. 2018).

Biochemical Properties

The differences of biochemical properties between Formulation 0 and Formulation 3 are highlighted in Table 5 in which significantly lower pH and TSS, as well as higher TTA were exhibited in Formulation 0. pH is a crucial characteristic in industrial application which is widely used to identify the acidity or alkalinity of a liquid or solution. It is a parameter for a product's sourness besides estimating the ability of the microorganisms to grow in a specific food (Flores-Martínez et al. 2018). Lower pH results in greater storage stability (Ndife et al. 2019). Also, pH is a very important property in terms of consumer's acceptance. A decrease in pH was due to an increase in the TTA from Formulation 3 to Formulation 0. This finding matches the study observed in mango peel powder drink. The decrease in pH might be due to the degradation of sugars and peptic bodies found in MMT peel powder into acidic components (Ahmed et al. 2020).

The TTA is another parameter for a product's sourness, as it estimates the effect of acid content on the flavor of a food product (Jiménez-Aguilar et al. 2015; Naa et al. 2013). Tartness is the key factor in the acceptability of any beverage (Ahmed et al. 2020). It quantifies the total acid concentration in food and indicates the ionic strength of a solution which can influence the rate of chemical reaction (Akande and Ojekemi, 2013). This study observed a higher acidity with the increasing concentration of MMT peel which is consistent with another study on mango peel powder drink (Ahmed et al. 2020). This could be attributed to the breakdown of sugars present in MMT peel into carboxyl acids (Ahmed et al. 2020). Both the formulations were acidic which can be attributed to the degradation of acidic compounds in MMT peel as the drying process may cause certain acidic compounds to evaporate (Guehi et al. 2010).

Sugars, acids, traces of dissolved vitamins, fructans, proteins, pigments, phenol compounds, and minerals are known as soluble solids. Evidence suggested that TSS and sugar content becomes synonymous as approximately 85% of TSS of most of the fruits comprised of sugars (glucose, sucrose, and fructose) and sugar alcohols (sorbitol and mannitol) (Magwaza and Opara, 2015). In this study, a higher TSS observed in Formulation 3 was probably due to the inclusion of sweetener in the formulation as compared to the absence of sweetener in Formulation 0. A high TSS value implies a better quality of material whereas a low TSS value might be attributed to the respiratory losses and relatively to a polyphenolic oxidation product combined with protein during manufacturing (Azli et al. 2018). Ndife et al. (2019) stated that a beverage should not contain free sugar or added sugar more than 5% of the daily total energy requirement of an individual.

CONCLUSION

Formulation 0 had superior nutritional composition and physicochemical properties compared to Formulation 3, except for carbohydrate content. The findings might be important in delivering health benefits to consumers upon consumption of the different formulated MMT peel powders.

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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