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Effects of drying on the physical characteristics of dehydrated watermelon rind candies

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Abstract

Dehydrated watermelon (*Citrullus lanatus*) rind candy was prepared using osmotic dehydrated process that involves slow impregnation of syrup before drying at 50 °C and 60 °C for 8, 14 and 20 h. It can be seen that the drying temperature and time significantly affected the moisture content and water activity of the dehydrated candy. The moisture content and water activity significantly decreased with increasing drying temperature and time. The hardness and stickiness of the watermelon rind candy slightly increased with increasing drying time at 50 °C and 60 °C. For colour evaluation, the L* values of dehydrated watermelon rind candy slightly decreased with increasing drying time while the a* values slightly increased with increasing drying time. Watermelon rind candy that was dehydrated at 50 °C for 14 h was the most preferred sample by the panellists as it received the highest score for texture, taste and overall acceptability attributes.

Keywords: watermelon rind, drying time, dehydrated candy, physical characteristics, drying temperature

Introduction

Watermelon, *Citrullus lanatus* (Thunb.) is a tropical fruit which grows in almost all parts of Africa and South East Asia (Koocheki et al. 2007). It belongs to the family of cucumber (Cucurbitacea) with large, oval, round or oblong shape. The skin is smooth, with dark green rind or sometimes pale green stripes that turn yellowish-green when ripe. Watermelon is a very rich source of vitamins and often used as an appetiser or snack, depending on how it is prepared (Kerje and Grum 2000). Watermelon biomass can be categorised into three main components i.e. the flesh, seed and rind. The flesh constitutes approximately 68% of the total weight, the rind approximately 30%, and the seeds approximately 2% (Kumar 1985).

The rind is usually discarded, applied to feeds or used as fertiliser. They are also edible and sometimes used as vegetable. In China, they are stir-fried, stewed, or more often pickled (Erukainure et al. 2010). Pickled watermelon rind is also commonly consumed in Southern US, Russia, Ukraine, Romania and Bulgaria (Southern U.S. Cuisine 2010). Various studies had been conducted on the utilisation of the rind as an ingredient in products including pickle,

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candy, vadiyam and cheese (Kumar 1985; Simonne et al. 2002; Madhuri and Devi 2003).

Watermelon rind has 95% water content, thus making it susceptible to deterioration (Athmaselvi et al. 2012). Hence, it is important to reduce the moisture content to produce shelf stable products from watermelon rind. Air drying is a primeval method used to preserve food in which the solid to be dried is exposed to a continuously flowing hot air stream where moisture evaporates. According to Ratti (2001), although air drying offers dehydrated products that can have longer shelf-life but the products usually have low quality. Therefore, pre-drying treatment such as osmotic dehydration is commonly used in order to minimise adverse changes occurring during drying.

Osmotic dehydration is a method for partial dehydration of water-rich foods, such as fruits and vegetables, by immersing them in a concentrated solution of sugar. It results in two simultaneous crossed flows; a water outflow from the food to the solution and a solute inflow from the solution into the food (Hough et al. 1993; Raoult-Wack et al. 1994; Spiazzi and Mascheroni 1997). Removal of water content in fruits or vegetables occurs during treatment with sugar solution, while the sugar solution diffuses into the food (Giangiacomo et al. 1987; Rastogi and Niranjan 1998). According to Rastogi and Raghavarao (1997), osmo-air drying is the combined approach of drying method in which osmotic dehydration and hot air drying is carried out simultaneously one after another. This drying process is an economical method of drying for fruits or vegetables containing more than 70% moisture content (Vishal et al. 2012). Candied products were predicted to have a longer shelf-life with no microbial growth as they contain 65 – 70% of sugar with water activity values at 0.6 – 0.8 (Chen 1989).

The effect of drying temperature and time on the dehydrated watermelon rind candy has not been studied. Thus, this study was carried out to determine the effects of drying temperature and time on the physical characteristics of dehydrated watermelon rind candy.

Materials and methods

Preparation of dehydrated watermelon rind candies

The watermelons were purchased from a local supplier at Larkin market in Johor Bahru, Johor. The dehydrated watermelon rind candies were processed using the method described by Zainun (2007) with minor modifications. The watermelons were washed thoroughly and peeled. The red flesh was discarded while the rinds were used to develop the dehydrated candies. The green layers of the rinds were removed and the remaining white flesh was cut into 3 cm long and 1 cm wide pieces. They were then blanched in boiling water for 1 min to inactivate the enzyme that would lead to the deterioration of the product.

The rinds were then submerged in sugar syrup which slowly impregnated the rind tissues with sugar until the sugar concentration was high enough to prevent microbial spoilage. Initial sugar concentration of 40 °Brix was employed and the concentration was increased everyday by 5 °Brix until a final concentration of 55 °Brix was reached. Each time an increase in the sugar concentration was made, the syrup was drained, heated and sugar was added to bring the total soluble solids up to the desired level. The hot syrup was cooled to 60 °C before adding to the rinds.

At the final syrup concentration, the rinds were kept for 3 days and drained. Then, 650 g rind samples were weighed and arranged on stainless steel perforated tray (57 cm x 57 cm) before drying in a cabinet dryer at 50 °C and 60 °C for 8, 14 and 20 h respectively. The dehydrated candies then underwent a sweating process at room temperature for 24 h to stabilise the moisture content with the relative moisture of the environment (Hasimah 1988). Afterward, the candies were coated with a mixture of icing sugar and corn flour (1:1) and packed in high density polyethylene bags until the evaluation process.

Determination of moisture content

The moisture content was determined using the air oven method (AOAC 2000). The candy samples were dried in the oven at 105 °C for 24 h. The moisture content was calculated from the weight difference between the original and dried sample and expressed in percentage. For each sample, the observation was done in duplicates and the average was reported.

Determination of water activity

The water activity (a_w) of dehydrated watermelon rind candies was determined using Labswift-a_w hygrometer (Novasina, Switzerland). The dehydrated candies were cut into small pieces then loaded into a sample dish and put in the measurement chamber. The equilibrium of the air humidity over a sample (water-vapour pressure), which is proportional to the a_w value, was measured. For each sample, duplicates were obtained and the mean was reported.

Determination of colour intensity

The colour index of the dehydrated watermelon rind candies was measured using a chroma meter CR400 (Minolta Camera Co.) based on the L* a* b* colour system. L* denotes the lightness on a 0 – 100 scale from black to white while a* and b* denote the hues which represented two colour axes with a* denoting redness (+) or greenness (–) and b* denoting yellowness (+) or blueness (–). The equipment was calibrated using a white tile for the Y, x, y values of 92.5, 0.3134 and 0.3194 respectively. Each of the samples was measured in five replicates and the average was reported.

Determination of hardness and stickiness

The hardness and stickiness of the dehydrated watermelon rind candies were determined using a texture analyser (Model TA-HD$_{plus}$ Texture Technologies, Surrey, UK) and controlled by the Texture Expert Exceed software version 2.54a from Stable Micro System as described by Bourne (2002). The acquisition rate was set at 400 pps. A 5-mm diameter cylindrical probe (P/5) was attached to the 25 kg load cell. The pre-test speed, test speed and post-test speed were set at 1.0, 2.0 and 10.0 mm/sec respectively. The sample was cut into a constant size of (1.5 x 1.5 cm^3).

During the analysis, the sample was placed on a blank plate of the heavy-duty platform and positioned centrally under the probe. The probe was then moved down to penetrate the sample. The distance of penetration was set at 2 mm. All samples were determined at room temperature. The test was carried out in five replications and the results were statistically analysed using the SAS version 9.0. The means of the maximum positive force (g) and negative force (g) upon compression were measured as hardness and stickiness respectively.

Sensory evaluation

The sensory evaluation was carried out at MARDI Johor Bahru, with 14 experienced panellists according to Stone and Sidel (1985). Each sample was served and coded with three digits chosen at random. Sensory attributes evaluated were according to the degree of liking (DOL) in the aspects of taste, colour, texture and overall acceptability. All panellists evaluated the samples using a 7-point category hedonic scale (1 = Dislike very much; 4 = Neither like nor dislike; 7 = Like very much) as described by Meilgaard et al. (1999).

Statistical analysis

Experimental data were analysed using the analysis of variance (ANOVA) and the significant differences among means were determined by the Duncan Multiple Range

Test (DMRT) at $p \leq 0.05$ using the Statistical Analysis System (SAS 9.0) computing program.

Results and discussion

Effect of drying on the moisture content, water activity and colour of the dehydrated watermelon rind candies

There was no significant difference in the moisture content between fresh and blanched watermelon rinds as shown in *Table 1*. However, the increase in moisture content of blanched watermelon rind may be due to the migration of water molecules from the boiling water used for blanching into the rind cells. Osmotic dehydration and drying significantly affected the samples. The subsequent processes following blanching such as osmotic dehydration, hot air drying and coating caused significant losses in moisture content of the dehydrated watermelon rind candies. Osmotic dehydration is an important pre-treatment used prior to air-drying for water removal in cellular solids (Rahman and Perera 1996). The results showed that watermelon rind candies dried at 60 °C had significantly lower moisture contents compared to those dried at 50 °C for the same drying times (8, 14 and 20 h). The result also showed that the moisture content during the air-drying process decrease with time which was in compliance with the nature of drying characteristics of various fruits, vegetables and cereals (Lyderson 1983; Gabriela et al. 2004)

Table 1. Moisture content of fresh, blanched and dehydrated candy of watermelon rind

Sample	Moisture content (%)
Fresh	94.60 ± 0.07a
Blanched	96.18 ± 0.04a
50 °C, 8 h	22.82 ± 0.02b
50 °C, 14 h	16.68 ± 0.11c
50 °C, 20 h	15.07 ± 0.23d
60 °C, 8 h	14.28 ± 0.04e
60 °C, 14 h	10.74 ± 0.01f
60 °C, 20 h	10.54 ± 0.02f

Means with the same letter are not significantly different at $p < 0.05$

Drying is a critical process in developing a dehydrated candy product. According to Zainun (1995), the standard moisture content for dehydrated fruit candy should be in the range of 12 – 21% so that the candy to be stored for longer period of time without any deterioration caused by microorganisms. The drying time of 14 and 20 h at 50 °C and 8 h at 60 °C (*Table 1*) were adequate to produce good quality dehydrated watermelon rind candies compared to the 8 h drying time at 50 °C which contained higher moisture content (22.8%). Higher moisture content resulted in products that are highly vulnerable to damage especially mould growth which can endanger the health of consumers due to food poisoning (Fellows and Hampton 1992). However, drying at 60 °C for 14 and 20 h resulted in lower moisture content (10.7% and 10.5% respectively) in comparison to what was suggested by Zainun (1995). This indicated that higher drying temperature and longer drying time significantly affected the moisture content of the dehydrated watermelon rind candies.

The stability and safety of food is improved when water activity (a_w) of the product is decreased. The a_w of foods influences the multiplication, metabolic activity, resistance and survival of the microorganisms present (Leistner et al. 1981). The a_w for dehydrated candy samples ranged from 0.625 to 0.671 (*Table 2*). Samples dried at 60 °C for 20 h had significantly different a_w compared to other samples. This indicated that higher temperature and longer drying time reduced the water activity significantly along with osmotic dehydration process whereby the amount of water was removed during osmosis and the incorporation of sugar occurred. According to Jangam et al. (2008), food with water activity between 0.4 and 0.6 is considered as a dry product, whereas food with water activity between 0.65 and 0.75

Table 2. Water activity (a_w) of dehydrated watermelon rind candies

Sample	Drying temperature (°C)	Drying time (h)	Water activity (a_w)
A	50	8	0.656 ± 0.004ab
B		14	0.671 ± 0.009a
C		20	0.658 ± 0.005ab
D	60	8	0.671 ± 0.001a
E		14	0.659 ± 0.002ab
F		20	0.625 ± 0.006c

Means with the same letter are not significantly different at $p < 0.05$

Table 3. Colour of dehydrated watermelon rind candies

Sample	Drying temperature (°C)	Drying time (h)	Colour		
			L*	a*	b*
A	50	8	66.86 ± 6.63a	1.86 ± 0.46a	6.45 ± 0.54a
B		14	60.63 ± 8.86ab	0.59 ± 0.63a	7.83 ± 0.62a
C		20	53.56 ± 2.11b	1.21 ± 0.63a	8.10 ± 0.75a
D	60	8	67.92 ± 5.12a	1.70 ± 0.90a	8.75 ± 0.57a
E		14	60.66 ± 4.56ab	1.46 ± 0.12a	9.11 ± 3.59a
F		20	57.82 ± 7.99ab	0.88 ± 0.87a	9.19 ± 1.30a

Means in the same column with the same letter are not significantly different at $p < 0.05$

is considered to be an intermediate moisture content product.

There was no significant difference in colour measurement between samples dried for 8, 14 and 20 h at 50 °C and 60 °C (Table 3). The L* value for samples dried at 50 °C and 60 °C decreased slightly with increased drying time. It showed that longer drying time darkened the colour of the dehydrated candy compared to samples dried with shorter drying time. However, b* values for dried samples were slightly increased with increasing drying temperature and time. The colour changes may be due to non-enzymatic browning and formation of brown pigments (Lopez et al. 1997; Maskan 2001; Diamante et al. 2010). According to McBean et al. (1971) and Kresic et al. (2004), non-enzymic browning is responsible for tissue darkening during drying due to both condensation of reducing sugars with amino acids and pigment conversion.

Effect of drying on hardness and stickiness of watermelon rind dehydrated candy

The effects of drying temperature and time on hardness and stickiness profile of the dehydrated candy were observed (*Table 4*). There was a significant increase ($p \leq 0.05$) of hardness of the dehydrated watermelon rind candies dried for 20 h at 50 °C and 60 °C. The increase was due to long drying hours that caused the solidification of syrup as described by Chalmers (1987). However, according to Winarno (1990), texture in terms of the level of hardness and tenderness of materials is related to the amount of water content, whereby the higher water content material will be tenderer than that of a lower water content material. The significant increase ($p \leq 0.05$) of stickiness of the dehydrated watermelon rind candies dried for 8 h at 50 °C was probably due to a condition known as 'moisture graining' as its relatively high moisture content (22.8%) caused the candies to be less resistant to graining as described by Chalmers (1987).

Table 4. Hardness and stickiness of dehydrated watermelon rind candies

Sample	Drying temperature (°C)	Drying time (h)	Hardness (g)	Stickiness (g)
A	50	8	336.71 ± 102.7c	–2.63 ± 0.11a
B		14	488.93 ± 66.1c	–3.56 ± 0.45bc
C		20	1917.31 ± 150.45a	–4.26 ± 0.56de
D	60	8	833.32 ± 512.18b	–3.27 ± 0.24b
E		14	1049.85 ± 125.9b	–3.86 ± 0.14cd
F		20	1856.49 ± 76.71a	–4.32 ± 0.19e

Means in the same column with the same letter are not significantly different at p <0.05

Table 5. Average scores for colour, texture, taste and overall acceptability of dehydrated watermelon rind candies

Sample	Drying temperature (°C)	Drying time (h)	Colour	Texture	Taste	Overall acceptability
A	50	8	5.40 ± 0.82a	5.20 ± 1.15a	4.70 ± 1.22ab	4.90 ± 1.03ab
B		14	5.33 ± 0.97a	5.60 ± 0.83a	5.67 ± 0.98a	5.60 ± 1.05a
C		20	5.00 ± 1.41a	5.00 ± 1.13a	4.60 ± 1.12b	4.90 ± 1.06ab
D	60	8	5.47 ± 1.40a	4.80 ± 1.37a	4.80 ± 1.57ab	4.80 ± 1.37ab
E		14	5.80 ± 0.68a	5.13 ± 1.19a	5.13 ± 1.19ab	5.20 ± 1.20ab
F		20	5.40 ± 0.83a	4.80 ± 1.26a	4.53 ± 1.55b	4.47 ± 1.70b

Means in the same column with the same letter are not significantly different at p <0.05

Figure 1 showed the force-time graph for one cycle compression of watermelon rind dehydrated candy. The result indicated that the longer drying time significantly influenced the hardness and stickiness profiles of the dehydrated candy compared to shorter drying time.

Sensory evaluation of dehydrated watermelon rind candies

The mean scores given by the panellists for sensory attributes of dehydrated watermelon rind candies are presented in *Table 5*. The results showed that there were no significant differences for colour and texture attributes among all the samples. For taste attribute, there were significant differences in sample B (dried at 50 °C for 14 h), sample C (dried at 50 °C for 20 h) and sample F (dried at 60 °C for 20 h). However, the panellists preferred the taste of sample B by giving it the highest score compared to the others. For overall acceptability, there were significant differences between sample B and sample F. Sample B received the highest score (5.6) while sample F received the lowest scores (4.5). Sample B also received the highest score for texture (5.6), taste (5.7) and overall acceptability (5.7).

This indicated that sample B was the most acceptable dehydrated watermelon candies. This result was in accordance with Morita et al. (2005) whose finding showed good acceptability in crystallised melon products processed through the slow method of sugar impregnation and further drying at 50 °C. In contrary, sample F received the lowest mean score for texture (4.8), taste (4.5) and overall acceptability (4.4) from the panellists. This may be due to the moisture content of the sample which was the lowest (10.5%) compared to the other samples. According to Jainudin and Mazuin (1988), excessive removal of water will lead to tough and leathery products. This showed that higher temperature and longer drying

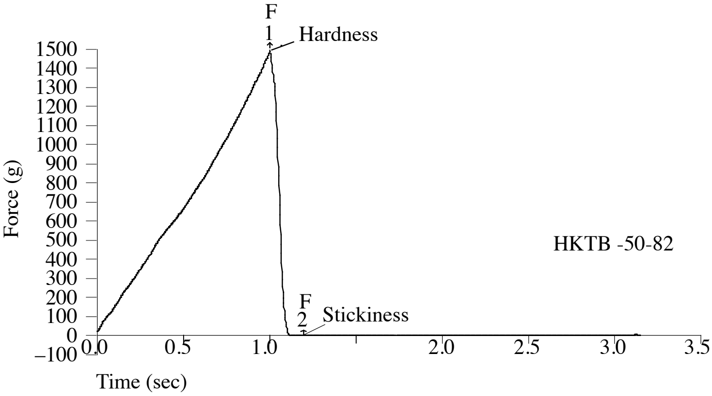

Figure 1. Force-time graph for one cycle compression of dehydrated watermelon rind candies

time can affect the sensory characteristics and acceptance of dehydrated watermelon rind candies.

Conclusion

The physical characteristics and sensory acceptance of the dehydrated watermelon rind candies as influenced by the drying temperature and time have been assessed. The drying temperature and time significantly affected the moisture content and water activity of the dehydrated watermelon rind candies. These results proved that higher temperature and longer drying time will result in a significant decrease in the moisture content and water activity of the dehydrated candies. The hardness and stickiness of the watermelon rind candies slightly increased with increasing drying time. For colour, the L* value of the dehydrated candies slightly decreased with lower drying time while the a* value slightly increased with longer drying time. Sample B (dried at 50 °C for 14 h) was the most acceptable dehydrated watermelon rind candies as the sample received the highest score for overall acceptability compared to the sample F (dried at 60 °C for 20 h), which received the lowest score. This showed that drying temperature and time affect the sensorial characteristics of the dehydrated watermelon rind candies. Therefore, it can be concluded that the drying temperature of 50 °C and 14 h of drying time is the most appropriate temperature-time combination to dry the candied watermelon rind.

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Abstrak

Kandi kulit tembikai (*Citrullus lanatus)* kering disediakan melalui proses nyahhidrat osmosis yang melibatkan pengisitepuan sirap secara perlahan sebelum dikeringkan pada suhu 50 °C dan 60 °C selama 8, 14 dan 20 jam. Suhu dan masa pengeringan didapati mempengaruhi kandungan lembapan dan nilai keaktifan air (a_w) kandi kulit tembikai kering. Kandungan lembapan dan a_w menurun secara signifikan dengan peningkatan suhu dan masa pengeringan. Kekerasan dan kelekitan kandi kulit tembikai meningkat sedikit dengan peningkatan masa pengeringan pada suhu 50 °C dan 60 °C. Bagi penilaian warna, nilai L* bagi kandi kulit tembikai kering adalah sedikit menurun dengan peningkatan suhu pengeringan manakala nilai a* pula sedikit meningkat dengan peningkatan suhu pengeringan. Kandi kulit tembikai yang dikeringkan pada 50 °C selama 14 jam adalah sampel yang paling disukai oleh para panel dengan markah paling tinggi bagi atribut tekstur, rasa dan penerimaan keseluruhan.