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Full Paper

Influence of drying method on drying kinetics and qualities of longan fruit leather

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Abstract: The effects of some drying techniques (hot-air drying, far-infrared drying and microwave-vacuum drying) on the qualities of longan fruit leather, as well as on the drying rate, specific energy consumption, and other properties of longan fruit leather were studied. The drying time for microwave vacuum drying was shortest and the specific energy consumption was also lowest. However, far-infrared drying gave products with the best qualities. It also reduced the drying time and specific energy consumption in comparison to hot-air drying and was found to be suitable for the production of longan fruit leather.

Keywords: longan fruit leather, hot-air drying, microwave-vacuum drying, far-infrared drying, fruit leather

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INTRODUCTION

Drying is one of the most common methods of food preservation. The major aim is to remove moisture to the desirable level at which microbial spoilage and deteriorative chemical reactions are avoided or greatly minimised. Every drying technique has its own advantages and disadvantages. Hot air (HA) drying is a conventional method, but its long exposure times can cause serious damage to the flavour, colour, nutritional value and rehydration capacity of the dried products [1]. Drying by far-infrared (FIR) radiation is a technique for speeding up the conventional drying process as well as improving the quality of the dried product. FIR drying can be used to accelerate a drying process because this form of energy can be directly absorbed by the dried product without significant losses to the environment. The reduction in drying time for a variety of food products has been reported by many researchers. FIR drying has also been proven to be more effective with products that have a high moisture content [2-5]. Microwave vacuum (MWV) drying is a method that can be utilised at low temperatures in the absence of oxygen. MWV drying combines the advantages of rapid volumetric heating by microwaves and low-temperature evaporation of moisture, with faster moisture removal than vacuum drying. This method can dry a product in a shorter time because microwaves penetrate into the interior of the product and cause the water to boil at a comparatively low temperature, owing to the reduced pressure in the drying chamber [6]. Due to the water boiling inside the product, there is a relative difference in pressure between the interior of the product and the environment, enabling extremely quick water vapour removal and producing favourable conditions for the occurrence of the puffing phenomenon [7].

Fruit leather is a dried sheet of fruit pulp that has a soft, rubbery texture and sweet taste. It can be made from most fruits, although mango, apricot, banana, tamarind and longan leathers are amongst the most popular [8]. Fruit leathers are made by removing moisture from a large flat tray of wet puree until the desired cohesive leathery composition is obtained [9]. The fruit leather should not be dried in direct sunlight as this will cause the fading of colour and reduction of the levels of vitamins A and C. Indirect solar dryers or mechanical dryers should be used [10, 11]. The objective of this study is to compare the effect of HA, FIR and MWV drying methods on the drying kinetics, physical characteristics and qualities of longan (*Dimocarpus longan*) fruit leather.

MATERIALS AND METHODS

Experimental Set-up

A double-function dryer, which can be used either as an HA or FIR dryer, is shown in Figure 1. The dryer consists of a blower for supplying air into the drying chamber. The entering air velocity can be varied between 0-4.5 m/s and the temperature can be controlled at 30-80^{o}C by an electrical heater. The drying chamber is a well-insulated rectangular duct equipped with an FIR ceramic heater (800W maximum power, Model EL-3, EDF Industrial Automation Co., Malaysia) and an intensity-level control. The sample to be dried is kept in a tray under the heater.

The weight of the sample can be recorded every 5 minutes during drying by an electronic balance (cp3202s, Sartorius, Germany) with an accuracy of ± 0.01 g. The air velocity is measured by an anemometer with an accuracy of ± 0.1 m/s at the position over the sample. The fan speed is controlled by a variable electronic transistor inverter (Model VFD-S, Delta Electronics Inc., Taiwan). The air temperature and relative humidity are controlled by a digital controller (Model MAC3F, Shimax Co., Japan).

A K-type thermocouple (30-gauge hypodermic needle probe, Omega Engineering Co., USA) is inserted from the top into the centre of the sample to be dried. The thermocouple wire is kept inside an aluminum rod that serves as a shield from radiation. The surface temperature is measured by an infrared optical pyrometer (Model OS550, Omega Engineering Co., USA), which is focused at a 0.009-m-diameter circle from a 0.61-m distance. The spot location is confirmed by a laser sighting viewer (Model OS550-LS, Omega Engineering Co., USA) prior to each run. A monitoring programme is used to log the data, which are then downloaded into a computer.

A 22-L, 800W MWV dryer with a 0.2-kW motor (Model R-254, Sharp Corp., Japan) used in this experiment is shown in Figure 2. The vacuum in the drying cavity is maintained by a vacuum pump (1.5 kW, ICME, TMB90LB4, Busch Vacuum Co., Italy). The dimensions of the microwave chamber are 500 x 500 x 500 mm. The plate in the chamber rotates at 10 rpm during its operation to even out the volumetric heating of the product. The microwave power density used is 1,000 W and the microwave frequency is 2,450 MHz. The maximum vacuum pressure is 15 inches Hg.

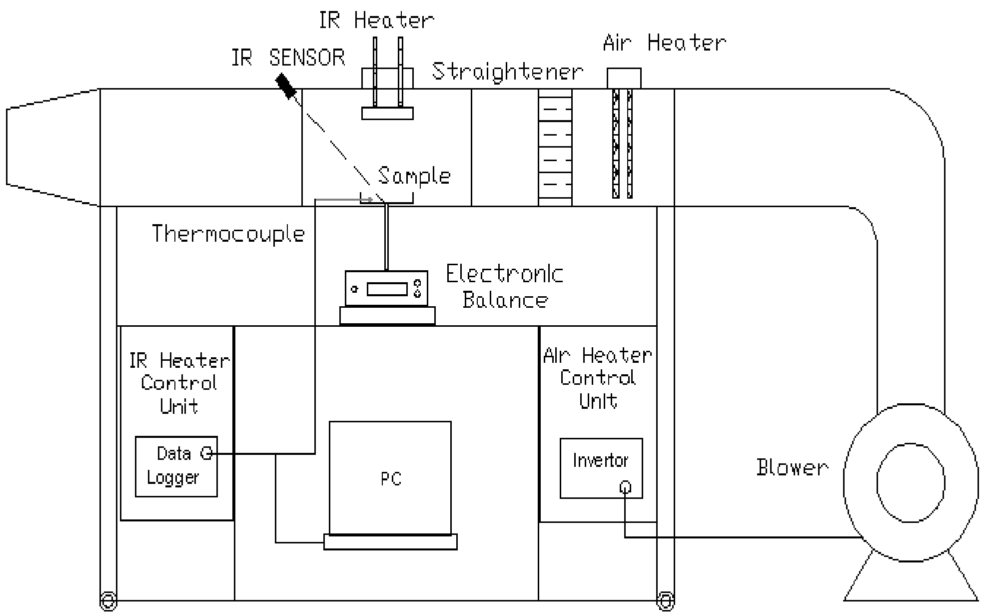

Figure 1. Schematic diagram of a double-function (HA/FIR) dryer [3]

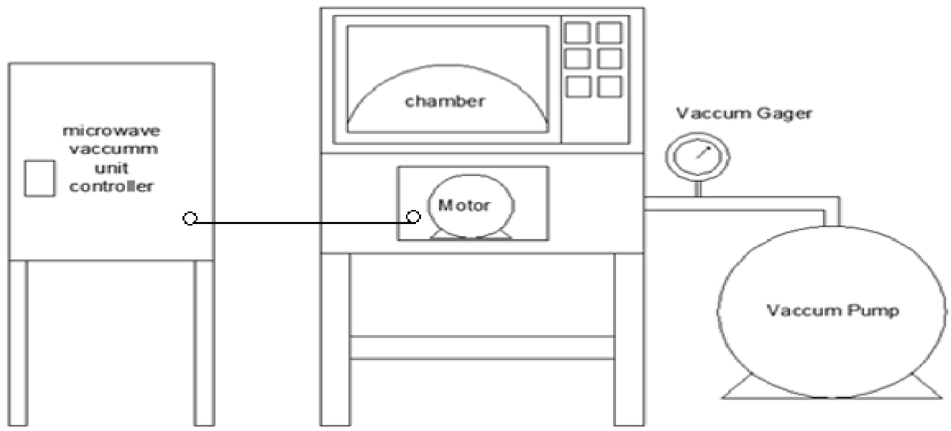

Figure 2. Schematic diagram of MWV dryer

Materials

Each sample of 150 g of longan puree was prepared by blending fresh longan and spreading the blend uniformly in a single layer in an aluminum tray (Figure 3) that was kept inside the drying chamber. The sample thickness was measured with a dial micrometer; at least five measurements of the thickness were made at different points and only 5% deviation of the average thickness was allowed for each sample. The final moisture content of the longan fruit leather was considered at a 13 % (dry basis) [10].

Methods

Drying

HA drying was done with hot air temperatures of 70^o, 75^o and 80^o C and air velocities of 0.50, 0.75 and 1.00 m/s. FIR drying was conducted at three radiator temperatures of 350^o, 400^o and

450^{o} C with distance between the samples and the infrared heat source of 15-25 cm. The inlet air temperature and velocity were kept constant at 30^{o}C and 0.5 m/s respectively. MWV drying was done at the microwave power densities of 60.8 and 121.7 W, and 10 and 15 inches of vacuum with a fixed mass load of product.

a) Longan puree b) Longan fruit leather

Figure 3. Longan fruit in drying tray

Moisture content

The moisture content was determined by the oven method. At regular time interval during the drying process, samples were taken out and dried in the oven for 3-4 hours at 105^{o} until a constant weight was achieved. Weighing was performed using a digital balance and the moisture content (wet basis) was calculated. The tests were performed in duplicate.

Colour

Colour measurements were performed using a colour difference meter (Model CR-200, Konica Minolta Co., Japan). The coordinates of the colour, viz. CIE L* (whiteness/darkness), a* (redness/greenness) and b* (yellowness/blueness), of the skin of the leather samples were obtained by reflection. Each sample was measured in quintuplicate. The total colour difference (ΔE) was determined as follows:

$$\Delta E = \sqrt{(L_0^* - L^*)^2 + (a_0^* - a^*)^2 + (b_0^* - b^*)^2} ,$$

where subscript 0 denotes the colour of the referenced classical production of longan fruit leather [8].

Texture

A texture analyser (Model TA-XT2i.plus, Stable Micro System Ltd., UK) was used to measure the hardness and gumminess in Newton (N) unit. A spherical stainless probe (2.5-mm diameter) was passed through the fruit leather sample with the test parameter set at 2 mm/s for pre-speed and post-speed, 2 mm/s for test speed and 20 g trigger. In penetration test, the hardness is the maximum force required to break the sample. Three samples were used in each treatment.

Specific energy consumption

The energy efficiency of the drying process was indicated in terms of specific energy consumption (SEC), which was calculated as: total energy used for drying (kJ) / total amount of water evaporataed from product (kg).

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RESULTS AND DISCUSSION

Drying Kinetics of Longan Fruit Leather

Figure 4 shows the drying rates of the samples subjected to HA, FIR and MWV drying. For HA drying, at the same air velocity (0.5 m/s), the average drying rates at 70°, 75° and 80° were 0.244, 0.269 and 0.358 kg_{water}/h $kg_{dry\ solid}$ respectively. It can be clearly seen that the drying rate increased with an increase in air velocity and hot air temperature. In the case of FIR drying, at the same distance (25 cm) between the samples and the infrared heat source, the average drying rates at 350°, 400° and 450° were 0.255, 0.314 and 0.508 kg_{water}/h $kg_{dry\ solid}$ respectively. The drying rate was found to increase with increased radiator temperatures and decreased distance between the sample and the infrared heat source. For MWV drying, at the same vacuum level (10 in.Hg), the average drying rates at 60.8 W and 121.7 W were 0.815 and 1.952 kg_{water}/h $kg_{dry\ solid}$ respectively. The drying rates at 10 inches and 15 inches of vacuum were not significantly different.

Table 1 shows the drying kinetics data involved in producing longan fruit leather by HA, FIR and MWV drying. HA drying took the longest time while the drying time for MWV drying was the shortest (Table 1 and Figure 5). MWV drying is therefore the fastest drying option based solely on drying time. Note that drying by the classical method of longan fruit leather production by combining solar drying and HA drying takes roughly 32 hours [8].

The total energy used for HA drying was measured by the electric power supplied to the air heater and the air blower motor, while that for FIR drying was measured by the electric power supplied to the infrared heater and the air blower motor. For MWV drying, the electric power supplied to the microwave generator and the vacuum pump motor was taken into account in the energy analysis. Figure 6 shows that the SEC of MWV drying is lowest due to the least electric power consumed, while FIR drying exhibits lower SEC than does HA drying (more than 50% lower).

Qualities of Longan Fruit Leather

Table 2 and Figure 7 show experimental results on the qualities of longan fruit leather. Compare to fresh longan, the dried longan fruit leather gave a lower value of lightness and higher value of redness and yellowness. For FIR drying, the sample was brightest due to its lightness and yellowness values. Increasing higher power into FIR drying led to greater colour changes, indicating a phenomenon that accelerates non-enzymatic browning reactions. The same reason can also be applied to other methods. The colour difference (ΔE value) from the classical production of longan fruit leather [8] is an indication of the drying qualities. It was found that FIR drying gave the smallest colour difference values.

Texture is considered as one of the most important criteria for consumer acceptance of snack foods. As shown in Table 2, the texture of the fruit leather from MWV drying is harder than that from HA and FIR drying. MWV drying has also been reported to increase the hardness of texture and result in a more rigid structure of a dried product [7]. There is no significant difference between the gumminess values of the leather from different drying methods. Figure 7 shows the appearance of longan leather samples from HA, FIR and MWV drying methods. The surface of the fruit leather from MWV drying is rougher and more brittle than those from HA and FIR drying. It is also dense in structure and shows fractures, while the surface of the sample from FIR drying is smooth and bright.

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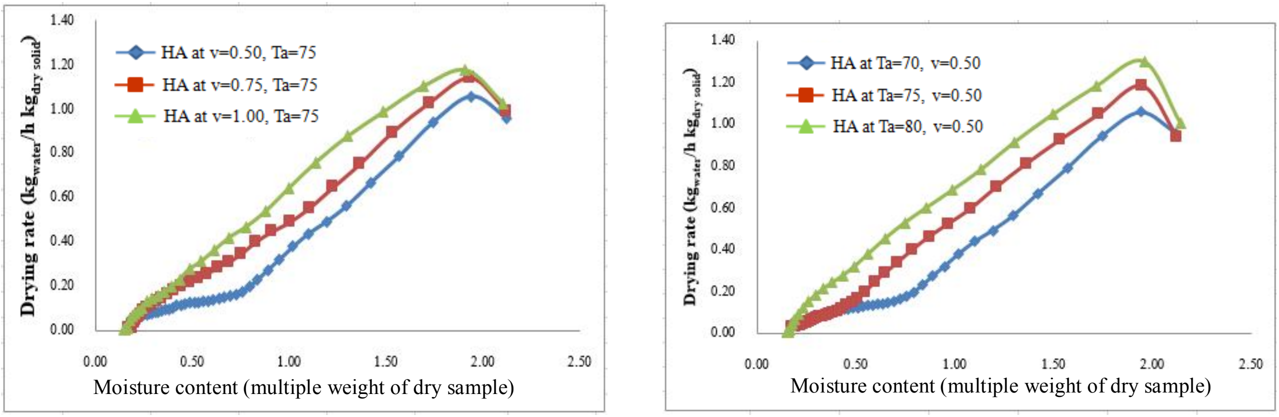
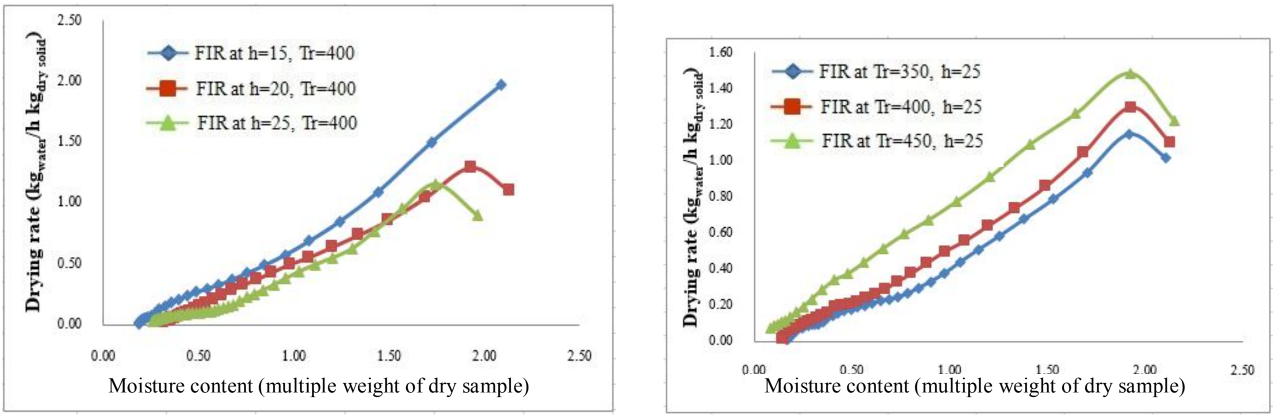
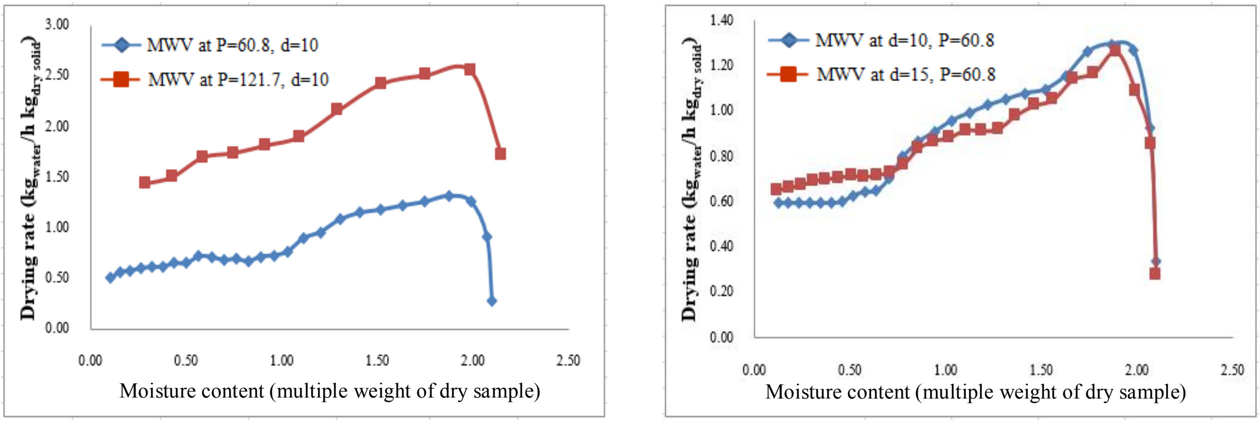


a) HA drying at constant hot air temperature and constant air velocity



b) FIR drying at constant radiator temperature and constant distance between sample and infrared heat source



c) MWV drying at constant vacuum and constant microwave power density

Figure 4. Comparison of drying rate for (a) HA (b) FIR and (c) MWV drying.
Notation: Ta = hot air temperatures (^{o}C); v = air velocity (m/s); Tr = radiator temperature (^{o}C); h = distance between sample and infrared heat source (cm); P = microwave power density (W); d = vacuum degree (inches Hg)

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Table 1. Drying times, drying rates and specific energy consumption during the drying process of longan fruit leather

Drying method		Drying kinetics		
		DT (hr)	DR (kg_{water}/h $kg_{dry\ solid}$)	SEC (kJ/ kg_{water})
HA	0.50 m/s, 70°C	24.0	0.244	6,555.2
	0.50 m/s, 75°C	22.0	0.269	6,447.8
	0.50 m/s, 80°C	20.0	0.358	6,179.1
	0.75 m/s, 70°C	22.0	0.269	5,319.4
	0.75 m/s, 75°C	19.5	0.310	5,050.8
	0.75 m/s, 80°C	18.0	0.416	4,889.6
	1.00 m/s, 70°C	20.0	0.380	4,567.2
	1.00 m/s, 75°C	18.5	0.420	4,513.4
	1.00 m/s, 80°C	17.0	0.450	4,405.9
FIR	15 cm, 350°C	12.5	0.394	1,714.8
	15 cm, 400°C	11.5	0.490	1,333.7
	15 cm, 450°C	10.0	0.530	952.7
	20 cm, 350°C	13.0	0.268	1,952.9
	20 cm, 400°C	12.5	0.375	1,714.8
	20 cm, 450°C	11.5	0.516	1,143.2
	25 cm, 350°C	14.5	0.255	2,191.1
	25 cm, 400°C	13.5	0.314	2,048.2
	25 cm, 450°C	12.5	0.508	1,428.9
MWV	10 inches Hg., 60.8 W	4.3	0.841	822.6
	15 inches Hg., 60.8 W	4.1	0.844	846.4
	10 inches Hg., 121.7 W	2.2	1.950	365.6
	15 inches Hg., 121.7 W	2.1	1.952	386.5
Sampanvejsobha et al. [8]		32.0	-	-

Notes: DT = drying time; DR = drying rate; SEC = specific energy consumption. Each value represents means of three replications and drying time is that taken to dry sample to 13% moisture (dry basis).

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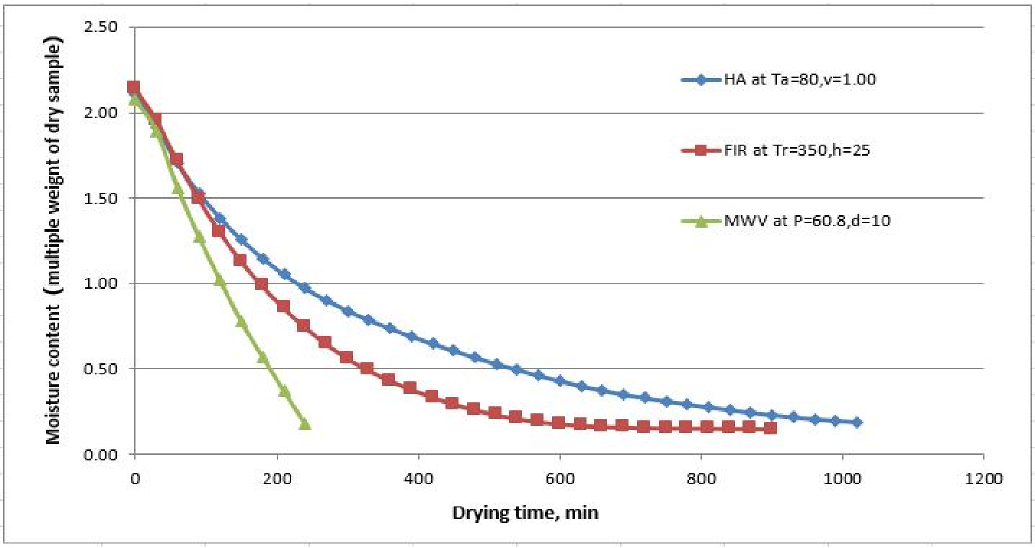

Figure 5. Comparison of drying curves for: 1) HA drying at 80°C and 1.00-m/s air velocity; 2) FIR drying at 350°C and 25-cm distance; 3) MWV drying at 60.8 W and 10-inch vacuum

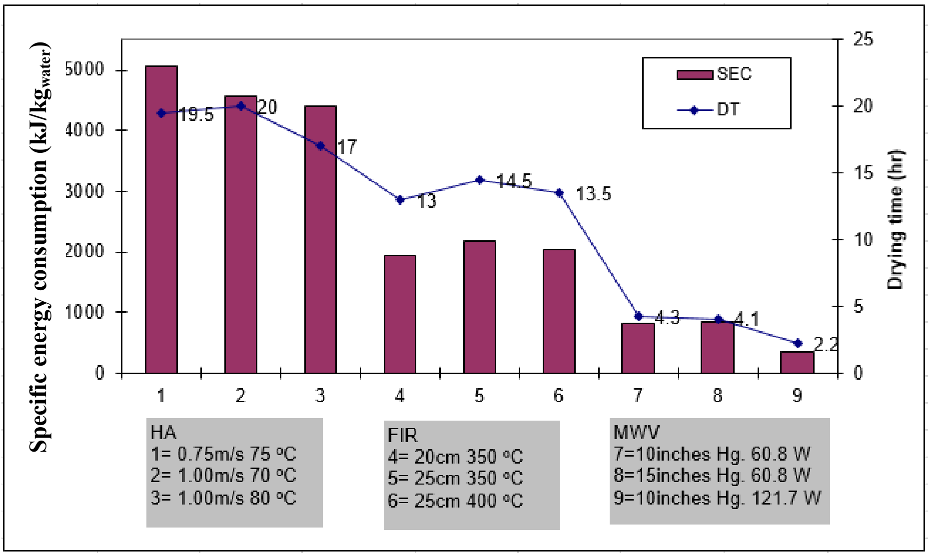

Figure 6. Comparison of drying time (DT) and SEC for HA, FIR and MWV drying

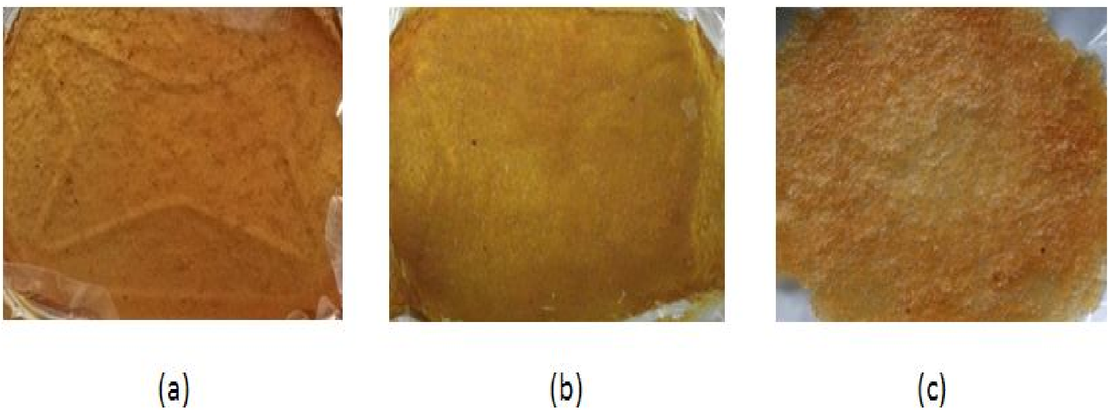

Figure 7. Surface appearance of longan leather samples from different drying methods: (a) HA drying; (b) FIR drying; (c) MWV drying

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Table 2. Qualities of longan fruit leather

Drying method		Drying qualities					
		L*	a*	b*	ΔE	Hardness (N)	Gumminess (N)
HA	0.75 m/s, 75°C	40.43	12.70	26.61	15.50	5.47	1.77
	1.00 m/s, 70°C	40.76	13.61	26.77	16.61	1.84	1.60
	1.00 m/s, 80°C	48.04	11.10	31.98	14.69	2.57	1.01
FIR	20 cm, 350°C	47.26	9.69	25.55	9.09	2.41	2.08
	25 cm, 350°C	49.22	10.95	18.68	4.58	1.43	2.86
	25 cm, 400°C	46.65	12.43	24.64	9.36	2.39	2.30
MWV	10 in. vac., 60.8 W	48.85	4.83	27.90	11.14	19.09	1.35
	15 in. vac., 60.8 W	44.89	6.69	28.53	9.19	12.53	1.54
	10 in. vac., 121.7 W	39.79	11.11	24.59	14.95	12.39	1.76
Fresh longan		50.80	-1.50	12.20	-	-	-
Conventional method [8]		53.59	9.62	19.03	-	1.49	2.83

Note: Each value represents means of three replications.

CONCLUSIONS

Although MWV drying seems to be the fastest drying method, FIR drying gives longan fruit leather of apparently optimum qualities. It also displays important advantages over HA drying, viz. increased drying rate (hence shorter drying time) and substantially less energy consumption.

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REFERENCES

1. R. B. Keey, "Drying Principles and Practices", Pergamon Press, Oxford, **1972**, pp.197-203.
2. M. Adonis and M. T. E. Khan, "Combined convective and infrared drying model for food applications", Proceedings of 7th AFRICON Conference in Africa, **2004**, Gaborone, Botswana, vol. 2, pp.1049-1052.
3. S. Jaturonglumlert and T. Kiatsiriroat, "Heat and mass transfer in combined convective and far-infrared drying of fruit leather", *J. Food Eng.*, **2010**, *100*, 254-260.
4. D. Nowak and P. P. Lewicki, "Infrared drying of apple slices", *Innov. Food Sci. Emerg. Technol.*, **2004**, *5*, 353-360.
5. T. Swasdisevi, S. Devahastin, P. Sa-Adchom and S. Soponronnarit, "Mathematical modeling of combined far-infrared and vacuum drying banana slice", *J. Food Eng.*, **2009**, *92*, 100-106.
6. S. Tontand and N. Therdthai, "Preliminary study of chili drying using microwave assisted vacuum drying technology", *Asian J. Food Agro-Ind..*, **2009**, *2*, 80-86.
7. J. Varith, P. Dijkanarukkul, A. Achriyaviriya and S. Achriyaviriya, "Combined microwave-hot air drying of peeled longan", *J. Food Eng.*, **2007**, *81*, 459-468.
8. S. Sampanvejsobha, Y. Attabhanyo and A. Jangchud, "Effect of temperature on fruit leathers drying", *Agric. Sci. J.*, **2006**, *37*, 21-27.

Maejo Int. J. Sci. Technol. **2015**, *9*(01), 54-63; doi: 10.14456/mijst.2015.6

9. S. Jaturonglumlert and T. Kiatsiriroat, "Mass transfer kinetics of longan leather between hot air and far-infrared drying, Proceedings of 3rd International Symposium on Longan, Lychee and Other Fruit Trees in Sapindaceae Family, **2008**, Fuzhou, China, pp.119-129.
10. N. A. Q. Ruiz S. M. Demarchi and S. A. Giner, "Research on dehydrated fruit leathers: A review", Proceedings of 11th International Congress on Engineering and Food, **2011**, Athens, Greece, FPE398.
11. S. Jaturonglumlert and T. Kiatsiriroat, "Far-infrared radiation properties of longan leather drying", Proceedings of 8th Conference on Energy, Heat and Mass Transfer in Thermal Equipment, **2009**, Chiang Rai, Thailand, pp.193-197.