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The effects of drying method and temperature on the nutritional quality of watermelon rinds

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Abstract

The present work was aimed to investigate the effect of drying methods (oven drying, foam mat drying) and temperatures (40°C, 60°C) on the nutritional characteristics of red- and yellow-watermelon rinds. It was found that foam mat drying produced the best results for preserving the most nutrients as compared to the conventional oven drying for both red- and yellow watermelon rinds. Temperature is a significant parameter that affects the nutritional characteristics of watermelon rinds powder for both methods. Finding suggests that foam mat drying at 40°C was the best method for producing watermelon rinds powder as it requires shorter treatment time and gave the best retention of protein and carbohydrate.

Introduction

Watermelon (*Citrullus vulgaris*) is native to South Africa, where it has been cultivated and consumed for over 5,000 years. It is now widely grown in tropical and sub-tropical areas including in Asian countries (Johnson *et al*., 2013). In 2013, watermelon became the world's largest fruit crop when global production reached approximately 109 million tonnes (FAOSTAT, 2016). It is a rich source of nutrients including vitamins (A, B, C and E), mineral salts (K, Mg, Ca, and Fe), amino acids (arginine and citrulline), antioxidants such as lycopene, phenolic compound and antibiotics (Perkins-Veazie *et al*., 2007).

Watermelon has three major components: flesh, seed and rind. The flesh is either yellow or red. It has been reported that approximately one-third of the total fruit mass is rind (Kumar, 1985; Romdhane *et al*., 2017). In 2013, nearly 36 million tonnes of watermelon rind was discarded despite it being edible (Al-Sayed and Ahmed, 2013; Petkowicz *et al*., 2017). In fact, the rind has no commercial value, although it can be used as an ingredient in various dishes (Al-Sayed and Ahmed, 2013), as an animal feed and as a fertiliser, and has even been reported to have the potential to be used as an absorbent for the removal of heavy metals (Petkowicz *et al*., 2017). Watermelon rind is therefore becoming an increasing disposal problem. The FAO (2016) reported that approximately of 1.6 billion tonnes of food wastage is being generated per year, with the highest percentage of that coming from fruits.

Watermelon rind consists of cellulose, hemicellulose, pectins and lignins with entrapped sugars, lycopene, carotenoids, citrulline and phenolics (Rimando and Perkins-Veazie, 2005). Many studies have reported on the extraction of valuable compounds such as pectin or citrulline from watermelon rind (Rimando and Perkins-Veazie, 2005). Watermelon rind also contains mineral salts, fat, protein, carbohydrates, vitamins and phytochemicals (Al-Sayed and Ahmed, 2013). Therefore, watermelon rind could be used as functional food ingredient due to these potential health benefits. For instance, the bioactive compounds present in watermelon rinds have been reported to be beneficial for people with hypertension (high blood pressure), age-related health disorders and degenerative diseases, largely on the basis of the non-nutritive phytochemicals they contain (Figueroa *et al*., 2011).

Devising processing techniques that could retain

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the bioactive compounds present in watermelon rinds is therefore crucial. Drying is one of the most important techniques in fruit processing as it extends the fruit's shelf-life by inhibiting the growth of microorganisms while preserving the nutrient content, biologically active compounds and antioxidants (Danso-Boateng, 2013; Sogi *et al*., 2015). It should be conducted carefully to ensure the preservation of the valuable compounds in watermelon rinds as a poor drying process may lead to the loss of volatile compounds or to the formation of new ones (Díaz-Maroto *et al*., 2002). Drying can also be used to develop new consumer products, one example being watermelon rind powder, which can be used as a functional food additive to improve the nutritional value of a foodstuff (Quek *et al*., 2007).

Foam mat drying is a relatively simple drying process that can be applied to foods of a wide range of consistency, from liquid to semi-solid to solid; foaming agents or stabilising agents are generally needed in this technique (Hardy and Jideani, 2017). It works by converting the liquid present in the fruit into a stable foam by adding gas and foaming agents. Hot air then dries the food further to powder form. The function of the foaming agent is to increase the surface area and form a porous structure (i.e. the foam), as this increases the mass transfer rate and hence shortens the drying time. It can also produce a higher-quality food product by preserving the nutrient content in the sample and reduce the browning rate. Moreover, it is cheaper than other drying methods such as freeze drying and spray drying.

If watermelon rind is to be commercialised, a good understanding is required of the effect of drying technique on its nutritional composition. Most studies have focused on the recovery of a valuable compound such as pectin or citrulline from watermelon rind. Little research however has been carried out on the effect of drying on the composition of watermelon rind. Previous studies have investigated the effects of hot air drying and of freeze drying on the composition of the rind of red and yellow watermelon (Ho *et al*., 2016). The freeze drying technique was found to preserve more nutrients (Ho *et al*., 2016). The aim of the present work was therefore to extend that previous study by evaluating the effects of oven drying and foam mat drying under different conditions on the nutritional value of watermelon rind powder.

Materials and methods

Materials

Watermelons and Nutriplus class eggs were purchased from a local market in Serdang, Selangor, Malaysia. The selection of ripe watermelon followed the guidelines reported by Sapii and Muda (2005). Separate samples of red watermelon and yellow watermelon were prepared.

The watermelon rind was obtained after the flesh was manually removed using a knife. The rind was cut into pieces of 8 mm dimension using a dicer. The same sample of fresh watermelon rind was divided into four to test for two drying techniques (oven drying, foam mat drying) and two conditions (40°C, 60°C). These moderate temperatures were chosen as they allow the nutritional contents of the watermelon rind to be retained.

Drying technique

Oven drying

Fresh watermelon rinds of 8 mm thickness were placed overnight in an oven dryer at an air temperature of either 40°C or 60°C. The rate of drying is dependent on the moisture content of the sample, the drying temperature, the relative humidity and the velocity of the air in contact with the sample. The dried watermelon rind was then milled to a fine powder using an analytical mill.

Foam mat drying

Fresh samples were cut, peeled and diced. The rind was processed in an electrical blender for 10 min, and then whipped into white foam in a food processor at constant speed for 2 min. The slurry was separated from the foam, placed in a bowl and whipped for an additional 10 min. During whipping, 10 g/100 g maltodextrin and 10 g/100 g egg albumen were added to the sample. Egg albumin is an excellent foaming agent and is widely used in the processing of mango, mandarin and banana. However, the stability of the foams made with egg albumin is inadequate for foam mat drying. Therefore, a food stabiliser such as maltodextrin was added. The thick foam of watermelon rind was spread on a stainless-steel tray and dried overnight at 40 ± 1°C or 60 ± 1°C in a cabinet dryer. After drying, the flakes of watermelon rind were scraped from the tray, ground into a powder and sieved through a mesh (a 400 US size sieve).

Physicochemical analysis

The composition (moisture, ash, crude protein, crude fibre and crude fat) of the watermelon rind powder was determined according to the methods recommended by the Association of Official Analytical Chemists (AOAC) (AOAC, 1995). The moisture content was determined using the oven drying method (AOAC Method 977.11), and the ash content was obtained by heating the sample (AOAC

Method 923.03). The crude protein and crude fibre were determined using the Kjeldahl's method (AOAC Method 955.04) and the gravimetric method (AOAC Method 991.43), respectively. The carbohydrate content was estimated by the formula given by BeMiller and Low (1998), and the calorific value of sample was calculated following the formulae used by Maclean *et al*. (2003).

Statistical analysis

All the data obtained were evaluated and presented as means with standard deviations. Analysis of variance (ANOVA) and calculation of statistical significance were done using MINITAB® software (Minitab package version 16.0 Inc., USA). A value of $p < 0.05$ was taken to indicate statistically significant differences.

Results and discussion

Physicochemical properties

Dried watermelon rind powders were analysed for selected physicochemical properties based on its further utilisation as a functional food. Table 1 presents the composition of the rind of red and yellow watermelon after oven drying and foam mat drying.

Moisture contents

Moisture content is an important factor in determining the powders qualities. The moisture content of the raw red and yellow watermelon rinds was 94.83% and 94.54%, respectively. The final moisture content of the dried rind powder varied from 5.61% to 9.82% depending on the type of watermelon, the drying technique and the temperature (Table 1). The variation in the final moisture content was statistically significant ($p < 0.05$), which were due to the subjective temperature and method used. The final moisture content of the samples was significantly less with the higher drying temperature (60°C rather than 40°C) in both drying methods. Similarly, it was reported in a previous study that higher drying temperature produced greater heat transfer and moisture evaporation (Methakhup *et al*., 2005).

With regard to the methods used, there were significant differences between the oven drying and foam mat drying at the tested temperatures (40°C or 60°C). For instance, the final moisture content of the powder produced using foam mat drying at 40°C was 7.54%, which was significantly lower than that of the sample produced using oven drying (9.82%) at the same temperature. This is because the increased surface area of the foamed pulp allows rapid drying through internal moisture movement within the pulp, and hence drying rates are higher (Kadam *et al*., 2011). The foam mat drying method thereby reduces the availability of water for chemical reactions and microbial growth (Franco *et al*., 2015). However, there was no significant difference between the rinds of the red and yellow watermelons in relation to moisture content. The results indicate that temperature is an important parameter influencing the moisture content of dried powders in both methods. The final moisture content of samples observed in the present work however was lower than that found by Al-Sayed and Ahmed (2013) of 10.72%, and Hoque and Iqbal (2015) of 10.61%. This might be due to

Table 1. Composition (%) of the powdered rinds of red and yellow watermelons prepared by two drying methods at two temperatures.

Sample	Properties	Oven Drying		Foam Mat Drying	
		40°C	60°C	40°C	60°C
Red	Moisture	$9.82^{A} \pm 0.15$	$6.93^{C} \pm 0.15$	$7.54^{B} \pm 0.15$	$5.61^{D} \pm 0.15$
Yellow		$9.43^{A} \pm 0.19$	$6.56^{C} \pm 0.13$	$7.36^{B} \pm 0.07$	$5.80^{D} \pm 0.08$
Red	Ash	$17.10^{B} \pm 0.21$	$18.11^{A} \pm 0.15$	$7.30^{E} \pm 0.15$	$8.11^{D} \pm 0.15$
Yellow		$16.38^{C} \pm 0.18$	$18.08^{A} \pm 0.15$	$7.14^{E} \pm 0.13$	$7.97^{D} \pm 0.07$
Red	Crude protein	$10.83^{B} \pm 0.15$	$9.43^{DE} \pm 0.15$	$11.64^{A} \pm 0.15$	$10.74^{B} \pm 0.15$
Yellow		$10.14^{E} \pm 0.13$	$9.33^{F} \pm 0.06$	$10.96^{C} \pm 0.08$	$10.18^{D} \pm 0.06$
Red	Crude fibre	$15.79^{A} \pm 0.15$	$15.40^{A} \pm 0.15$	$14.61^{AB} \pm 0.15$	$13.97^{BC} \pm 0.15$
Yellow		$15.45^{AB} \pm 0.32$	$15.08^{A} \pm 0.44$	$13.43^{CD} \pm 0.42$	$12.95^{D} \pm 0.18$
Red	Carbohydrate	$59.59^{F} \pm 0.29$	$63.09^{D} \pm 0.13$	$71.65^{C} \pm 0.19$	$73.98^{A} \pm 0.35$
Yellow		$61.58^{E} \pm 0.31$	$63.70^{D} \pm 0.09$	$72.63^{B} \pm 0.12$	$74.54^{A} \pm 0.12$
Red	Energy (kcal/100 g)	$304.31^{D} \pm 3.14$	$312.09^{BC} \pm 0.18$	$350.03^{A} \pm 0.61$	$352.96^{A} \pm 1.16$
Yellow		$309.11^{C} \pm 1.22$	$313.08^{B} \pm 0.60$	$351.43^{A} \pm 0.39$	$352.36^{A} \pm 0.30$

Each value is expressed as means ± standard deviation ($n = 3$). Different superscripts in the same line indicate significant differences ($p < 0.05$) between treatments according to the Tukey's test.

different degrees of ripeness, the specific cultivar used, and the method of analysis employed.

Ash content

Fruits and vegetables, including watermelon rinds, have relatively high mineral content, such as sodium, potassium, magnesium, calcium and other trace minerals (zinc and iron) (Lakshmipathy and Sarada, 2013). The fixed mineral residue (ash) is the inorganic material that remains after heating a sample of organic matter, which is transformed into carbon dioxide, water and nitric oxide (Franco *et al*., 2016). In general, the total amount of mineral component can be estimated based on the ash content of the sample (Omotoso and Adedire, 2007). Mineral components are present in the form of oxides, sulphates, phosphates, silicates and chlorides depending on the conditions of incineration and food composition (Campbell-Plat, 2009). The ash content however does not necessarily indicate the mineral content of the original food as there may be losses through evaporation or interaction (Franco *et al*., 2016).

According to Table 1, the ash content of sample was significantly greater at 60°C than at 40°C with both methods of drying. However, the ash content was significantly lower (7.30% at 40°C and 8.11% at 60°C for red watermelon rind) using foam mat drying than with oven drying (17.10%– 18.11%, respectively). Foam mat drying is generally used to reduce drying times (Kadam *et al*., 2011). However, in the present work, the same drying times (24 h) was used in both methods. A shorter time for foam mat drying would allow more heat-sensitive minerals to be retained. The results show no significant differences in the ash content of the rinds of red and yellow watermelons except at 40°C using oven drying. The ash content in the present work was higher than that reported by Al-Sayed and Ahmed (2013), which was 13.09% for oven drying.

Crude protein

The influence of drying method on crude protein content is shown in Table 1. Significant differences were found in the crude protein content as the temperature increased from 40°C to 60°C. This outcome is likely due to denaturation or other changes in the food due to the heating (Danso-Boateng, 2013). Suarni and Firmansyah (2008) reported that decreases in crude protein as the temperature increased were probably found because the Kjeldahl method was used to analyse the protein content. The authors reported non-proteinaceous nitrogen was also detected in the Kjeldahl method and some of these nitrogenous compounds were dissolved and lost during the drying process, and hence the protein content was apparently less (Suarni and Firmansyah, 2008).

At a given temperature, there was a significant difference between the two drying methods. Foam mat drying of the watermelon rinds (both red and yellow) preserved more protein than oven drying. For instance, the highest crude protein content, 11.64% was achieved using foam mat drying at 40°C. The lowest crude protein content was produced by oven drying at 60°C in the rind of the yellow watermelon (9.33%). These findings show that foam mat drying was more effective in retaining crude protein than oven drying. Foam mat drying is a technique that involves air incorporated into the liquid sample with the addition of foaming agents to form a stable foam, and it employs moderate temperatures (Karim and Wai, 1999; Falade and Okocha, 2012). This method is able to retain the properties of the fresh fruit such as vitamin content, flavour and colour, according to Kadam and Balasubramaniam (2011). This might due to the foaming agent used, which facilitates the retention of volatiles compounds and reduces heat damage (Ratti, 2001; Kadam and Balasubramanian, 2011; Kadam *et al*., 2011). For example, Rajkumar *et al*. (2007) reported that the natural flavour and colour of mango are retained in the foam mat-dried mango powder. Similarly, the vitamin C content is retained in foam mat-dried citrus powder. This outcome indicated that foam mat drying can also improve product quality with the presence of the foaming agent. These findings are comparable with the previous studies by Hoque and Iqbal (2015) and Al-Sayed and Ahmed (2013), which reported crude protein contents of 11.21% and 11.17%, respectively.

Crude fibre

Fibre can improve digestibility and the absorption process of a food (Ogungbenle, 2003; Miranda *et al*., 2010). Therefore, it is very important to choose a drying method that retains this valuable constituent of a food. It can be seen from Table 1 that there was no significant difference in the crude fibre content when the temperature increased from 40°C to 60°C with either drying method. However, there was a significant difference in crude fibre content between oven drying and foam mat drying methods at 60°C. The lowest value for crude fibre was 12.95%, for yellow watermelon rinds using foam mat drying method at 60°C, and the highest crude fibre was 15.79%, for red watermelon rinds using oven drying method at 40°C. This could be due to the degradation of pectin and other fibres (including cellulose and hemicelluloses) during the rapid heat transfer using the foam mat drying method. Teoh *et al*. (2016) also reported lower fibre content after foam mat drying than after using other drying techniques. The fibre content found in the present work is comparable to the value reported by a previous study using hot air drying (Ho *et al*., 2016). However, it has also been reported by Ho *et al*. (2016) that the crude fibre content of watermelon rind was high (18.65 – 22.02%) using a freeze drying method. This variation might be due to the different maturity and methods employed.

Carbohydrate and energy

The carbohydrate content significantly increased with temperature for both methods. The highest values of carbohydrate were 73.98% and 74.54% using the foam mat drying method at 60°C, for red and yellow watermelon rinds, respectively. This higher carbohydrate content via foam mat drying was attributed to the low crude fibre content (12.95%) in the samples. The oven drying method at 40°C and 60°C produced lower carbohydrate content for both red and yellow watermelon rinds. Another study reported a carbohydrate content of 56.02% of watermelon rind using a similar method at 50°C (Al-Sayed and Ahmed, 2013). It is important to have a high carbohydrate content as this indicates the functionality of a food powder when consumed directly or as an ingredient in a food product (Franco *et al*., 2016).

The energy value via foam mat drying was significantly higher than via oven drying for red and yellow watermelon rinds at both temperatures. The lowest energy recorded was 304.31 kcal/100 g for red watermelon rind using oven air drying at 40°C. These findings are due to the effect of the drying method on the percentage differences of each property measured, including crude protein, crude fat, and carbohydrate contents.

Conclusion

The nutritional quality of watermelon rind powder depends on the drying method employed. The findings suggest that foam mat drying produces the best results for preserving most nutrients. This method utilises a foaming agent, and this results in the best quality of watermelon rind powder. It preserves more protein and carbohydrate than the oven drying method. There were no significance differences between the powdered rinds of red and yellow watermelons.

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