Effect of Different Drying Conditions on Proximate Compositions of Red- and Yellow-Fleshed Watermelon Rind Powders

*Lee-Hoon Ho, Mazaitul Akma Suhaimi, Ishamri Ismail and Kamarul 'Ain Mustafa

School of Food Industry, Faculty of Bioresources and Food Industry, Universiti Sultan Zainal Abidin, Besut Campus, 22200 Besut, Terengganu Darul Iman, MALAYSIA.

*Corresponding author; E-mail: holeehoon@unisza.edu.my

ABSTRACT

This study aimed to investigate the effect of different drying conditions (hot-air oven drying at 40 °C and 60 °C, and freeze drying) on nutritional quality of red- and yellow-fleshed watermelon rinds. The proximate compositions, carbohydrate content, and energy value of watermelon rind powders were determined. Freeze drying method preserved more nutrients followed by hot-air oven drying at 40 °C and 60 °C for red-fleshed watermelon rind powder. The freeze dried powder contains 18.86% moisture, 19.13% ash, 11.82% crude protein, 22.02% crude fiber, 2.21% crude fat, 47.77% carbohydrate, and 259.13 kcal of energy. Hot-air oven drying at 40 °C was the most effective method to preserve the nutrient of yellow-fleshed watermelon rind powder with chemical compositions of 15.12% moisture, 20.57% ash, 13.37% crude protein, 14.34% crude fiber, 0.70% crude fat, 50.31% carbohydrate, and 260.72 kcal of energy. Results suggest that freeze drying and hot-air oven drying (40 °C) methods had the highest potential to be applied in processing of red- and yellow-fleshed watermelon rind powders, respectively.

Keywords: Freeze drying, hot-air oven drying, proximate composition, watermelon rind powder

ABSTRAK

Kajian ini bertujuan untuk mengkaji kesan daripada keadaan pengeringan yang berbeza (pengeringan oven udara panas pada suhu 40 °C dan 60 °C dan pengeringan sejuk beku) terhadap kualiti nutrien kulit buah tembikai berisi merah dan kuning.
INTRODUCTION

Watermelon (Citrullus lanatus var. lanatus) which belongs to Cucubitaceae family, is a warm-season crop and usually grown in the warmer part of the world (Dane and Liu, 2007). The pulp and juice of watermelon are consumed by human, the rind and seeds which represent 30% of the whole fruit are the major solid waste (Bawa and Bains, 1997). According to Leong and Shui (2002), the rind of the watermelon is edible and often preserved as pickles. Agricultural and industrial residues are interesting sources of natural antioxidants and dietary fiber (Larrosa et al., 2002).

Currently, watermelon by-products are considered as important sources of protein, dietary fibers, and natural antioxidants (Mandel, 2005; Al-Sayed and Ahmed, 2013; Yadla et al., 2013).

According to Sewald and DeVries (2015), water is the most important factor to speed up food spoilage deterioration and microbial spoilage. Thus, processing of watermelon into powder by reducing the water content is needed for extension of the shelf life. Drying is the most common method used to lengthen the product shelf life, reducing packaging requirement and also minimize shipping weight (Hamrouni-Sellami et al., 2011). The most popular drying method used in food industry is conventional hot-air drying due to its low cost of processing (Fan et al., 2012). Apart from conventional air drying, the most common drying methods applied in food industry are vacuum, spray, and freeze-drying (Tsami et al., 1998). Guiné and Barroca (2012) reported that high temperature of hot-air drying causes an irreversible change in nutritional values of the products, but freeze drying
significantly reduces such damage. When compared with non-processed products, the products of hot-air drying are generally low porosity, high apparent density (Tsami et al., 1998) and reduced quality (Ratti, 2001), while the products of freeze drying are generally low bulk density, high porosity as well as good aroma, and taste retention (Krokida and Maroulis, 1997).

Watermelon rind powder has good potential to be developed as an innovative value-added product in the market. The powder can be used as flour substitute for wheat flour in the preparation of bakery products such as cake (Al-Sayed and Ahmed, 2013; Hoque and Iqbal, 2015). The dried form of watermelon rind allows it to be exported for worldwide consumption due to its stability during storage. In addition, development of high quality watermelon rind powder may be able to meet global increasing demand for foods with high dietary fiber and some chemical compound (citrulline). To utilize watermelon rind powder as a functional ingredient in developing food products, understanding on the nutritional composition of this powder is necessary. However, no research has been conducted on the proximate composition of red- and yellow-fleshed watermelon rind powders. Most of the studies were focused on the antioxidant activities and citrulline contents of watermelon flesh from both varieties (Rimando and Perkins-Veazie, 2005; Choo and Sin, 2012; Oseni and Okoye, 2013). In this work, the content of moisture, ash, crude protein, crude fiber, crude fat, carbohydrate, and energy of the red- and yellow-fleshed watermelon rind powders obtained from different drying conditions (hot-air oven drying at 40 °C and 60 °C) and freeze drying were investigated.

**MATERIALS AND METHODS**

**Sample collection and experimental design**

Ripe watermelon (*Citrullus lanatus* var. *lanactus*) was procured from Besut, Terengganu in the hot months of June-July. The watermelon was selected according to the guidelines described by Sapii and Muda (2005), whereby the characteristics of a ripe watermelon should include the yellowish-cream ground spot, shining skin, dispersed stripes, and producing hollow sound when flicked. Watermelon rinds from red- and yellow-fleshed watermelons were separated from the fruit manually by using knife and then sliced using slicer. The slices were divided into three groups according to their drying conditions; hot-air oven drying at 40 °C and 60 °C for overnight and freeze drying for two days. The rate of drying (drying time) was depended by the moisture content (before drying: 85-90% of moisture content and after drying: 14-18% of moisture content) of the samples, the drying temperature, the relative humidity, and the velocity of the air in contact with the samples. The dried slices of watermelon rind were then ground in laboratory
mill to fine powder, kept in an airtight plastic container and stored in chiller prior to use.

**Proximate compositions**

The proximate composition (moisture, ash, crude protein, crude fiber, and crude fat) of watermelon rind powder was determined according to the official method as described by AOAC (1995). The moisture content of the samples was determined by oven drying (AOAC Method 977.11), while ash content was investigated by dry ashing (AOAC Method 923.03). Crude protein content was quantified by Kjeldahl’s method (AOAC Method 955.04). Crude fiber content was analyzed using gravimetric method (AOAC Method 991.43), and crude fat content was determined according to the Soxhlet method (AOAC Method 960.39).

**Carbohydrate determination**

The carbohydrate content was estimated by difference [Carbohydrate (%) = 100% - % (moisture + crude protein + crude fat + ash)] (BeMiller and Low, 1998).

**Calculation of energy**

The calorific value of the sample was calculated according to Maclean et al. (2003). The total crude protein, crude fat, and carbohydrate contents were multiplied by the factorial values (For each gram of protein and carbohydrate, 4 kcal of energy is obtained and 1 g of crude fat provides 9 kcal of energy). Energy = [(crude protein x 4) + (carbohydrate x 4) + (crude fat x 9)].

**Statistical analysis**

Statistical analyses of the tabulated data were performed using the SPSS version 20 software. The results obtained in the present study were represented as mean values of three individual replicates ± standard deviation (n = 3 ± S.D.). One-way analysis of variance was conducted and significant differences between the mean values were analyzed using Duncan’s multiple range tests at a significance level of p < 0.05.

**RESULTS AND DISCUSSION**

The proximate compositions of red- and yellow-fleshed watermelon rind powders processed by hot-air oven drying (40 °C and 60 °C) and freeze drying were tabulated in Table 1.
Table 1. Proximate compositions (%) of watermelon rind powders prepared by different drying methods

<table>
<thead>
<tr>
<th>Drying method(^1)</th>
<th>Moisture</th>
<th>Ash (^a)</th>
<th>Crude protein (^b)</th>
<th>Crude fiber (^c)</th>
<th>Crude fat (^d)</th>
<th>Carbohydrate (^2)</th>
<th>Energy (^3) (kcal/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Red-fleshed</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HAD40</td>
<td>14.75 ± 0.15(^a)</td>
<td>13.09 ± 0.24(^a)</td>
<td>6.02 ± 0.14(^a)</td>
<td>17.10 ± 0.03(^b)</td>
<td>0.66 ± 0.12(^a)</td>
<td>65.41 ± 0.02(^c)</td>
<td>291.93 ± 1.69(^b)</td>
</tr>
<tr>
<td>HAD60</td>
<td>14.98 ± 0.21(^a)</td>
<td>17.86 ± 0.37(^b)</td>
<td>8.34 ± 0.37(^b)</td>
<td>14.26 ± 0.49(^a)</td>
<td>4.25 ± 0.28(^c)</td>
<td>54.76 ± 0.11(^b)</td>
<td>284.50 ± 3.04(^b)</td>
</tr>
<tr>
<td>FD</td>
<td>18.86 ± 0.19(^a)</td>
<td>19.13 ± 0.56(^c)</td>
<td>11.82 ± 0.19(^c)</td>
<td>22.02 ± 0.67(^c)</td>
<td>2.21 ± 0.24(^b)</td>
<td>47.77 ± 0.28(^c)</td>
<td>259.13 ± 2.87(^a)</td>
</tr>
<tr>
<td><strong>Yellow-fleshed</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HAD40</td>
<td>15.12 ± 0.10(^a)</td>
<td>20.57 ± 0.24(^c)</td>
<td>13.37 ± 0.14(^c)</td>
<td>14.34 ± 0.13(^a)</td>
<td>0.70 ± 0.12(^a)</td>
<td>50.31 ± 0.16(^c)</td>
<td>260.72 ± 2.00(^a)</td>
</tr>
<tr>
<td>HAD60</td>
<td>14.80 ± 0.24(^a)</td>
<td>16.05 ± 0.22(^c)</td>
<td>5.50 ± 0.28(^a)</td>
<td>12.79 ± 0.23(^a)</td>
<td>5.97 ± 0.12(^c)</td>
<td>57.92 ± 0.36(^c)</td>
<td>312.52 ± 7.39(^c)</td>
</tr>
<tr>
<td>FD</td>
<td>17.55 ± 0.19(^b)</td>
<td>17.02 ± 0.12(^b)</td>
<td>7.91 ± 0.14(^b)</td>
<td>18.65 ± 0.74(^b)</td>
<td>3.10 ± 0.12(^b)</td>
<td>54.30 ± 0.13(^b)</td>
<td>273.05 ± 7.28(^b)</td>
</tr>
</tbody>
</table>

Notes:
Presented data are the means ± standard deviation (n = 3). Value bearing different superscripts letters in the same column for each watermelon variety are statistically significant from each other (p < 0.05)

\(^1\)HAD40: Hot-air oven drying at 40 °C; HAD60: Hot-air oven drying at 60 °C; FD: Freeze-drying
\(^2\)Results obtained by difference
\(^3\)Results obtained by multiplying
The moisture contents of red- and yellow-fleshed watermelon rind powders were between 14.75-18.86% and 14.80-17.55% (dry basis), respectively. The present study showed that freeze drying method is less effective in reducing moisture content of watermelon rind compared to hot-air oven drying method (40 °C and 60 °C). Yellow-fleshed watermelon rind powder processed using hot-air oven drying method (40 °C and 60°C) showed lower moisture content than freeze drying method. Morris et al. (2004) reported that moisture removal by heat improved food digestibility, increased concentration of nutrients and increase the nutrient availability. The results obtained in the present work was in agreement with other findings for bitter leaf flour, soursop flour, and African metallic wood-boring beetle flour (Aliero and Abdullahi, 2009; Iombor et al., 2014; Theron et al., 2015). This could be attributed to different dry bulb temperature was applied to process powder (Iombor et al., 2014). According to Akubor and John (2012), samples dried using freeze drying technique is prone to freezing injury which might cause mechanical damage to the plant cell membrane due to the formation of ice during freezing. This consequently resulted in increase of the moisture content. The moisture results obtained in the present study is in agreement with the crude fiber results (Table 1), where a positive correlation between moisture and crude fiber of red- and yellow-fleshed watermelon rind powders processed using freeze drying method was observed. This might be attributed to the presence of foreign material such as fiber from watermelon rind, which is a highly hydrophilic constituents (Al-Sayed and Ahmed, 2013), that may have contributed to the high water absorption capacity of the flours, thereby causes the high moisture content. Freeze drying results in products with the highest moisture contents that might not be favorable for prolonged storage of watermelon rind powder. The results obtained from the present study showed higher moisture content (14.75-18.86% and 14.80-17.55% for red- and yellow-fleshed watermelon rinds, respectively) compared to watermelon rind powder as reported by Al-Sayed and Ahmed (2013) at 10.61%.

Ash is the inorganic residue remaining after the water and organic matter have been removed by heating in food. Generally, the ash content of a sample is the reflection of the total amount of minerals present in the test sample (Omotoso and Adedire, 2007), whereas, the mineral content is a measure of the amount of specific inorganic components present within a test sample. Minerals are less susceptible to heat and less volatile compared to other food components (Agoreyo et al., 2011). Freeze dried powder of red-fleshed watermelon rind demonstrated to contain higher ash component (19.13%) than the powder processed using hot-air oven drying. This was attributed to the freeze drying method that work by eliminating water from a frozen material at a very low temperature under vacuum condition which sublimed directly from a solid phase into a vapor phase. Thus, this mechanism can prevent some heat sensitive minerals from loss during drying at longer time (Haïle et al., 2015). Lower ash content (13.09%) obtained in the watermelon rind powder made by hot-air oven drying at
40 °C were in accordance with previous study by Al-Sayed and Ahmed (2013), who reported that the watermelon rind dried in hot-air oven dryer at 50 °C has 13.09% of ash content. However, the ash content (20.57%) was the highest in yellow-fleshed watermelon rind powder that was dried using hot-air dryer at 40 °C \( (p < 0.05) \). The increase in the ash content observed in this study could be as a result of the removal of moisture which tends to increase the concentration of nutrients (Morris et al., 2004).

According to Agoreyo et al. (2011), application of heat can be both beneficial and detrimental to nutrients. Heat improves the digestibility of food, promotes palatability and also improves the keeping quality of food, making them safe to eat. Heating process also results in nutritional losses by inducing biochemical and nutritional variation in food composition. The highest crude protein content of red-fleshed watermelon rind powder (11.82%) was recorded for sample produced by freeze drying method. Wiriya et al. (2009) reported that the decrease in protein content probably occurs as a result of Maillard reaction; which results in complex changes in food due to the reaction between protein and carbohydrate. The decrease in protein content of food on the application of heat might be also attributed to the effect of tannins that form complexes with protein and reducing their availability (Enomfon-Akpan and Umoh, 2004). The current obtained results for crude protein content was comparable with previously published results by Al-Sayed and Ahmed (2013) and Hoque and Iqbal (2015); which were 11.17% and 11.21%, respectively. However, hot-air oven drying at 40 °C was more effective in retaining crude protein (13.37%) of yellow-fleshed watermelon rind powder than other drying methods. According to Suarni and Firmansyah (2008), the decrease of protein content with increasing in drying temperature was probably caused by the Kjeldahl method used for protein analysis in which non-protein nitrogen is also detected. Furthermore, the authors also reported that some nitrogen compounds might be dissolved and loss during drying at 60 °C, resulting in less protein content detected in the analysis. The variation of the results obtained between red- and yellow-fleshed watermelons may also be attributed to interactions between genetic make-up and environmental conditions.

Crude fiber is a compound which cannot be hydrolyzed by alkali and it consists of cellulose, lignin and pentosan. Watermelon rind powder produced by hot-air oven drying method at different temperatures (40 °C and 60 °C) seems to have no significant effect on crude fiber content of the yellow variety. However, the highest crude fiber content for both varieties was shown for powder produced by freeze drying (22.02% and 18.65% for red- and yellow-fleshed watermelon rind powders, respectively). The crude fiber content of the powders made from both varieties of watermelon was recorded to decrease as the drying temperature increases. This indicates that the fiber content of the samples can be enhanced by applying lower temperature during drying. The noticeable loss of crude fiber content with increasing drying temperature can be explained by the fact that heat
treatment involved during drying can disrupt the cellular matrix of the product (Onifade et al., 2013). This trend was also observed by Adeboye et al. (2014) who worked on green plantain. According to the authors, the amount of soluble fiber in fruit may increase by partial breakdown of pectin during drying process at high temperature (Adeboye et al., 2014). The values of crude fiber obtained in the present study were higher than those of other fruit peels such as mandarin peels and orange peels (7.14% and 13.38%, respectively) (Magda et al., 2008). In addition, crude fiber content observed in the present study was higher than that reported by Al-Sayed and Ahmed (2013), where the value was 17.28% for crude fiber content of watermelon rind powder. Thus, watermelon rind powders could be considered as a source of fiber and might be suitable to be utilized in food products to increase their fiber content. The crude fiber contents of the dried watermelon powders would be significant in human nutrition. The therapeutic effects of fiber in the prevention of several chronic diseases such as diabetes, colon cancer and heart disease, and their roles in the treatment of digestive disorders (constipation and diverticulosis) are widely reported (Akubor and John, 2012).

Crude fat content of red- and yellow-fleshed watermelon rinds was significantly affected by drying methods. Results from Table 1 show a significant difference in crude fat content between two studied varieties. Crude fat content presented in both varieties were ranging from 0.66% to 5.97%. Samples dried using hot-air oven at 60 °C showed the highest content of crude fat (4.25% and 5.97% for red- and yellow-fleshed watermelon rinds, respectively), followed by freeze drying and hot-air oven drying at 40 °C. Crude fat content of red- and yellow-fleshed watermelon rind powders obtained through hot-air oven drying at 40 °C were the lowest, which was 0.66 and 0.70%, respectively. Low crude fat content indicates that the powder is less susceptible to quick rancidity. Thus, hot-air oven drying method at temperature of 40 °C could be a suitable drying method to be applied for drying of watermelon rind. According to Iombor et al. (2014), plant samples subjected to high temperature may have undergone decomposition of crude fat during the drying process and hence reducing their nutrients.

In this study, the highest value of carbohydrate (65.41% and 57.92%) was found for hot-air oven dried (40 °C and 60 °C) of red- and yellow-fleshed watermelon rind powder, respectively. Other authors reported similar amounts of carbohydrate content for watermelon rind powder (56.02%) obtained using hot-air oven drying method at 50 °C (Al-Sayed and Ahmed, 2013), but lower than those values reported by Hoque and Iqbal (2015), who reported that watermelon rind powder contains 73.18% of carbohydrate content. The lower carbohydrate content of red-fleshed watermelon rind powder obtained via freeze drying method was attributed to the high crude fiber content (22.02%) of the sample. Red-fleshed watermelon rind powder obtained by freeze drying had significantly lower energy content (259.13 kcal/100g) as compared to other dried samples. However, yellow-fleshed watermelon rind powder processed through hot-air oven drying (40 °C) showed the lowest energy content (260.72 kcal/100g), followed by freeze drying.
(273.05 kcal/100g) and hot-air oven drying at 60 °C (312.52 kcal/100g). The different in the energy content of the powders might be attributed to the differences in their crude protein, crude fat and carbohydrate contents.

CONCLUSION

The findings of the current study suggest that freeze drying method preserves more nutrients, followed by hot-air oven drying at 40 °C, and 60 °C for red-fleshed watermelon rind powder. However, for yellow-fleshed watermelon rind powder, the most effective drying method to preserve its nutritional values was hot-air oven drying at 40 °C, followed by freeze drying, and hot-air oven drying at 60 °C.

ACKNOWLEDGEMENTS

The authors wish to thank Universiti Sultan Zainal Abidin for the financial support from the University Research Grant [UNISZA/2015/DPU/(2)].

REFERENCES


