JOURNAL OF AGROBIOTECHNOLOGY 2019, VOL 10(1S):46-58
e-ISSN: 2180-1983
http://dx.doi.org/
https://journal.unisza.edu.my/agrobiotechnology/index.php/agrobiotechnology/index

PENERBIT
Universiti Sultan Zainal Abidin

JOURNAL OF AGROBIOTECHNOLOGY
eISSN : 2189-1983

Effects of Drying Methods on the Quality Parameters of Dried Manis Terengganu Melon (*Cucumis melo)*

Norlia Muhamad* and Nurul Adillah Mohd Redzuan

Faculty of Bioresources and Food Industry, Universiti Sultan Zainal Abidin, Besut Campus, 22200, Besut, Terengganu, Malaysia.

***Corresponding author: norliamd@unisza.edu.my**

Received: 05/08/2019, Accepted: 06/10/2019, Available online: 31/10/2019

ABSTRACT

The objective of this study was to identify the suitable drying methods for preservation of immature Manis Terengganu melon by using different temperatures which are 40 °C, 50 °C and 60 °C. The osmotically pre-treated samples were dried by using three types of convective dryer; cabinet dryer, oven dryer and rotary dryer. The drying time and drying rates were determined through drying curve. Rotary dryer had the shortest drying time and drying rates followed by cabinet dryer and oven dryer. The quality parameters on dried melon were identified. The range of water activity achieved for dried melon was 0.46-0.52. The hardness and chewiness of dried melon showed significantly difference between fresh and dried sample. The browning absorbance of dried melon at 420 nm for each equipment at temperature 50 °C showed significant difference at $p<0.05$. Rotary dryer at 50 °C was preferred as the suitable drying equipment to dry melon in terms of time consumption as well as produced acceptable physicochemical quality of dried melon.

Keywords: *Cucumis melo*, drying, osmotic dehydration, quality parameters

INTRODUCTION

Rock Melon or its botanic name as *Cucumis melo* is a Cantaloupe family that comes from America. Most of rock melon has grown in Asian continent. In Malaysia, rock melons are cultivated in Selangor, Kedah, Terengganu, Negeri Sembilan and Sabah (Lembaga Pemasaran Pertanian Persekutuan, 2012). This melon has yellow-skinned background with orange flesh and a musky aroma (Parnell et al., 2003). Rock melon has a wide variety of health benefits including improved immune system strength, healthy skin and eyes, reduces chances of cancer, healthy lungs, decreased stress level as well as prevention of arthritis and boosted management of diabetes. This is due to the high vitamins and minerals content in the rock melon especially in Vitamin A (68 %), Vitamin C (61%) and Potassium (8%) (Anonymous, 2016).

Manis Terengganu melon is the one of rock melon variety and has been planted in Terengganu. The maturity level of ripe Manis Terengganu melon is about 60 days and the shelf life of ripe Manis Terengganu melon is 2 weeks depends on storage condition. Its degree of ºBrix at full maturity is 13 - 19 °Brix. Immature Manis Terengganu melon also is high perishable and rapidly deteriorates due to short shelf life. It is a waste from the plantation as it will be removed to reduce competition and provide adequate nutrients (fertilizer, minerals, water and sunlight) for selected fruits from the trees in order to produce good quality of fruits for harvesting. This study focused on the immature fruits that have been removed from the plants. This fruits are not fully utilized and become waste to agriculture crop.

Drying method is the oldest method used in food preservation. This is because drying helps food keep well due to low moisture content that can inhibits the growth of microorganisms. Drying process is the most useful large scale operation method of keeping solid foods safe for long period of time. This operation need to be precisely controlled and optimized so that the good quality of product can be produced (Chen & Mujumdar, 2008). However, the drying method of immature Manis Terengganu melon has not yet been established.

According to Dias da Silva et al. (2016), pre-treatments are used in order to accelerate the drying process, enhance quality and improve the safety of foodstuffs. Osmotic dehydration is simple process involving peeling, slicing or cutting. The sample will be immersed in the 'osmotic solution' such as concentrated solution of sugar, or salt or both. In this study, the immature Manis Terengganu melon was osmotically pre-treated prior to drying.

In drying process, the major challenge is to remove water from a material in the most efficient way while retaining the product quality, with the lowest cost and minimal impact on the environment. Thus, this study aimed to identify the suitable drying methods for preservation of Manis Terengganu melon and to determine its physico-chemical quality affected by using different convective-dryer and temperatures.

MATERIALS AND METHODS

Materials

The fresh immature Manis Terengganu melon (*Cucumis melo*) was obtained from Ladang Tanaman Manis Terengganu, Besut, Terengganu. The samples were selected with similar °Brix or total soluble solid. The fruits were chilled at 4 °C to maintain its physical and chemical properties. Food grade sucrose and calcium lactate were obtained from local supplier and Merck (Darmstadt, Germany), respectively.

The selection of young melon was sorted based on the similar ripeness which is about 5 °Brix and size of young melon that was determined by average weight (150 – 200 g), diameter (6-9 cm) and length (8-12 cm).

Preparation of sample

Samples were washed thoroughly using tap water to remove dirt. Samples were peeled and sliced by using fruit slicer (Sirman, Italy) with approximately 0.5 cm thickness. The samples were weighed and pre-treated with osmotic solution by immersing in the bowl containing 40 °Brix sucrose solution at room temperature (~25 °C) for 132 minutes with syrup-to-fruit ratio of 1:4 (w/w) (Yadav & Singh, 2014). The samples were blotted with absorbing paper to remove remaining moisture on the surface and weighed. The pre-treated samples were vacuum packed and stored at 4 °C prior to drying process.

Drying process

The convective-drying of osmotically pre-treated samples was conducted using cabinet dryer (CB) (Pro-tech Model FDD 720, Malaysia), oven dryer (OV) (Memmert, Germany) and rotary dryer (RD) (JR Ricky Dryer, Thailand) at temperature 40 °C, 50 °C and 60 °C until constant weight were obtained . The perforated tray was placed at the centre of the dryer. During drying the samples were removed at intervals of 1 hour and weighed, before being returned to the dryer. Similar experiments were performed for each dryer and temperature.

Analysis

Moisture content

The initial moisture content of fresh and pre-treated samples were analysed by using oven drying method (AOAC, 2000). The moisture content was calculated by using Eqn. 1:

$$\text{Moisture content, X (\%)} = \frac{(W_1 - W_2)}{W_1} \text{ x } 100\% \qquad \text{Eqn. 1}$$

where:

W1 = weight of wet sample (g)
W2 = weight of dried sample (g)

The moisture content at time interval, t during drying was calculated by using Eqn. 2:

$$\text{MC}, X_{dry} = \frac{\text{Mass of water at t (g)}}{\text{Mass of dry solid (g)}} \qquad \text{Eqn. 2}$$

From Equation (2), different moisture content at time interval was calculated by using Eqn. 3:

$$\frac{\Delta X}{\Delta t} = \frac{(X_1 - X_2)}{\text{Time interval}} \qquad \text{Eqn. 3}$$

where:

X_1 = initial moisture content at t_1
X_2 = final moisture content at t_2

From Equation (3), drying rate, R was calculated by using Eqn. 4:

$$R = \frac{\text{Mass of water dry solid (kg)}}{\text{Area of sample (m}^2\text{)}} \text{ x } \frac{\Delta X}{\Delta t} \qquad \text{Eqn. 4}$$

Water activity

Water activity in fresh and dried samples was measured using water activity meter (AquaLab Dew Point 4TE, USA) at room temperature (~25 °C). It was calibrated with distilled water before conducting sample analysis. Sample was placed into plastic cells and the reading was recorded when the equilibration was achieved.

Texture profile analysis

The texture profile of fresh and dried samples was performed using Double Arm TAXT2i texture analyzer (Stable Micro Systems Ltd, Godalming, UK). The hardness and chewiness test were selected in the texture analysis. These parameters were automatically computed from each curve of texture analyzer software by using knife blade probe.

Browning analysis

Browning analysis was performed by using methodology previously described by (Phisut & Jiraporn, 2013) with some modifications. About 10 g of dried sample were ground and rehydrated for 10 minutes in 50 mL of 1% (v/v) of acetic acid. Sample was mixed until dissolved for 5 minutes. Then, 75 mL of 1% (v/v) of acetic acid were added to dilute the mixture and was filtrated by using filter paper. After the filtration completed, the browning intensity of clarified sample solution was determined by using UV-VIS spectrophotometer (UVmini-1240, Shidmadzu, Japan) at absorbance 420 nm.

Statistical analysis

Statistical analyses were conducted using Statistical Package for the Social Science (SPSS) 14.0 software (SPSS Inc., Chicago, IL, USA). All analysis and measurements were performed in triplicates. A one-way analysis of variance (ANOVA) with Tukey test was used to determine the significant differences between means at the 5% confidence level.

RESULTS AND DISCUSSION

Moisture content

The initial moisture content of fresh sample and osmotically pre-treated samples are 95.38 % and 83.00 %, respectively. Water content in fresh sample has been removed during osmotic dehydration (OD) process. Osmotic dehydration has been frequently used as pre-treatment before drying process due to its efficiency in reducing energy consumption and improves the product quality (Kaushal & Sharma, 2016).

Table 1 shows the drying time and moisture content of samples using different drying methods at different temperatures. At temperature 40 °C, OV40 has the highest value of drying time to reduce the moisture content of sample from 1.2 g.H2O/g.DM to 0.2 g.H2O/g.DM while the RD40 has the lowest value of drying time with 1.8 hrs difference. There was a significant difference between drying time for CB40, OV40 and RD40 at 5% significance level. At temperature 50 °C, RD50 has taken 3 hours to achieve 0.2 g.H2O/g.DM moisture content. There was a significance different between CB50, OV50 and RD50 with drying time of 4.00 hrs, 4.67 hrs and 3.17 hrs, respectively. The drying time of RD60 was 2.00 hrs - 84% shorter than OV60 and recorded as the lowest drying time among the studied parameters. There was a significance different between CB60, OV60 and RD60. The moisture content of all samples were not significantly different because each samples reached the same equilibrium moisture content of 0.2 g.H20/g.DM after drying process completed.

From these results, rotary dryer at temperature 40 °C, 50 °C and 60 °C lead the drying time faster than cabinet and oven dryer. The different in drying time for each drying methods was due to the efficiency of the equipment where each equipment has their own performance to reduce the moisture content of the sample. In this study, rotary dryer was the fastest method to dry the sample by achieving final moisture content with less time taken compared to the other two methods.

Rotary dryer used the concept of hot air drying in which same as cabinet dryer but the tray in rotary dryer has been rotated during its operation and the hot air used are from the source of liquefied petroleum gas (LPG) (Saravacos & Kostaropoulus, 2002). The rotation creates turbulence flow of air that speed up the migration of moisture to the surface of food leading to a shorter drying time.

Table 1. Drying time and moisture content constant at different drying methods and temperature

Methods	Temperature (℃)	Drying time (hrs)	Moisture content,MC ($g.H_20/g.DM$)
Cabinet drying (CB)	40	4.50 ± 0.50^d	0.25 ± 0.01^a
	50	4.00 ± 0.00^c	0.24 ± 0.01^a
	60	3.17 ± 0.29^b	0.23 ± 0.01^a
Oven drying (OV)	40	5.83 ± 0.58^e	0.25 ± 0.00^a
	50	4.67 ± 0.29^d	0.24 ± 0.01^a
	60	3.67 ± 0.29^{bc}	0.25 ± 0.00^a
Rotary drying (RD)	40	4.00 ± 0.30^c	0.26 ± 0.01^a
	50	3.17 ± 0.29^b	0.25 ± 0.01^a
	60	2.00 ± 0.00^a	0.25 ± 0.01^a

From these results, rotary dryer at temperature 40 °C, 50 °C and 60 °C lead the drying time faster than cabinet and oven dryer. The different in drying time for each drying methods was due to the efficiency of the equipment where each equipment has their own performance to reduce the moisture content of the sample. In this study, rotary dryer was the fastest method to dry the sample by achieving final moisture content with less time taken compared to the other two methods.

Rotary dryer used the concept of hot air drying in which same as cabinet dryer but the tray in rotary dryer has been rotated during its operation and the hot air used are from the source of liquefied petroleum gas (LPG) (Saravacos & Kostaropoulus, 2002). The rotation creates turbulence flow of air that speed up the migration of moisture to the surface of food leading to a shorter drying time.

At three different temperatures studied, oven dryer showed the longest drying time in removing moisture content due to low heat applied over a long drying time and consistent drying curve (Elizabeth, 2016). Harrison and Andress (2017) have reported that oven drying has slower operation than other dehydrators because there is no built in-fan which indicates source of hot air movement. Thus, this slow operation leads to time and energy consumption since longer drying time needed to achieve the final moisture content of the sample.

Compared to cabinet dryer, it was faster by 22% and 14% than oven dryer at 40 °C and 50 °C, respectively, although no significance difference in drying time at 60 °C. Cabinet dryer is able to remove moisture faster than oven dryer due to hot air movement directed up towards perforated trays and passes across the tray that placing the sample (Okos et al., 1992). Hence, the movement of air around the tray in cabinet dryer helps the drying process depends on temperature set.

This study has identified that drying time reduced by almost 2 times by increasing the drying temperature from 40 °C to 60 °C. Therefore, increasing temperatures during drying could enhance the vapour pressure in the samples to be removed from inside of sample tissue to the outer surface.

Study by Aral & Beşe (2016) reported that drying times decreased by almost 5 to 6 times when temperature raised from 50 °C to 70 °C for hawthorn fruit and similar results have been reported earlier for sweet cherry and peach slices (Doymaz & Smail, 2011; Zhu & Shen, 2014)

Drying rate

Fig. 1 presents the drying rate as a function of time at with 40 °C, 50 °C and 60 °C respectively by using different drying methods. The symbol of R (kg.H_20/h.m^2) represents drying rate and was determined by using Eqn. 4. By plotting these graphs, the effect of using different drying method can be observed significantly through the rate of drying at first period of time. This is known as falling rate period. The trend of drying rate for each drying methods and temperature shown significantly difference because the rate-controlling factors in falling-rate period are complex in which depends on the rate of diffusion through food that changing energy-binding pattern of the water molecules (Hui, 2012).

Based on previous study by Kaushal and Sharma (2014), the drying rate or loss of moisture was faster at the first period of time where the decreasing of drying rate with drying process progression may due to reduction of moisture and caused by development of case hardening. The trend in Fig. 1 shows that as the drying time increased, the drying rates also continuously decreased and this pattern indicates that drying of samples takes place in falling-rate period and no constant-rate period were observed. This may due to a diffusion controlled process by the movement of the moisture in the fruit during drying period (Aral & Beşe, 2016).

Arévalo-Pinedo and Murr (2005) reported that constant drying rate period was not observed because of significant shrinkage of sample that occurs during drying of very wet biological materials. According to Parikh (2014), the drying rate was determined based on the set factors that affect heat and mass transfer. Heat transfer involves the evaporation of liquid by transfer heat into product while mass transfering occurs as a vapour into gas surrounding.

In addition, the capacity of air or gas stream to absorb and carry away moisture from fruit tissues could determine rate of drying and also identify duration of drying take place. There are two essential elements in drying process which is inlet air temperature and air flow rate of dryer. Hence, the selection of dryer needs to take into consideration of these two essential elements influence the drying rate.

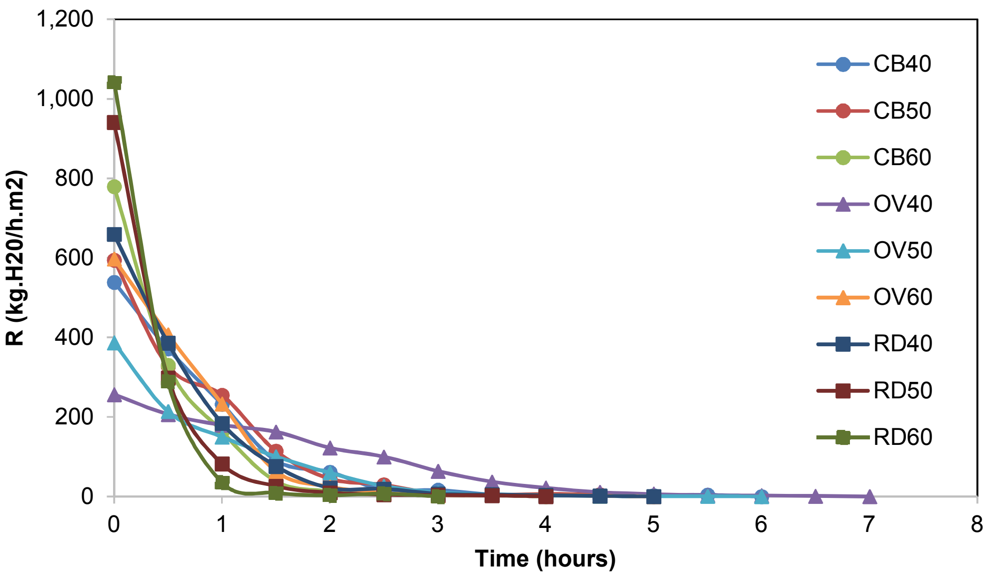

Fig. 1. Drying rate of immature Manis Terengganu melon at temperature 40 °C, 50 °C and 60 °C by using different drying methods

Rotary dryer at temperature 40 °C, 50 °C and 60 °C had shown the most decreasing trends followed by cabinet dryer and oven dryer. The average drying rates of rotary dryer for entire drying period were 145.8 kg.H_20/h.m^2

at 40 °C, 203.8 kg. H_20/h.m^2 at 50 °C and 274.0 kg. H_20/h.m^2 at 60 °C. The large surface area of rotary dryer may become one of the factors that influence the drying rates increases tremendously. This is because in air drying, rate removal of moisture influenced by the condition of the air, the properties of food and the design of dryer (Earle, 1983).

As the rotary dryer use LPG as hot drying source, it helped the moisture content in the sample to evaporate quickly than convective air drying such as cabinet dryer. LPG will evaporate quickly at normal temperatures and pressures due to its boiling point is below room temperature and thus speed up the evaporation of moisture in the sample. Other than that, agitated or rotated tray in rotary dryer resulting in higher drying rates per unit heating area as the continuous renewal of solids in contact with the dryer's heated surface and at the same time could performed in improving uniformity of the product (Parikh, 2014; Ross, 2017).

For oven dryer, the drying rate at three different temperatures had shown the consistent trend where it results in the slowest rate of drying between the drying methods. This could be due to its indirect method in removing a liquid phase from the solid material by the application of heat where heat-transfer medium is separated from the fruit to be dried by a metal wall. This performance of drying is also known as conduction or non-adiabatic dryer. Thus, the rate of drying was limited by heat transfer area and may lead to low production rates in terms of industry-based (Parikh, 2014).

In terms of drying temperature, as temperature increases, the higher drying rates occur since high moisture gradient occur during beginning of drying or in falling-rate period (Katekawa & Silva, 2007). From Fig. 1, the initial drying rates at three different temperatures for cabinet, oven and rotary dryer were different since the capability of dryer to remove moisture at one interval of time greatly depends on temperature used to heat up the air surrounding in dryer.

Water activity

It is important to control the water activity of a food that is highly perishable especially fruits and vegetables in a way to extend the shelf life of the food. The optimum water activity recommended for dried fruit is 0.60 with 15 to 20% of moisture content as reported by Sablani et. al (2007). Fig. 2 shows the water activity of fresh, treated OD and also dried samples at temperature 40 °C, 50 °C and 60 °C by using different drying methods.

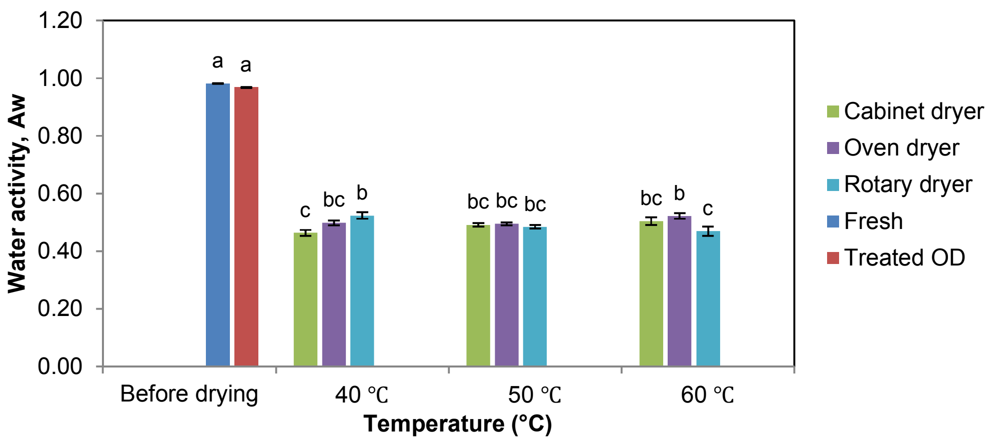

Fig. 2. Water activity of fresh, treated OD and dried samples at different temperatures and drying methods. Means with same lower case letter at different temperatures do not differ significantly at $p<0.05$

The trends of bar from fresh to dried has been decreased gradually for each temperature applied. Water activity of fresh and treated sample showed no significance difference at $p \leq 0.05$. This might due to the mechanisms of osmotic dehydration that generally not reduce moisture content of food product to a low-enough level in which to achieve shelf-stable product. Osmotic dehydration only act as an intermediate step to improve product quality for further processing such as drying (Agnelli, 2012).

There is significantly difference at $p<0.05$ between fresh and dried samples at different temperatures and drying methods. The range of water activity achieved for dried samples were 0.46-0.52; considered as shelf stable since it is under optimum level recommended by Beuchat (1983). At temperature 40 °C, the water activity level for cabinet dryer is significantly lower than rotary dryer.

This may due to long drying time for cabinet dryer to dry the sample which is 6 hours to achieve 20% of moisture content. Phunggamngoen et al. (2013) reported that water activity decreased with the drying time due to the correspondence of the extent of water loss during drying.

Texture profile analysis

Hardness of Manis Terengganu Melon

Texture is important in determining the quality of dried fruit and hardness is one of texture attributes that indicate mouth feel of dried fruit (Chong et al., 2008; Kek et al., 2013). Hardness or firmness of fresh, treated OD and dried samples were measured by computing the maximum penetration force as shown in Fig. 3.

The hardness of dried fruit was significantly higher than treated OD samples. This result indicates that the texture of sample become harder when heat applied on the surface.

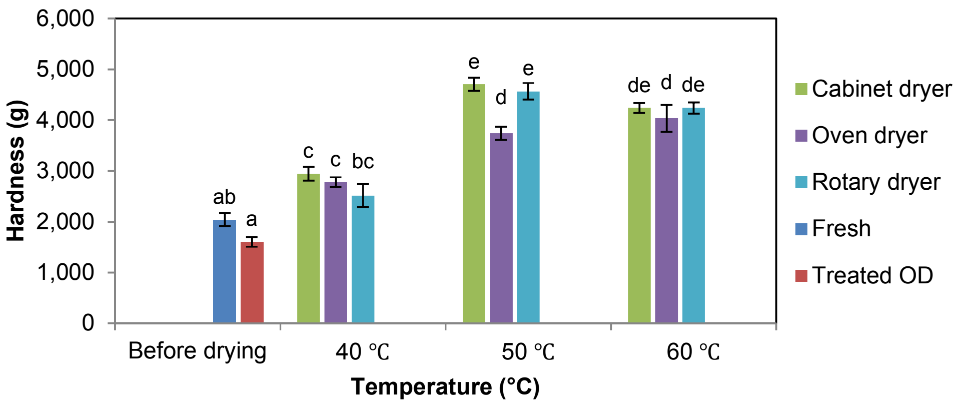

Fig. 3. Hardness of fresh, treated OD and dried sample at different temperature and drying methods. Means with same lower case letter at different temperatures do not differ significantly at $p<0.05$

Higher temperature leads to harder texture of sample due to rapid moisture losses during drying and cause compaction to the structure of cell tissue. From Fig. 3 it can be observed that hardness significantly increased when the temperature increased from 40 °C to 60 °C. This is due to texture of dried sample becomes harder as the fruit become less plasticized and produce crispy sheets in higher temperature (Jafari et al., 2015). Based on similar finding by Maskan (2000), higher drying temperature caused the texture of dried fruit harsher.

The higher drying rate also can correspond to harder surface of the sample as temperature increased. It is known as case hardening by migration of the soluble solids to the surface of the samples as water evaporates during drying (Orikasa et al., 2008). During beginning of drying process, the formation of crust on the surface of fruit can occur due to high moisture content gradient in which harden the texture of fruit by high temperature (Katekawa & Silva, 2007).

At temperature 50 °C, the significance different exist between OV and the other two drying methods at $p<0.05$. While for cabinet and rotary dryer at 50 °C there were also significant difference with oven dryer at 60 °C as the force implied on sample during drying at 50 °C was harder than oven. This may due to heat capacity and air movement by the efficiency of the dryer as discussed earlier. As the source of air for CB and RD was hot air, it probably caused the surface of the texture become firm and hard to cut by knife blade during analysis.

Chewiness of Manis Terengganu melon

Chewiness or toughness was analyzed by texture analyzer in terms of energy required to masticate a solid food and the value was determined by total positive area under the curve (Chong et al. 2008). Higher value of area under the curve indicates a higher amount of energy needed to perform the test.

Fig. 4 shows the value of chewiness for fresh, treated OD and dried sample at different temperatures and drying methods. There was significance different of chewiness at $p<0.05$ between fresh and dried sample at temperature 40 °C, 50 °C and 60 °C by different drying methods with 29 to 39% increment.

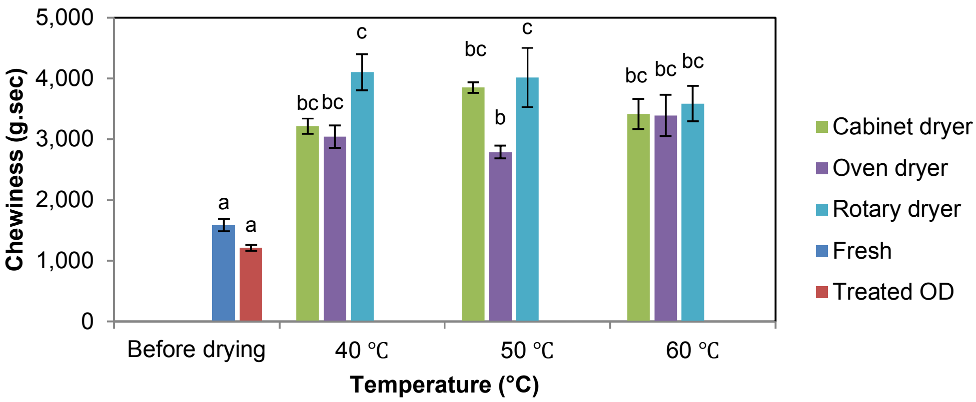

Fig. 4. Chewiness of fresh, treated OD and dried sample at different temperature and drying methods. Means with same lower case letter at different temperatures do not differ significantly at $p \leq 0.05$

The significance different occur between oven dryer at 50 °C and rotary dryer at 40 °C and 50 °C. This is might due to long duration of drying for oven thus results in high ability to chew the dried sample. Hence, sample dried by oven at 50 °C produce better chewy texture than sample dried by rotary dryer at 40 °C and 50 °C. This is possibly caused by the slow heat applied by the oven, thus reducing the hardness of dried sample as it influences the energy need to cut by knife blade.

Compared to rotary dryer performance, rapid drying due to high drying rates may affect the chewiness and more energy needs to perform texture test. However, this resultcontrast with finding by Chong et al. (2008), where the dehydrated of chempedak at 50 °C and 60 °C gives better chewiness product although by instrumental analysis shown no significant different at $p<0.05$ but relatively significant compared to sample dried at 70 °C. This finding can be concluded that the dried fruit at too high temperature may cause the difficulty to chew as relate to hardness of fruit.

Browning measurement

In food processing especially drying processing, browning effect on the dried sample is a factor to determine the quality changes after drying in terms of appearance, flavor and nutritive value. For dried fruit, browning reaction gives undesirable effect as it may result in off-flavor and dark in color which could influence the consumer acceptance (UNIDO, 2014).

Rate of browning reaction depends on a few factors such as drying temperature, pH and moisture content of the product, time of treatment and the concentration and nature of reactant used on the products (Nie et al., 2013). Table 2 shows the intensity of browning for dried sample assessed at absorbance 420 nm.

The results showed that there was significant difference at $p<0.05$ for cabinet dryer between CB40, CB50 and CB60 but there was no significance different between CB50 and CB60. For oven dryer, OV60 had significant difference with OV40 and OV50 with 0.087of browning intensity while for rotary dryer, the sample dried at three different temperatures had been shown significantly difference among them at $p<0.05$. As the temperature increases, the absorbance value of browning intensity also increases due to Maillard reaction by the formation of brown polymers formed during drying (Raju et.al., 2006; Tamanna & Mahmood, 2015).

Table 2. Browning absorbance (A_{420}) of dried sample at different temperatures and drying methods

Methods	Temperature (°C)	A_{420} (nm)
Cabinet drying (CB)	40	0.050 ± 0.012^{a}
	50	0.071 ± 0.003^{b}
	60	0.073 ± 0.013^{b}
Oven drying (OV)	40	0.048 ± 0.003^{a}
	50	0.050 ± 0.004^{a}
	60	0.087 ± 0.003^{bc}
Rotary drying (RD)	40	0.038 ± 0.005^{a}
	50	0.101 ± 0.005^{c}
	60	0.136 ± 0.009^{d}

The values indicate mean ± standard deviation from three replications. Values within the same column with similar letters are not significantly different.

These results indicate the occurrence of non-enzymatic reaction on dried sample. The highest browning value was sample dried with rotary dryer at 60 °C as the mean value of absorbance increased by 72% when temperature raised from 40 °C to 60 °C. Based on research by Udomkun et al. (2015), the higher the drying temperature induced the browning rate of papaya samples and the mean value for degree of browning at absorbance 420 nm increased by 26% when the temperature increased from 50 °C to 80 °C.

The production of browning on the surface of compound can occur through enzymatic or non-enzymatic process. The reaction of enzymatic occur when the enzyme of polyphenoloxidase in fruit come into contact with endogenous phenolic compounds during drying process (Udomkun et al., 2015). Non-enzymatic browning can be divided into three categories which are Maillard reaction, caramelization and ascorbic acid oxidation (Sumnu & Ozkoc, 2011). However, most of dried fruit cases have been involved in two categories; Maillard reaction or ascorbic acid oxidation since caramelization involved the degradation of sugars in absence of amino acids under anhydrous conditions with heat. Ascorbic acid oxidation may become the agent of browning to dried sample. Oxidation of ascorbic acid involved during discoloration of dehydrated samples by the formation of dehydroascorbic acid and diketogluconic acids from ascorbic acid. It is capable to interact with free amino acids by producing red-to-brown discoloration UNIDO (2014).

Furthermore, Queiroz et al. (2011) reported that the formation of brown pigments after drying may due to oxidation of phenolic and ascorbic acid. Thus, in this browning measurement, the browning intensity by absorbance value greatly affected when increasing the temperature to 60 °C although different drying methods have been used. Although temperature 60 °C was used for each drying methods, the mean of absorbance value of RD60 was highly significance difference between OV60 and CB60. This could be due to the rotation of rotary dryer that influenced the air movement during drying by initiating the browning reaction faster than cabinet dryer and oven dryer.

The time for Maillard browning can be minimized through rapid drying by the range 15 to 20% of moisture (Kadam et al., 2008). Other than that, the non-enzymatic browning could be influenced by low water activity of RD60 because based on Sagar and Suresh (2010), browning effect become more severe when the moisture level of the sample is low and less evaporative rate take place at the end of drying period.

CONCLUSION

From this research, the suitable drying methods for preservation of Manis Terengganu melon was identified and drying temperature influenced the drying time and drying rate of dried immature Manis Terengganu melon. The higher temperature used for drying, the less time taken to achieve constant level of for moisture content and the higher drying rates occurred. Based on drying time and drying rates, rotary dryer was the best drying method at three different temperatures followed by cabinet dryer and oven dryer. In terms of energy consumption, the less drying time is important especially for industrial purpose since the large production of products need to be achieved at short time in a way to implement cost-efficiency products. The texture properties of dried Manis Terengganu melon in terms of hardness and chewiness are important in producing and maintaining quality of products. In a way to produce good quality of dried fruits, the softer texture is preferred rather than harder texture. For chewiness of dried fruit, sample dried by oven at 50 °C produce better chewy texture than sample dried by rotary dryer at 40 °C and 50 °C. The results obtained are useful in the determination of the suitability of equipment and operating parameter that can be used in drying process to reduce the number of food waste and develop new product.

ACKNOWLEDGMENTS

Financial support from the University Research Grant of Universiti Sultan Zainal Abidin (UniSZA/ 2017/DPU/59) is gratefully acknowledged.

REFERENCES

Agnelli, M. E. (2012). Air and Osmotic Partial Dehydration, Infusion of Special Nutrients. In R. O. Mascheroni (Ed.), Operation in Food Refrigeration (p. 203). Boca Raton: CRC Press.

Anonymous. (2016). *Health Benefits of Cantaloupe: Organic Facts*. Retrieved from https://www.organicfacts.net/health-benefits/fruit/health-benefits-of-cantaloupe.html.

Anonymous. (2016). Melon Manis Terengganu. Terengganu Agrotech Development Corporation. Retrieved from http://www.melonmanisterengganu.com.my/hubungi_kami.html.

AOAC. (2000). Official Method of Analysis. 17th Edition. Association of Official Analytical Chemistry, Washington.

Aral, S., & Beşe, A. V. (2016). Convective drying of hawthorn fruit (Crataegus spp.): Effect of experimental parameters on drying kinetics, color, shrinkage, and rehydration capacity. *Food Chemistry*, 210, 577-584.

Arevalo-Pinedo, A., & Murr, F. E. X. (2005). Kinetics of vacuum drying of pumpkin (*Cucurbita maxima*): Modeling with shrinkage. *Journal of Food Engineering*, 76(4), 562-567.

Sablani, S. S., Kasapis, S., & Rahman, M. S. (2007). Evaluating water activity and glass transition concepts for food stability. *Journal of Food Engineering*, 78(1), 266-271.

Chen, X. D. & Mujumdar, A. S. (2008). *Drying technologies in food processing (1st ed.).* Oxford: Blackwell Pub.

Chong, C. H., Law, C. L., Cloke, M., Hii, C. L., Abdullah, L. C., & Daud, W. R. (2008). Drying kinetics and product quality of dried Chempedak. *Journal of Food Engineering*, 88 (4), 522-527.

Dias da Silva, G., Barros, Z. M., De Medeiros, R. A., De Carvalho, C. B., Rupert Brandão, S. C., & Azoubel, P. M. (2016). Pretreatments for melon drying implementing ultrasound and vacuum. *LWT - Food Science and Technology*, 74, 114-119.

Doymaz, I., & Ismail, O. (2011). Drying characteristics of sweet cherry. *Food and Bioproducts Processing*, 89, 31–38.

Elizabeth, M. (2016, August 31st). *wise GEEK. What is Drying Oven?.* Retrieved from http://www.wisegeek.com/what-is-a-drying-oven.htm.

Earle, R. L. (1983). *Unit Operations in Food Processing*. Retrieved from http://www.nzifst.org.nz/unitoperations/ drying5.htm.

Harrison, J. A., & Andress, E. L. (2017). *Preserving of drying fruits and vegetables (0700*). Retrieved from University of Georgia Cooperative Extension Service website: http://nchfp.uga.edu/publications/uga/ uga_dry_fruit.pdf

Hui, Y. H., In Evranuz, E. O., & Hui, Y. H. (2012). *Handbook of plant-based fermented food and beverage technology*. New Jersey, US: Wiley Publishers.

Jafari, S.,Azizi, D., Mirzaei, H., & Dehnad, D. (2015). Comparing Quality Characteristics of Oven-Dried and Refractance Window-Dried Kiwifruits. *Journal of Food Processing and Preservation*, 40(3), 51-56

Kadam, D.M., Samuel, D.V.K., Chandra. P., Sikarwar, H.S. (2008) Impact of processing treatment and packaging material on some proteins of stored dehydrated caulifl ower. *International Journal of Food Science Technology*, 43(1), 1-14

Katekawa, M. E., & Silva, M. A. (2007). Drying rates in shrinking medium: case study of banana. *Brazilian Journal of Chemical Engineering*, 24(4).

Kaushal, P., & Sharma, H. (2016). Osmo-convective dehydration kinetics of jackfruit (Artocarpus heterophyllus). *Journal of the Saudi Society of Agricultural Sciences*, 15(2), 118-126.

Kek, S., Chin, N., & Yusof, Y. (2013). Direct and indirect power ultrasound assisted pre-osmotic treatments in convective drying of guava slices. *Food and Bioproducts Processing*, 91(4), 495-506.

Lembaga Pemasaran Pertanian Persekutuan. (2012). *Kualiti Rock Melon Berpandukan Malaysian Standard MS1325:2012*. Retrieved from http://www.fama.gov.my/documents/10157/6c10d802-62ee-48fa-aae768b07d40e5ea.

Maskan, M., (2000). Microwave/air and microwave finish drying of banana. *Journal of Food Engineering,* 44, 71–78.

Nie, S., Huang, J., Hu, J., Zhang, Y., Wang, S., Li, C., Xie, M. (2013). Effect of pH, temperature and heating time on the formation of furan in sugar–glycine model systems. *Food Science and Human Wellness*, 2(2), 87-92.

Okos, M. R., Narsimhan, G., Singh, R. K., Weitnauer, A.C.(1992). *Food Dehydration, Handbook of Food Engineering*. Ed. D.R. Heldman and D. B. Lund, New York: Marcel Dekker Inc.

Orikasa, T., Wu, L., Shina, T. & Tagawa, A. (2008). Drying characteristics of kiwifruit during hot air drying. *Journal of Food Engineering*, 85, 303–308.

Parikh, D. M. (2014). *Solids Drying: Basics and Applications - Chemical Engineering*. Retrieved from http://www.chemengonline.com/solids-drying-basics-and applications/?printmode=1.

Parnell, T. L., Suslow, T., & Harris, L. J. (2003). *Cantaloupe: Safe method to store, preserve and enjoy*. Retrieved from University of California: Division of Agriculture and Natural Resources. http://anrcatalog.ucanr.edu/ pdf/8095.pdf.

Phisut, N., & Jiraporn, B. (2013). Characteristics and antioxidant activity of Maillard reaction products derived from chitosan-sugar solution. *International Food Research Journal*, 20(3), 1077–1085.

Phungamngoen, C., Chiewchan, N., & Devahastin, S. (2013). Effects of various pretreatments and drying methods on Salmonella resistance and physical properties of cabbage. *Journal of Food Engineering*, 115(2), 237-244.

Queiroz, C., da Silva, A. J. R., Lopes, M.L.M., Fialho, E. & Valente-Mesquita, V.L., (2011). Polyphenol oxidase activity, phenolic acid composition and browning in cashew apple (*Anacardium occidentale, L.*) after processing. *Food Chemistry*, 125, pp.128–132.

Raju, P. S., Bawa, A. S., & Sinha, N. K. (2006). *Food additives in food processing*. In Y. H. Hui, J. Barta, P. Cano, T. W. Gusek, & J. S. Sidhu (Eds.), Handbook of Fruits and Fruit Processing. Iowa: Blackwell Publishing.

Ross, C. (2017). *Vertical blender/dryers deliver high drying rates with negligible risk of product attrition (21)*. Retrieved from Charles Ross & Son Company website: http://www.mixers.com/insights/mti_vb_21.pdf

Sagar, V. R., & Suresh, K.P. (2010). Recent advances in drying and dehydration of fruits and vegetables: A review. *Journal of Food Science and Technology*, 7(1), 15–26.

Saravacos, G.D. & Kostaropoulus, A.E. (2002). Food Dehydartion Equipment. In G.D. Saravacos & A.E. Kostaropoulus, *Handbook of Food Processing Equipments* (p. 356). New York: Plenum Publishers.

Sumnu, S. G., & Ozkoc, S. O. (2011). *Infrared baking and roasting*. In Z. Pan & G. G. Atungulu (Eds.), Infrared heating for food and agricultural processing (p. 215).: Boca Raton., NY: CRC Press.

Tamanna, N., & Mahmood, N. (2015). Food Processing and Maillard Reaction Products: Effect on Human Health and Nutrition. *International Journal of Food Science*, 1-6.

Udomkun, P., Nagle, M., Mahayothee, B., Nohr, D., Koza, A., & Müller, J. (2015). Influence of air drying properties on non-enzymatic browning, major bio-active compounds and antioxidant capacity of osmotically pretreated papaya. *LWT - Food Science and* Technology, 60(2), 914-922.

UNIDO. (2014). *Quality of dried foods and deteriorative reactions during drying (31)*. Retrieved from http://www.unido.org/fileadmin/import/32142_31QualityofDriedFoods.14.pdf.

Yadav, A. K., & Singh, S. V. (2014). Osmotic dehydration of fruits and vegetables: a review. *Journal of Food Science and Technology*, 51(9), 1654–1673.

Zhu, A., & Shen, X. (2014). The model and mass transfer characteristics of convection drying of peach slices. *International Journal of Heat and Mass Transfer*, 72, 347–351.

How to cite this paper:
Muhamad, N. & Mohd Redzuan, N. A. (2019). Effects of different drying methods and quality parameters on dried manis Terengganu melon (*Cucumis melo*). *Journal of Agrobiotechnology, 10*(1S), 46-58