Pertanika J. Sci. & Technol. **19 (2)**: 389 – 396 (2011)

ISSN: 0128-7680

Effects of Different Operating Parameters in Papaya Halwa Drying

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ABSTRACT

An experimental study was performed to determine the drying characteristics of dried papaya using different drying methods. They were dried using several methods, such as sun drying, solar drying, oven drying, and microwave drying. The effects of different operating conditions on physical quality attributes were investigated. The papaya were cut into different thicknesses and cooked in sugar syrup with different sugar concentration for 24 hours. Three different temperature settings were used in oven and microwave drying. The drying curve and drying rate of each method, temperature, sample thickness and sugar concentration were studied. The drying times were found as in 6-15 minutes, 5 to 11 h, 10 to 18 h, and 14 to 23 h for the microwave, oven, sun and solar drying, respectively. The drying time increased with the increase of sample thickness and sugar concentration, as well as with the decrease of the drying temperature. In this study, quality attributes like colours and textural property of dried papaya were explored. Among the various methods of the drying characteristics of papaya halwa, oven drying was preferred with the optimum sample in 5 mm thickness and at the air temperature of 70ºC as it saved up to 40% of the drying time as compared to other methods, except microwave, and produced acceptable physical quality of product.

Keywords: Papaya halwa, drying methods, drying curves, colour, texture

INTRODUCTION

Dried fruit is becoming more popular these days due to their longer shelf life, taste, and product diversity, but most importantly, it is due to the increased awareness in consumers in avoiding chemical and food preservatives. Papaya is one of the major horticultural crops of the tropics and sub-tropics. After harvesting, the quality of papaya deteriorates easily. Drying is largely utilized to stabilize the product by reducing its moisture content. It is the oldest method of food preservation by removing water from the food. Reduction in water activity prevents the growth of micro-organisms and this consequently reduces the rate of chemical reaction (Wallace & Arsedec, 1973). The reductions in weight and volume upon drying also reduce transportation and storage costs, and for some types of food, these provide greater variety and convenience for the consumers. Drying involves heat and mass transfer which will change the nutritive quality of the product and affect the taste. Physical changes that may occur include shrinkage, puffing, and crystallization. In some cases, desirable or undesirable chemical or biochemical reactions may occur, leading to changes in colour, texture, odour or other properties of the food product (Bala *et al*., 2002). Halwa are relatively dense confections that are sweetened with sugar or honey. In Malaysia, halwa are usually made from fruits and are quite popular, especially among the Malays and Indians.

Received: 15 January 2011
Accepted: 28 March 2011
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There are different types of dryers and drying methods, each being better suited for a particular situation and are commercially used to remove moisture from a wide variety of food products. The drying method is chosen not only to obtain the required properties of the drying product, but also to meet certain requirements on the final product. The methods used for drying of food are such as sun drying, solar drying, oven drying, freeze drying, vacuum drying, microwave drying, and others (Wallace & Arsedec, 1973). Sun drying is a traditional and the oldest method, where it directly utilizes heat from the sun. Nonetheless, it has several disadvantages; for instance, the slowness of the process, risk of contamination, and total dependency on weather condition (Doymaz, 2004). It is widely used as it is efficient and economical. A solar cabinet dryer can be successfully used for drying mango, apples, figs, and other fruits (Bala *et al.*, 2002; Brenndorfer & Kennedy, 1985).

Oven drying is suitable for small-scale drying, gives good protection from insects and dust, and does not depend on weather conditions. The dry oven method is much easier, and its drying time may vary considerably, depending on the temperature variation used (Bouraoui *et al.*, 1993). Oven-dried foods are usually darker, more brittle and less flavoured compared to sun-dried product (Wallace & Arsedec, 1973). Recently, microwave drying is increasingly becoming popular in the drying of food, particularly fruit. It is more efficient and provides rapid and uniform drying compared to conventional drying methods (Wang & Chao, 2001; Maskan, 2000). One study has showed that microwave drying reduced the drying time significantly and the sensory acceptance of the microwave processed samples was much higher than that of commercial products (Yang & Atallah, 1985). However, this method may result in poor quality products if it is not applied properly (Maskan, 2001). Dried products are subject to physical characteristics, such as colour, textural properties and nutritional changes (Prachayarawarakom *et al.*, 2007). The colour changes according to sugar content, temperature, and exposure time (Doymaz, 2004). Several studies have reported that higher drying rates, obtained by higher drying temperatures, result in higher degrees of deformation of food products (Orikasa *et al.*, 2007). Thus, the aim of this study was to investigate the effect of different drying methods and operating parameters on the physical attributes of dried papaya halwa.

MATERIALS AND METHODS

Materials

Papaya Carina was used in this experiment. It was selected based on ripeness, and for this reason, half ripe papaya is an ideal choice. The fruit were cleaned and cut into slices with different thicknesses of 3, 5 and 7mm, respectively. They were boiled in water and sugar for 15 minutes to produce halwas. The halwas were dried using 4 different methods with different temperatures (for oven and microwave drying). The weight loss of the sample for sun, solar, and oven drying was recorded at 1 hour intervals until the final stage of drying was reached. The effects of different variables on the physical attributes, such as texture, colour, and drying rate were evaluated.

RESULTS AND DISCUSSION

In this study, the effects of different drying methods on the drying rate and physical properties were evaluated. For this purpose, different operating conditions were applied and the effects on drying rate and other physical characteristics were studied.

TABLE 1
Drying time for different drying methods

Drying method	Time taken to reach final moisture content
Sun	18-23 hours
Solar	15-19 hours
Oven	5-7 hours
Microwave	0.08 – 0.33 hours

The Effect of the Drying Method on Drying Time

The drying process started with an average initial moisture content of 1.15kgH_2O/kg dry solid until it reached 0.10kgH_2O/kg dry solid. Table 1 shows the drying time for the different drying methods. The time was found to vary according to the different temperatures, thicknesses, and sugar concentrations of the samples. It is evident that microwave drying is much faster than other methods. Faster drying time obtained by the solar drier compared to sun drying is due to the fact that the samples in the dryer receives more energy from the collector and incident solar radiation which reduces a bit of the drying time compared to sun drying. As expected, microwave drying may be perceived as the most efficient method in terms of the time it takes to reach the final dried condition. In food processing, however, there are also other qualities that need to be taken into consideration before making any conclusion. Microwave drying has been found to increase the elasticity and decrease the viscosity of products (Krokida & Maraoulis, 1999). Meanwhile, the drying time was significantly reduced (up to 90%) compared to other methods. Similar results were also found in the existing literatures (Maskan, 2001; Funebo & Ohlsson, 1998). The significantly shorter drying time could be due to the rapid heat penetration by microwave. Sun drying took the longest time and consequently, it increased the risk of microbial growth in the product.

The Effect of Temperatures

It is important to note that temperature plays a vital role in the effect of drying process because it represents the quantity of heat externally supplied. As the temperature is increased, the drying time is reduced as the driving force for heat transfer to the samples increases. Three different operating temperatures (50^{o}C, 60^{o}C and 70^{o}C, respectively) were used for oven and microwave drying. The effect of temperature on the drying kinetics was one of the interests in this study. Increasing the temperature would reduce up to 30% of drying time in oven drying and more than 60% in microwave drying. In microwave drying, for instance, the time requires to reach 0.10kgH_2O/kg dry solid ranges from 5-20 minutes, depending on the microwave temperature. *Fig. 1* shows the changes in the moisture content of papaya slices in oven drying while *Fig. 2* illustrates the changes in microwave drying at constant thickness and sugar concentration. It was evident from these curves that the moisture contents decreased continuously with the drying time. At constant sample thickness, increasing air temperature resulted in reduced drying time. According to the kinetic theory, this phenomenon is a result of the increased energy of water molecules as the temperature is increased. The total drying time was found to be 7.0h, 5.7h, and 4.9h at the air temperature of 50ºC, 60ºC and 70ºC, respectively. The drying curves were similar with the other research that were observed in kiwifruit drying by Orikasa *et al.* (2007) and the drying characteristics of irradiated apple slices (Wang & Chao, 2001). Drying temperature also affects the hardness of papaya slices and the high temperature drying also induces greater changes of papaya colour.

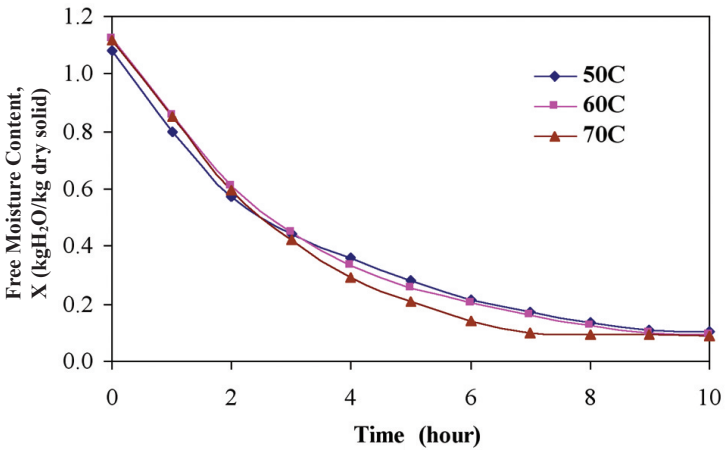

Fig. 1: Drying curves for oven drying (7 mm thickness, 60 °brix)

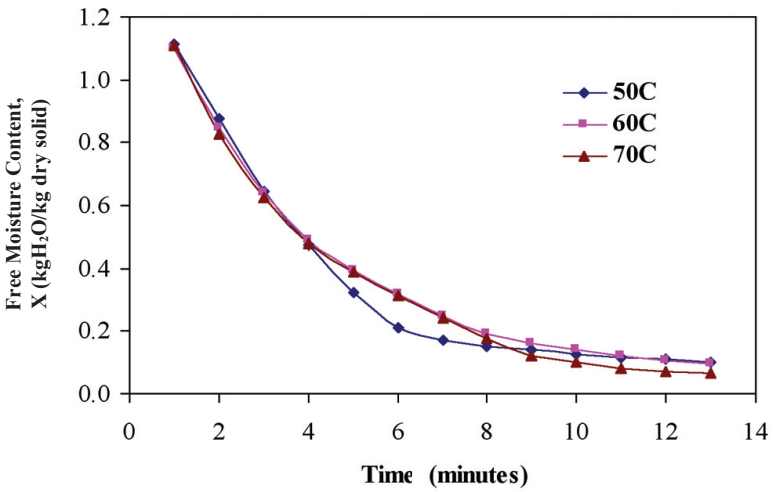

Fig. 2: Drying curves for microwave drying (7 mm thickness, 60 °brix)

The Effects of Sample Thickness

The papayas were sliced into three different thickness; 3, 5, and 7 mm respectively. *Fig. 3* shows that the drying curves of papaya slices were affected by their thicknesses as more rapid moisture removal at thinner initial thickness was due to the reduced distance between the moisture molecules moving. During the same drying period, more water was lost in the thinner sample and this explained the steeper curve. The results are in agreement with the findings of other researchers (e.g. Wang & Chao, 2001; Maskan, 2000).

The moisture contents versus drying time curves at a variation of thickness for sun drying of papaya slices samples under natural convection are given in *Fig. 4*. The drying time to reach the final moisture content was in between 14-23 hours. The drying time for the sun and solar drying was higher than oven drying. This is due to the temperature fluctuations resulting from the changes in weather and the environment (Bala *et al.*, 2002).

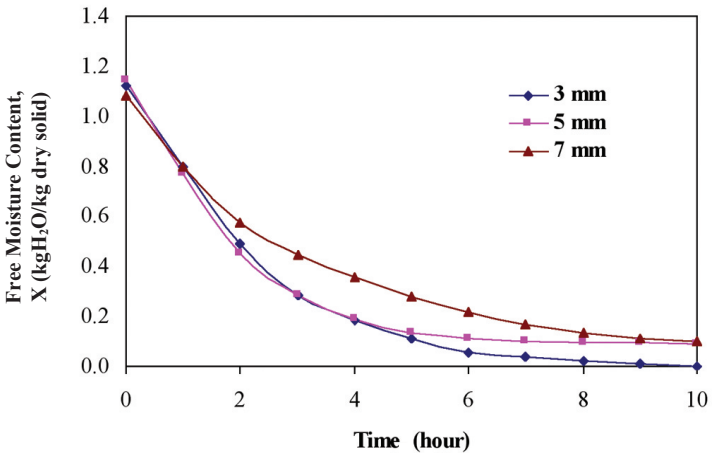

Fig. 3: Drying curves for oven drying (70°C, 60 °brix)

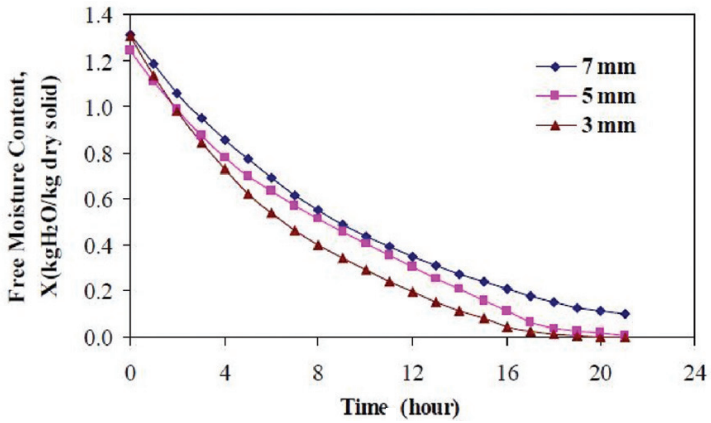

Fig. 4: Drying curves for sun drying (60 °brix)

The Effects of Sugar Concentration

In general, halwa has higher sugar concentration than fresh dried samples. This affects drying rate and it takes longer drying time (to reach the desired moisture content) for all the drying methods. This is because at higher sugar concentration, water under the surface is trapped and it takes a longer time to evaporate (Togrul & Pehlivan, 2004). In addition, the presence of sugar also affects the physical properties and the appearance of the samples, making it harder and darker in colour as compared to the fresh samples. *Fig. 5* shows the drying curves for sun and solar drying under different sugar concentrations. At the same sugar concentration, it was found that solar-dried samples dried faster than sun-dried samples, and this was due to the fact that the papaya slices in the drier received energy from the collector and incident solar radiation which led to the reduction of drying time up to 20% compared with sun drying method (Bala *et al*., 2002).

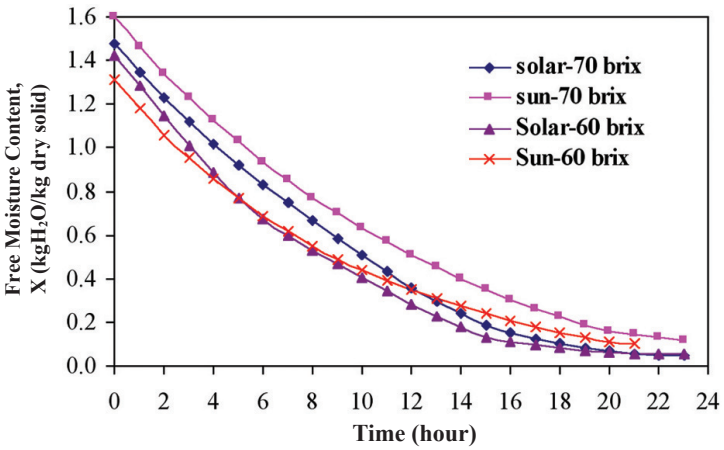

Fig. 5: Drying curves sun and solar drying (5 mm thickness)

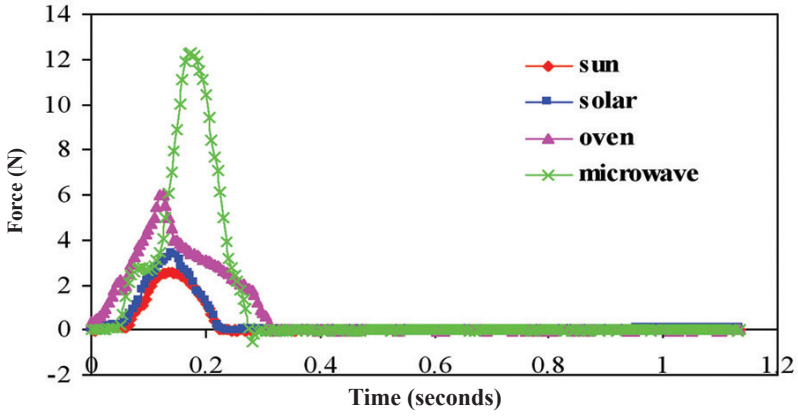

Fig. 6: Hardness of papaya slices for different drying methods

Texture Measurement

The samples were tested for texture analysis using texture analyser (INSTRON 5566, USA). *Fig. 6* shows the forces needed to penetrate the samples. The peak indicates the maximum force that is needed to compress the samples. The hardness of the samples during sun, solar, oven, and microwave drying was found to be 2.0 to 3.0, 2.5 to 3.5, 4.0 to 6.5, and 5.0-13.0N, respectively. Meanwhile, the samples dried using microwave were the hardest with the highest peak as they were very dry and had hard surfaces as compared to the solar-dried and sun-dried samples with the hardness value in the range of 2N – 3.5N only.

As expected, the thicker the sample is, the higher forces are needed to compress the sample. This can be observed in the results presented in Table 2. However, note that in microwave drying, the hardness of the samples increased significantly (more than 100%) as the thickness was increased from 3 mm to 7 mm. On the other hand, the increment of hardness dried using other methods only

TABLE 2
Sample hardness for different thicknesses

Method	Thickness		
	3 mm	5 mm	7 mm
Sun drying	2.1±0.4	2.5±0.4	2.8±0.4
Solar drying	2.8±0.4	3.1±0.4	3.4±0.4
Oven drying	4.2±0.6	4.8±0.6	6.5±0.6
Microwave drying	5.3±0.8	8.1±0.8	12.2±0.8

TABLE 3
Colour quality for the fresh and dried samples

Method	Thickness		
	L*	a*	b*
Fresh	55±1.6	36±2.1	40±2.0
Sun drying	50±2.4	32±1.4	38±1.2
Solar drying	48±2.1	30±1.8	37±1.4
Oven drying	43±1.5	26±0.9	35±1.6
Microwave drying	25±0.8	17±1.7	30±2.8

increased between 21% -55%. Meanwhile, the samples dried using microwave tended to be the hardest due to effect of rapid drying and rapid evaporation.

Colour Measurement

Colour is one of the most important physical quality attributes in a product. In this study, the colour was analysed using Ultrascan PRO Spectrophotometer (HunterLab, USA). Table 3 presents the results of colour measurements of fresh and dried papaya slices at the end of drying. The lightness (L*) of the dried samples ranged from 25 to 57, while redness value (a*) ranged from 17 to 38, and yellowness (b*) from 32 to 42. The colour values of the microwave dried sample indicated the highest change with the lowest value of L (lightness) and a* (redness), and this simply meant the colour was darker as compared to other drying methods.

CONCLUSION

Factors such as air temperature, sample thickness, drying time, and sugar concentration played a major role during the drying process in all drying methods applied. At high temperature, the samples at any thickness dried faster than those at lower temperature. Meanwhile, the samples with lower thickness also resulted in faster drying time. The moisture in the thinner samples was removed faster than the thicker samples at any temperature and sugar concentration. An increase in sugar concentration resulted in longer time for the moisture to evaporate at different thicknesses and temperatures. Similarly, different drying methods resulted in different drying rates and affected the physical attributes of the dried samples such as colour and texture. Depending on the temperature, sample thickness and sugar concentration, the time needed to achieve the equilibrium moisture

content (0.10 kgH_2O/kg dry solid) for oven drying ranged between 5 to 11 hours. For the solar and sun drying, the drying time was between 14-23 hours; whereas, it only took 6-15 minutes using microwave to achieve particular moisture content. Although microwave drying method could save up to 90% of the drying time, as compared to the sun drying method, the microwave dried samples were the least popular when colour appearance and texture were considered.

Among the various methods of drying characteristics of papaya halwa, oven drying was preferred with the optimum sample in 5mm thickness and at the air temperature of 70ºC, as it saved up to 40% of drying time compared to other methods (except microwave) and produced acceptable physical quality of the product.

REFERENCES

Bala, B.K., Mondol, M.R.A., Biswas, B.K., Das Chowdury, B.L., & Janjai, S. (2002). Solar drying of pineapple using solar tunnel drier. *Journal of Food Engineering*, *28*, 183-190.

Bouraoui, M., Richard, P., & Fichtali, J. (1993). A review of moisture content determination in foods using microwave oven drying. *Journal of Food Engineering*, *26*, 49-51.

Brenndorfer, B., & Kennedy, L. (1985). *Solar drier- their role in post harvest processing*. Commonwealth Science Council, London.

Doymaz, I. (2004). Pretreatment effect on sun drying kinetics of mulberry fruits (*Morus alba* L.). *Journal of Food Engineering*, *65*, 205–209.

Funebo, T., & Ohlsson, T. (1998). Microwave assisted air dehydration of apple and mushroom. *Journal of Food Engineering*, *38*, 353-367.

Krokida, M.K., & Maraoulis, Z.B. (1999). Effect of microwave drying on some quality properties of dehydrated product. *Drying Technology*, *17*(3), 449-466.

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

Maskan, M. (2001). Drying, shrinkage and rehydration characteristics of kiwifruits during hot air and microwave drying. *Journal of Food Engineering*, *48*(2), 177–182.

Orikasa, T., Wu, L., Shiina, T., & Tagawa, A.(2007). Drying characteristics of kiwifruit during hot air drying. *Journal of Food Engineering*, *85*, 303-308.

Prachayarawarakorn, S., Tia, W., Plyto, N., & Soponronnarit, S. (2007). Drying kinetics and quality attributes of low-fat banana slices dried at high temperature. *Journal of Food Engineering*, *85*, 509-517.

Togrul, I. T., & Pehlivan, D. (2004). Modeling of thin layer drying kinetics of some fruits under open-air sun drying process. *Journal of Food Engineering*, *65*, 413–425.

Wallace, B.V., & Arsedec, B.C. (1973). *Food dehydration*. New York: AVI Publishing.

Wang, J., & Chao, Y. (2001). Drying characteristics of irradiated apple slices. *Journal of Food Engineering*, *52*, 83-88.

Yang, C. S. T., & Atallah, W. A.(1985). Effect of four drying methods on the quality of intermediate moisture lowbush blueberries. *Journal of Food Science*, *50*, 1233-1237.