Quality Retention of Microwave Dried Pineapple Core and Peels

Siti Fabilah binti Ismail and Nurul Asyikin Md Zaki

Faculty of Chemical Engineering, Universiti Teknologi Mara

***Abstract*— The purpose of this research is to study the effect of microwave power on the drying characteristics of pineapple peels and core. This research is also done to evaluate the total phenolic content and antioxidant activity in fresh and dried pineapple peels and core. The pineapple peels and core were dried under different microwave power (180 W, 450 W and 850 W). After that, both peels and core of fresh and dried were extracted at 50 °C for 30 minutes using ethanol solution. The extract samples were used for analysis of total phenolic content and antioxidant activity (DPPH Assay). The results showed higher microwave power led to shorter drying time, thus resulting to high drying rate. Drying kinetic for microwave showed three drying periods, i.e. i) heating period, ii) constant drying rate period and iii) falling rate period. On the other hand, dried peels and core resulted in high total phenolic content compared to fresh ones. Dried peels and core exhibited 19.8 mg GAE/ g dry sample and 21.3 mg GAE/ g dry sample, respectively at microwave power of 180 W and 850 W. Furthermore, dried peels and core were also found to be potentially scavenged radical molecules. Dried core at 180 W revealed to be a good extraction to scavenge free radical as it was achieved around 74 % of DPPH inhibition. From forgoing results, microwave drying can be a good process to be practiced in food preservation as it helps improved the quality of product.**

Keywords*— *antioxidant, core, drying, microwave, peels, pineapple, total phenolic content.

I. INTRODUCTION

Malaysia is a country with a vibrant tropical climate where year – long heat and abundant rainfall permit a wide variety of delicious fruits to flourish. Some of the fruits such as durian, mangosteen, papaya, rambutan and the host of fruits were introduced to the country many years ago. Pineapple or *Ananas comosus* is one of the familiar fruits among citizens in Malaysia and the world especially in the country of Costa Rica, Brazil, Philippine, Thailand etc. as they are the largest countries of producing the pineapple crops. In Malaysia, this kind of fruit is well-liked in Pontian, Johor and commonly used in the food industry as food product. Pineapple has been widely consumed as jam, juice, canned fruits, dried fruits and fresh fruit.

Pineapple is an excellent source of vitamin A, B and C. It is also contain minerals like calcium, manganese, iron and phosphorus. People normally consume a pineapple juice because of high nutritional content. Apart from that, traditionally, pineapple juice has been practice to cure sore throats and seasickness. The presence of compound such as ascorbic acid, polyphenols, caffeic acid, flavonoids etc. contribute to the antioxidant activity in the fruit extract. However, the processing of pineapple juice will produce pineapple waste. The waste of pineapple includes peel, core, crown, bottom and trimming. These wastes are known as by-product of pineapple which commences about 70% of total pineapple weight and 50% of them are solely from pineapples cores and outer peel (Rashad, Mahmoud, Ali, Nooman & Al-Kashef, 2015). This wastes disposal may cause serious problem to environment especially to soil or landfill and lead to microbial spoilage. These wastes also can cause air pollution because the wastes have been disposed through open burning. In addition, the untreated liquid pineapple waste is discharges as effluent into the river eventually contributes to the decreasing of pH and BOD leading to bad odors and no doubt lead to change in the ecosystem and undeniably pose serious environment problems. Thus, the utilization of pineapple waste into value added product may be an innovative solution to the environmental waste problem.

Zainuddin, Shamsudin, Mokhtar and Ismail (2014) indicated that pineapple waste can be converting into animal feed by densification process. On the other hand, Roda, De Favera, Giacosa, Dordoni and Lambri (2016) stated that researchers used the wastes to study on the extraction of bromelain enzyme and as a low cost of raw material for the production of phenolic antioxidant, organic acids, bioethanol, biogas and fibre. However, the pineapple residues have high moisture content level that can cause the degradation of nutritional values and exhibit the growth of microorganism which can led to food spoilage. To prevent the degradation of their sensorial properties and bioactive compound, drying method is used to remove the water content.

Drying is one of the most effective techniques used to preserve food products normally fruits and vegetables. Drying is a process that related with the removal of small amount of water or liquid from materials. The reduction in moisture content resulting the inhibition of spoiled microorganism such as bacteria, mold and fungi. Apart from that, drying can avoid the deterioration of food nutrients and decrease the enzymatic activity. According to Lüle and Koyuncu (2015), drying food product makes the process handling, transportation and storage easier due to the volumetric shrinkage and weight losses during process.

Properly selected drying method of the raw material may increase the quality of product. Microwave drying is one of the methods used to preserve food. Microwave is a propagation of electromagnetic energy through space by means of time-varying electric and magnetic field (Wani & Khot, 2014). Microwave heating is specifically connected with dielectric loss of the material. When high frequency electric field is introduced, a material will absorb the energy. Subsequently, electric dipole polarization and conduction will be created inside a dielectric material made of positive and negative polar molecules. These organized scattered polar molecules vibrate promptly and aggressively in response to the high-frequency electric field of the microwave (Rattanadecho & Makul, 2016). Resistance to molecular attraction and motion must be overcome. The temperature of the material increments as friction produces heat.

Microwave drying has several advantages such as high drying rate and short drying time (Moghanaki, Khoshandam & Mirhaj, 2013; Lüle & Koyuncu, 2015; Simha, Mathew & Ganesapillai, 2016). Under microwave drying, internal heat helps increase the internal temperature and vapor pressure, then cause the liquid flow towards the surface, resulting in increasing the drying rate and shorten the time as well as improved the quality of the product

(Seremet, Botez, Nistor, Andronoiu & Mocanu, 2016). Other advantages includes instantaneous and precise electronic control, deep penetration of microwave energy that allows heat to be generated efficiently and cleaning heating processes do not generated secondary waste (Rattanadecho & Makul, 2016).

Previous studies revealed that microwave application can improve product qualities such as aroma, phenolic compound and antioxidant activity due to the disruption of cell wall (Inchuen *et al.,* 2010; Izli, 2016). The quality of dried product is strongly depend on the conditions in the drying process. It is of interest to investigate the effect of microwave properties on the quality of the pineapple wastes (core and peels) especially the beneficial phenolic compound and antioxidant activity of the dried pineapple wastes. Thus, the objective of the present study was to evaluate the effect of microwave power on the characteristic of pineapple wastes including total phenolic content and antioxidant activity.

II. METHODOLOGY

A. Materials

Fresh Josephine pineapple (*Ananas comosus L)* fruits were purchased from local market in Shah Alam. The pineapples were peeled and cored to obtain pineapple wastes and separated from edible flesh. The pineapple peels and core were washed with tap water before dried with tissue. The pineapple peels and core were sliced to small pieces by knife. Peels and core weighing around 100 g were used under each experimental condition.

B. Chemical and Instruments

The chemicals such as 2, 2-diphenyl-1-picrylhydrazyl (DPPH), Folin-Ciocultae reagent from Merck, sodium carbonate (Na_2CO_3), ethanol and gallic acid from Sigma-Aldrich were obtained from laboratory storage.

The drying process was carried out in microwave (SAMSUNG, Model M183GN, Thailand). The UV-Vis Spectrophotometer (SECOMAM) was used to read the absorbance value.

C. Microwave Drying Procedure

Different microwave powers were determined as 180, 450 and 850 W in drying experiments at constant sample loading density. An aluminum plate, containing the sample was set at the center of microwave. In all the drying experiments, 100 g of pineapple core and peel were utilized. The samples were consistently spread on the plate inside microwave during treatment for an even assimilation of microwave energy. Moisture losses were recorded at 60 seconds intervals during drying for determination of drying curves by weighing balance. Pineapple core and peels were dried until 10 % of wt basis moisture content of themselves left. All the data were recorded for the used in the calculation later.

D. Dry Matter Procedure

The pineapple core and peels were weighed of about 100 g each into the aluminium tray. The sample was spread uniformly on the tray. The tray containing the sample was placed in the center of oven for 24 hours at 60 ºC. After 24 hours, the sample was taken out and weighed. The steps were repeated until 3 times constant weight is achieved. The weight stops changing when all the water is out of the sample. The final dry weight was recorded.

E. Mathematical Modeling of the Drying Curve

The moisture content and drying rate of pineapple core and peel were calculated using the following equations:

$$Moisture\ content = \frac{W_i - W_e}{W_e}$$

$$Drying\ rate = \frac{M_{t+dt} - M_t}{dt}\ x\ 100\ \%$$

Where;
W_i = Weight sample at any time
W_e = Weight dry matter
M_{t+dt} = Moisture content at t+dt (kg H_2O/ kg dry matter)
M_t = Moisture content at t (kg H_2O/ kg dry matter)
dt = Time interval (s)

F. Extraction Procedure

Sample extraction was performed according to the method proposed by Arslan and Özcan (2011) with some modification. Approximately 1 g of peels of 180 W was weighed and 20 mL of ethanol was added. Both of the sample and ethanol were placed in a universal bottle. Then, the bottle was placed in an ultrasonic bath at 50 °C for 30 minutes. The mixture was filtered and the supernatant was transferred into a new universal bottle for analysis. The steps were repeated using another samples (Peels: 450W and 850 W; Core: 180 W, 450 W and 850 W). The evaluation of the phenolic compounds and the antioxidant activity was performed for each power level.

G. Total Phenolic Content (TPC)

The total phenolic compound was determined using the Folin-Ciocalteu method by Alfaro, *et al.,* (2014) with some modification. The extract samples (0.5 mL) were mixed with 2.5 mL of Folin-Ciocalteu reagent. Then, 2.5 mL of 7.5 % Na_2CO_3 was added to the reaction mixture, which was maintained at room temperature for 30 min in darkness. The gallic acid was used as standard. The absorbance was measured at 765 nm using a UV-Vis spectrophotometer, and the results were expressed as mg of gallic acid equivalent (GAE) per gram of dry weight (d.w.).

H. Antioxidant Activity by DPPH Assay

The antioxidant activities of the dried pineapple core and peel using DPPH assay was determined using the method by Yuris (2014) with some modifications. The DPPH solution was prepared by adding 10 mg DDPH into 100 mL of ethanol. Then, for sample analysis, 1 mL of extracts of pineapple core and peel at various condition were mixed with 1 mL ethanolic DPPH solution and 4 mL of ethanol. The sample was shaken and left in a dark to stand for 30 minutes at room temperature before reading the absorbance at 517 nm. The ethanol was used as the blank. Control was prepared using 4 mL of the ethanol mixed with 1 mL of DPPH. The inhibitory percentage of DPPH was calculated according to the following equation where A is absorbance:

$$\%\ inhibition = \frac{A_{control} - A_{sample}}{A_{control}}\ x\ 100\%$$

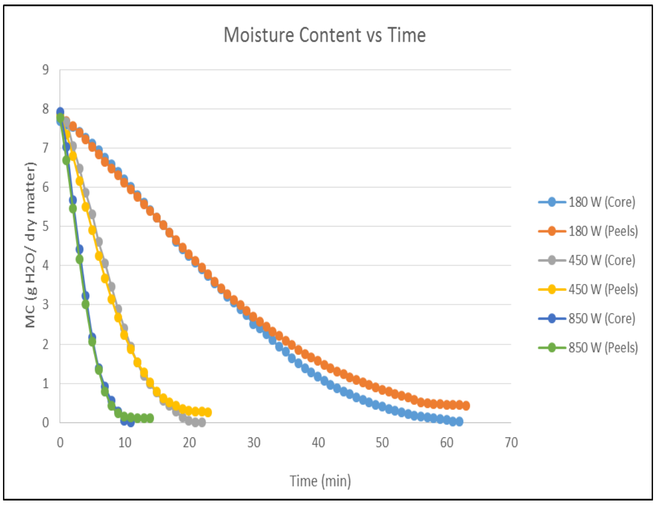
III. RESULTS AND DISCUSSION

A. The Effects of Power Level on Drying Rate

The moisture content and drying rate curve of the pineapple peels and core at different power level were illustrated in the Figure 1 and Figure 2, respectively.

Figure 1: Moisture Content of Pineapple Core and Peels at Different Power Level

Figure 1 showed the drying curves of pineapple peels and core under the three investigated power (180 W, 450 W and 850 W). The results showed the moisture content was inversely proportional to the drying time means that the moisture content during



microwave drying process decrease with time which was in compliance with the nature of drying characteristic of various fruits and vegetables. As illustrated in Figure 1, all the investigated power had similar pattern of drying rate. It can be seen that the power can manipulate the moisture content. A power level of 850 W provided a higher drying rates compared to microwave power at 180 W and 450 W. The pineapple core and peels at 850 W required only 11 minutes and 14 minutes to remove the moisture from the material, respectively. Meanwhile, both peels and core at 180 W and 450 W completed the drying process around 60 minutes and 20 minutes, respectively.

At higher power level, more microwave energy is produced, resulting the temperature of pineapple peels and core increased and then enhanced the evaporation rate inside the peels and core. The internal heat from microwave helps increase the internal temperature and vapor pressure, then cause the liquid flow towards the surface, resulting the mass transfer rate of the pineapple peels and core increased rapidly and reduced the drying time as well as improved the quality of product (Seremet *et al.,* 2016). Similar resulted was reported by Paengkanya, Soponronnarit and Nathakaranakule (2015) which using microwave vacuum (MWVC) and combined microwave-hot air drying method. Monteiro, Carciofi and Laurindo (2016) also testified that the higher microwave power resulted in lower drying times.

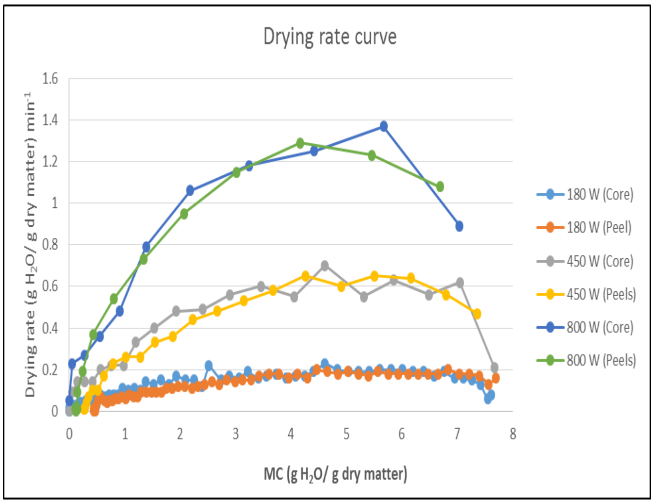


Figure 2: Drying rate curve of pineapple peels and core at different power

Figure 2 showed the good reproducibility of the drying rates curves resulted from all investigated power level of microwave drying. From the figure, it showed a variation of drying rate with moisture content for power of 180 W, 450 W and 800 W. Based on the figure, two period can be distinguished clearly. The first is called constant drying rate period and the second period is falling drying rate.

The drying rates of 450 W and 800 W increased continuously before decreased. This behavior showed drying of pineapple peels and core took place in falling period and there was not any constant rate period. The moisture content of the samples were very high during the initial phase of the drying which resulted in high drying rates due to the high moisture diffusion. According to Arslan and Özcan (2011), the falling drying rate period takes place resulting from the predominance of internal diffusion mechanism because of the presence of bound water. During the initial part of the falling drying rate period, water in larger capillaries is removed first then followed by water in smaller capillaries which resulting in a reduction in the rate of evaporation. Water highly bound to sites of water-holding components for example protein and starch which is removed at the end of drying process and thus water extraction becomes more difficult and drying rate decreases as the drying time progresses. Similar finding was reported in previous study by Darvishi *et al.,* (2013).

Meanwhile, both pineapple peels and core drying rates at 180 W showed different behavior compared to other power. It can be observed that the drying rate is constant along the moisture content. The constant drying period was well-marked for peels and core at 180 W, representing the major amount of water evaporation. Here, microwaves converted into thermal energy providing the latent heat of vaporization of free water. According to Lüle and Koyuncu (2015), the rate of moisture removal is mostly dependent on the surrounding conditions and only effected slightly by the nature of the product. A heating period also shown in the drying of pineapple peels and core at 450 W and 800 W. The minor water was loss where conversion of microwave energy into thermal energy took place within the moist material that increases its temperature.

Hence, it can be said that the samples are very responsive to microwave application and will absorb the microwave energy quickly and efficiently as long as there is residual moisture. The microwave applications for drying therefore offer a distinct advantage, i.e. high drying rate and short drying time (Moghanaki, Khoshandam & Mirhaj, 2013; Lüle & Koyuncu, 2015; Simha, Mathew & Ganesapillai, 2016). However, one of the disadvantage of this drying method is the lack of temperature control (Arslan and Özcan, 2011).

B. *Total Phenolic Compound*

The total phenolic content (TPC) is normally measured using Folin-Ciocultae reagent method and the absorbance is read at 765 nm using UV-Vis Spectrophotometer. The intensity of the blue color reflects the quantity of phenolic compound in plants, fruits or vegetables.

The total phenolic content in dried pineapple core and peels obtained by microwave drying at different power level were shown in Table 1 and illustrated into the chart in Figure 3. The result of dried core and peels were significantly different than the values recorded by fresh pineapple peels and core. The microwave drying had a positive effect by increasing the TPC in dried pineapple core and peels.

Table 1: Total phenolic content in pineapple peels and core.

Sample	mg GAE/ g dry sample	
	Peels	Core
Fresh	4.2	3.0
180 W	19.8	19.3
450 W	16.7	11.2
850 W	18.7	21.3

All dried peels and core exhibited higher phenolic content compared to fresh peels and core. The dried peels exhibited highest phenolic content (19.8 mg GAE/ g dry sample) at 180 W. Meanwhile, dried core exhibited its highest phenolic content (21.3 mg GAE/ g dry sample) at 850 W. In contrast, the fresh peels and core found to exhibit 4.2 mg GAE/ g dry sample and 3.0 mg GAE/ g dry sample of phenolic content, respectively.

Inchuen *et al.,* (2010) reported that microwave drying gave higher value of phenolic compound. The result also supported by Da Silva *et al.,* (2013) by stating that the phenolic content was increase after drying process. This behavior can be explained by liberation of phenolic compound during drying process. The authors explained that most fruits and vegetables outer layer contain large amount of phenolic compound to protect inner materials. In other words, phenolic compound occur in plants as the metabolic intermediates and normally accumulate in the vacuoles. It is assumed that more bound phenolic compound is releasing during food processes due to the breakdown of cellular constituents. Although, the disruption of cell wall may exhibit oxidative and hydrolytic enzyme that could destroyed antioxidant activity, but high power of drying process can counter back by deactivate the enzymes and prevent the loss of phenolic compound and thus, resulting to the increase of total phenolic compound.

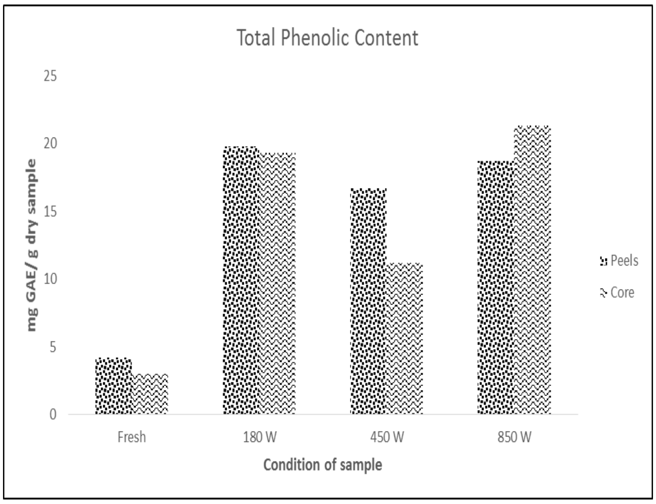


Figure 3: Total phenolic content of peels and core

Similar reason was found by Izli (2016), stated that the increase in phenolic compound in dried samples may occur because of intense heat from microwave created high vapor pressure and temperature inside the plant tissue causing the disruption of cell wall. In addition, it can be explained that increasing in total phenolic compound due to the degradation of complex phenolic tannins by heat and enzymatic or non-enzymatic oxidation which caused more phenolic to be extracted. Apart from that, these results could be explained by the formation of Maillard reaction product, which caused the new formation of phenolic from precursor during thermal treatment (Sultana *et al.,* 2012). However, some authors (Barroca *et al.,* 2013; Rababah *et al.,* 2015) found that the heat treatment can decrease the phenolic compound during thermal processing. Thus, the effect of drying methods on phenolic compound from different material may not be the same.

C. *Antioxidant Activity*

The analysis of antioxidant activity was conducted by using DPPH assay. DPPH assay is used to measure the ability of certain extract phytochemicals to scavenge free radicals. It is a useful analysis to understand whether the antioxidant enriched extract can block the oxidation initiation phase by the ability to neutralize or inhibit the formation of radical species. DPPH assay is used because of it is less expensive, rapid and simple assay which do not involve with many steps and reagents. DPPH is useful in examination of antioxidant activity for a quick estimation and preliminary data of radical scavenging capabilities as it is sensitive and requires a little specimen amounts.

The results of scavenging activity of the sample at different condition were tabulated in the Table 2 and the demonstrated into bar chart in Figure 4.

Table 2: DPPH inhibition of peels and core at different condition

Sample	**Inhibitory Percentage of DPPH (%)**	
	Peels	**Core**
Fresh	57.93	65.50
180 W	74.54	53.32
450 W	63.10	49.82
850 W	50.55	48.34

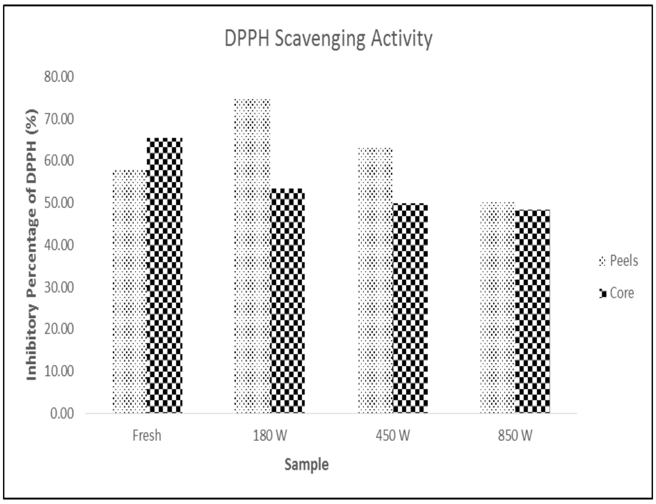


Figure 4: The DPPH radical scavenging activity

Based on Figure 4, a gradual decrease in the scavenging activity is observed as the power level of microwave is increased. Based on the power level, the scavenging activity reached maximum of 74% for pineapple peels and 53% for pineapple core at 180 W of power level. However, the resulted of fresh pineapple peels and core showed vice versa. For pineapple core, the fresh sample reached the maximum scavenging activity around 65% which was the highest radical inhibition between core samples. Meanwhile, fresh pineapple peels only inhibit 58% radical species which is lower compared to pineapple peels of 180 W. Among the samples, the 180 W of pineapple peels revealed to be a good extraction to scavenge free radical as it given the highest value. Clearly, there were more antioxidant activity present in the pineapple peels in 180 W compared to other samples, which could react rapidly with DPPH radicals and reduced almost DPPH radical molecules corresponding to available hydroxyl groups.

The decrease in the DPPH inhibition of pineapple peels and core treated by microwave drying discussed herein is not a distinctive behavior reported for other plants. According to Arslan and Özcan (2011), the DPPH free radical scavenging capacity is increased when using high output energy. Inchuen *et al.,* (2010) also reported the similar resulted. They revealed that an improvement in antioxidant activity is achieved when high microwave output power is used as the contact drying time is shorter. Conversely, in this study, high power level presented the lowest antioxidant activity. This occurred maybe due to decrease in product quality. High power input lead to poor quality products due to caramelisation, enzymatic reaction, pigment degradation and ascorbic acid oxidation.

IV. CONCLUSION

The drying process was found to have a significant effect on the moisture content of pineapple peels and core. Microwave drying at high power took shorter time to remove the moisture from material compared to other power. The power of 850 W only required 14 minutes and 11 minutes to dry the pineapple peels and core, respectively. Both dried peels and core found to be a positive effect on phenolic compound and antioxidant activity. The microwave application preserved both phenolic compound and antioxidant activity respect to fresh peels and core. The dried peels and core discovered to exhibit higher phenolic compound. This higher could be explained by degradation of complex phenolic tannin, thus resulting more phenolic is released. The similar pattern was found in analysis of antioxidant activity. High inhibition of DPPH radical molecule was found in dried peels at 180 W. This showed that the lower the microwave power, the higher the inhibition of DPPH radical molecules. The dried sample showed a good extraction to scavenge free radical and exhibit phenolic compound compared to fresh sample. In conclusion, microwave application found to be an effective method to preserve food as it is maintain the quality of product as well as required only shorter time.

ACKNOWLEDGMENT

First of all, I would like to eloquent my utmost appreciation to my research supervisor, Madam Nurul Asyikin Md Zaki for her kind assistance and supervision during the preparation of this project. Her encouragement, guidance, and support enabled me to develop a very detailed understanding of the subject thus ensured the smoothness and success of all the works involved. All the advisory and suggestions from her really help me a lot to do the best for my work. Besides that, I would like to show my gratitude to laboratory assistants that help me a lot during running the experiments. Their kindness and patience in assisting me during the laboratory works make me able to complete it perfectly. Also, I owe a favor to all my friends who always assisting and sharing their knowledge with me during completing this project. Last but not least, thanks to my parents for supporting me in everything that I am doing.

References

[1] Alfaro, S., Mutis, A., Quiroz, A., Segeul, I. & Scheuerman, E. (2014). Effects of drying techniques on Murtilla fruit polyphenols and antioxidant activity. *Journal of Food Research, 3(5),* 73-82.

[2] Arslan, D. & Özcan, M. M. (2011). Dehydration of red bell-pepper (*Capsicum annuum L.)*: Change in drying behavior, colour and antioxidant content. *Food and Bioproduct Processing 89,* 504-513.

[3] Barroca, M. J., Guine, R. P. F., Alves, M., Oliveira, S., Goncalves, F. J., & Correia, P. M. R. (2013). Effect of drying on the properties of pears *cv.* D. Joaquina. *SEAging SECH,* 1-6.

[4] Darvishi, H., Asl, A. R., Asghari, A., Azadbakht, M., Najafi, G. & Khodaei, J. (2013). Study of the drying kinetics of pepper. *Journal of the Saudi Society of Agricultural Science, 13,* 130-138.

[5] Da Silva, D. I. S., Nogueira, G. D. R., Duzzioni, A. G. & Barrozo, M. A. S. (2013). Changes of antioxidant constituents in pineapple *(Ananas comosus)* residue during drying process. *Industrial Crops and Products, 50,* 557-562.

[6] Inchuen, S., Narkrugsa, W., & Pornchaloeempong, P. (2010). Effect of drying methods on chemical composition, color and antioxidant properties of Thai red curry powder. *Nat. Sci., 40*, 142-151.

[7] Izli, G. (2016). Total phenolics, antioxidant capcity, colour and drying characteristic of date fruit dried with different method. *Food Sci. Technol, Campinas, 37(1),* 139-147.

[8] Lüle, F. & Koyuncu, T. (2015). Convective and microwave drying characteristics of sorbus fruits *(Sorbus domestica L.). Procedia-Social and Behavioral Sciences, 195,* 2634-2643.

[9] Moghanaki, S. K., Khoshandam, B. & Mirhaj, M. H. (2013). Calculation of moisture content and drying rate during microwave drying. *Applied Mechanics and Materials, 423-426,* 746-749.

[10] Monteiro, R. L., Carciofi, B. A. M., & Laurindo, J. B. (2016). A microwave mlti-flash drying process for producing crispy bananas. *Journal of Food Engineering, 178,* 1-11.

[11] Paengkanya, S., Soponronnarit, S., & Nathakaranakule (2015). Application of microwaves for drying of durian chips. *Food and Bioproducts Processing, 96,* 1-11.

[12] Rababah, T. M., Al-u'datt, M., Alhamad, M., Al-Mahasneh, M., Ereifej, K., Andrade, J., Altarifi, B., Almajwal, A. & Yang, W. (2015). Effects of drying process on total phenolics, antioxidant activity and flavoid contents of common Mediterranean herbs. *Int. J Agric & Biol Eng, 8(2),* 145-150.

[13] Rashad, M. M., Mahmoud, A. E., Ali, M. M., Nooman, M. U., & Al-Kashef, A. S. (2015). Antioxidant and anticancer agents produced from pineapple waste by solid state fermentation. *International Journal of Toxicological and Pharmacological Research, 7(6),* 287-296.

[14] Rattanadecho, P. & Makul, N. (2016). Microwave-assisted drying: A review of the State-of-the-Art. *Drying Technology, 34(1),* 1-38.

[15] Roda, A., De Favera, D. M., Giacosa, S., Dordoni, B. & Lambri, M. (2016). Effect of pre-treatment on the saccharification of pineapple waste as a potential source for vinegar production. *Journal of Cleaner Production 112,* 4477-4484.

[16] Seremet, L., Botez, E., Nistor, O., Andronoiu, D. G. & Mocanu, G. (2016). Effect of different drying methods on moisture ratio and rehydration of pumpkin slices. *Food Chemistry 195,* 104-109.

[17] Simha, P., Mathew, M. & Ganesapillai, M. (2016). Empirical modeling of drying kinetics and microwave assited extraction of bioactive compounds from *Adathoda vasica* and *Cymbopogon citratus*. *Alexandria Engineering Journal, 55,* 141-150.

[18] Sultana, B., Anwar, F., Ashraf, M., & Saari, N. (2012). Effect of drying technique on the total phenolic content and antioxidant actiity of selected fruits. *Journal of Medical Plants Research, 6(1),* 161-167.

[19] Wani, S. D. & Khot, N. A. (2014). Microwave and its role in pharmaceutical sector: A review. *International Journal of Research and Development in Pharmacy and Life Sciences, 3(5),* 1128-1135.

[20] Yuris, A. (2014). A comparative study of the antioxidant properties of three pineapple (*Ananas comosus L)* varieties. *Journal of Food Studies, 3(1),* 40-56.

[21] Zainuddin, M. F., Shamsudin, R., Mokhtar, M. N. & Ismail, D. (2014). Effect of moisture content on physical properties of animal feed pellets from pineapple plant waste. *Agriculture and Agricultural Science Procedia, 2,* 224-230.