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Original article

Studies on different combined microwave drying of carrot pieces

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Summary Three different combined microwave (MW) drying methods were compared, namely microwave-assisted vacuum drying (MWVD), microwave-assisted freeze drying (MWFD), microwave-enhanced spouted bed drying (MWSD), in terms of drying rate, drying uniformity, product colour, rehydration ratio, retention of β-carotene and vitamin C, and energy consumption. The drying rate of MWVD and MWSD were much faster than that of MWFD. The largest drying rate was obtained in MWSD with 3.5 W g^{-1}. In general, the colour of MWSD products was very uniform. Rehydration ratio of MWFD carrot pieces was almost the same as the freeze-dried (FD) products and better than MWVD and MWSD products. In addition, the highest retention of carotene and vitamin C was observed in MWFD carrot pieces. No significant differences were observed in carotene and vitamin C between MWVD and MWSD products. However, the energy consumption in MWFD was the highest.

Keywords Carotene, colour, combined microwave drying, drying rate, drying uniformity, rehydration ratio.

Introduction

Many drying methods are used in the food industry to remove moisture from fresh fruits and vegetables in the production of shelf-stable products (Wang, 2000). Conventional drying methods, such as airflow drying, vacuum drying (VD) and FD, result in low drying rates, in particular in the falling rate period of drying (Clary *et al*., 2005; Zhang *et al*., 2006; Wang *et al*., 2007). The long drying time may results in serious damage to flavour, colour and nutrients of the products. Among the above-mentioned methods, FD is the most expensive and only used for high-value products (Drouzas *et al*., 1999). It is, therefore, desirable to evaluate new drying technologies to achieve better product quality and more reasonable cost. Drying is one of the most energy consuming unit operation in food processing. Therefore, energy consumption index is one of important criteria for judging new emerging drying technologies. Microwave (MW) drying offers opportunities to shorten drying time, improves the final quality of the dried products and reduces energy consumption (Wang *et al*., 2004). In recent years, many studies on MW drying in fruits and vegetables were reported (Zhang *et al*., 2006; Wang and Sheng, 2006). Vega-Mercado *et al*. (2001) considered the use of MW drying as the fourth-generation drying technology. In general, a complete MW drying process consists of three drying periods: heating-up period, rapid drying period and falling rate drying period (Feng *et al*., 1999; Feng & Tang, 2002). MW drying method can be used to dry heat-sensitive materials as one of new drying technologies because of the high drying efficiency (Vadivambal & Jayas, 2007).

Although MW drying has higher drying rate than most of conventional drying methods (Cui *et al*., 2004; Giri & Prasad, 2007), nonuniformity, caused by uneven spatial distribution of electromagnetic field inside the drying cavity, is a major drawback of microwave drying. The nonuniform electric field intensity, combined with lack of proper means to remove excessive thermal energy from the product may cause over heating in certain part of the material, resulting in poor product quality (Cohen & Yang, 1995; Lu *et al*., 1999). Moreover, too rapid mass transport by MW power may cause tissue damage or undesirable changes in the food texture by ‘puffing’ (Nijhuis *et al*., 1998). Several different combination drying methods were used to overcome the disadvantages of a single MW drying method. For

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example, the uneven heating of single MW drying can be significantly improved by combining with spouted bed (MWSD) drying if the material to be dried is of particulate nature that can be spouted (Feng & Tang, 1998). Other combined microwave drying methods that have been researched in some research communities include MW-assisted vacuum drying (MWVD), MW-assisted freeze drying (MWFD) and MW-assisted finish drying following osmotic dehydration (MDOD), which could be used for various industrial applications.

Pilot-scale MWVD systems have been used successfully for the dehydration of grapes, cranberries, bananas, tomatoes, carrots, garlic, kiwifruit, apple and pear (Yongsawatdigal & Gunasekaran, 1996; Kiranoudis *et al.*, 1997; Durance & Wang, 2002; Clary *et al.*, 2005). The quality of these products was maintained well in terms of taste, aroma, texture and appearance. Regier *et al.* (2005) compared the convectional drying of lycopene-rich carrots with MW vacuum drying and concluded that the drying time was shortened to < 2 h comparing with 4.5–8.5 h in convectional drying. The disadvantages of conventional freeze drying are relatively small throughputs and high capital and energy costs resulting from the refrigeration and vacuum systems (Wang & Chen, 2003). Experimental studies based on MWFD have demonstrated that MWFD resulted in a 50–75% reduction in drying time in comparison with conventional freeze drying method (Cohen & Yang, 1995). Other food materials dried by MWFD were ground meat, beef, foamed milk, skim milk and egg (Sochanske *et al.*, 1990; Cohen & Yang, 1995). The MW energy averaging can be accomplished by either mechanical means (Torringa *et al.*, 2001) or through pneumatic agitation (Feng & Tang, 1998). Fluidisation provides pneumatic agitation for samples in the drying bed. It also facilitates heat and mass transfers because of a constant renewed boundary layer at the particle surface. Therefore, combined fluidised or spouted bed drying is considered as an effective method to solve the uneven in the single MW drying. Nindo *et al.* (2003) used MWSB to evaluate the retention of physical quality and antioxidants in sliced asparagus.

The objective of this article is to investigate the effect of three different MW-related drying methods (MWVD, MWFD and MWSD) on carrot pieces.

Materials and methods

Materials and equipment

Carrots were purchased from a local supermarket in Wuxi, China. The samples were washed, peeled, sliced to 8 × 8 × 8 mm, then blanched in a water-bath (90 °C, 10 min) and cooled in cold water (10–12 °C) for 60 s. The surface water of the slices was removed with handkerchief before each drying.

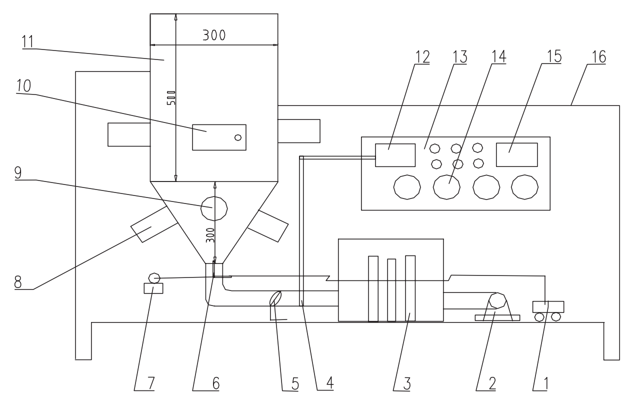

Figure 1 Schematic of the microwave spouted dryer (dimension in mm). 1. air compressor 2. blower 3. electric heating 4. pressure detector 5.valve 6. nozzle 7. peristaltic pump 8. magnetron 9. observation window 10. operation door 11. spouted bed 12. air flow detector 13. control box 14. power regulator 15. optical fibre measurement 16. equipment support.

The laboratory-scale microwave spouted dryer (Fig. 1) used in this research was developed by the authors. The system consisted of MW power sources, a cavity, a hot-air source, a spouted bed and a control system. Microwave power was provided by four 2450MHz magnetrons, each having 1 kW maximum power capacity. The total microwave power could be regulated continually from 0 to 4 kW. The temperature of the air for the spouted bed was controlled at 50 °C through a feed-back loop, and air velocity was maintained with an adjustable fan. The temperature in the drying cavity was detected by a fibre optic temperature sensor.

The laboratory-scale microwave freeze dryer (Fig. 2) was described in Duan *et al.* (2007). A laboratory-scale microwave-vacuum dryer (Fig. 3) (Song *et al.*, 2007) was operated at 5 kPa (absolute pressure), the output MW power was 146.5–488.5 W and the rotation speed of the turntable was 5 r.p.m.

Drying experiments

Experiments were carried out by using one of the three different drying methods (MWVD, MWFD and MWSD) until the final sample moisture content reached 8%. (w.b). The original weight of blanched carrot slices for MWVD, MWFD and MWSD were 100, 200 and 500 g, respectively. All experiments were performed in duplicate. Experimental conditions were selected based on previous literature (Feng & Tang, 1998; Nindo *et al.*, 2003; Duan *et al.*, 2007; Song *et al.*, 2007; Wang *et al.*, 2008) and preliminary tests as follows:

Carrots were dried by MWVD when microwave power was 2.4 W g^{-1} (wet basis) and the vacuum pressure was 5 kPa.

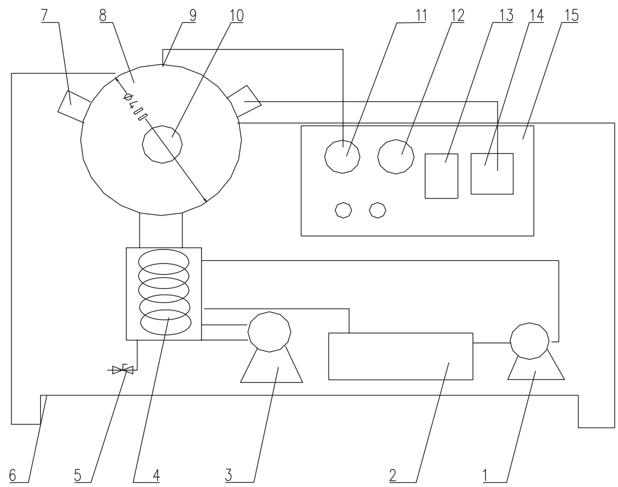

Figure 2 Schematic of the microwave freeze dryer. 1. refrigerator 2. cooler 3. vacuum pump 4. cold trap 5. blowdown valve 6. equipment support 7. magnetron 8. drying cavity 9. infrared thermoscope 10. observation window 11. thermometer 12. pressure detector 13. PLC controller 14. power regulator 15. control box.

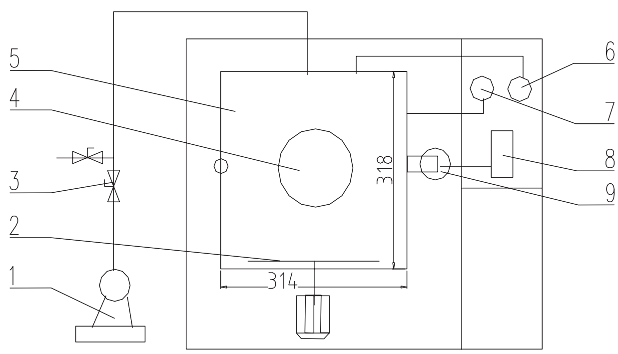

Figure 3 Schematic of the microwave vacuum dryer. 1. vacuum pump 2. rotating tray 3. valve 4. observation window 5. drying chamber 6. infrared thermometer 7. vacuum gauge 8. magnetron power control unit 9. magnetron.

MWFD was used to dry carrots with 2.0 W g^{-1} (wet basis) microwave power, pressure at 100 Pa abs. and −40 °C cold trap temperature.

Carrots were dried by MWSD using ingoing air at 50 °C under two microwave powers: 2.0 W g^{-1} and 3.5 W g^{-1} (wet basis).

Moisture content

Moisture content was determined by the oven method (AACC 44-16). At regular time intervals during the drying processes, samples were taken out and dried in the oven for 2–3 h at 105 °C until constant weight. Weighing was performed on a digital balance, and then moisture content (w.b) was calculated. The tests were performed in duplicate.

β-Carotene content

The carotene was determined according to Prakash *et al.* (2004). Specifically, dried carrot sample (2 g) was placed in a 250- mL flask, and 40 mL of acetone was added. A stirrer was used to aid extraction of the carotene, and the process was continued until the residue became colourless. The acetone extract was filtered and placed in a separating funnel, then petroleum ether (100 mL) was added (to absorb any moisture) and the separating funnel was shaken for 1 min. Two distinct layers were formed of which the yellow upper layer was collected and the lower layer was drained off to another separating funnel. The lower layer solution was again extracted with petroleum ether (100 mL) and the upper yellow layer was collected. The petroleum ether extracts were combined in a volumetric flask and the volume was made up to 250 mL by adding petroleum ether. An aliquot of this solution was placed in a cell of a spectrophotometer and the absorbance at 452 nm was measured for determination of the β-carotene content of the carrot sample. The standard curve was obtained within the range of 0–5 μg β-carotene per mL (Yen *et al.*, 2008).

Vitamin C content

Vitamin C content was determined using 2, 6-dichloroindophenol titration method (Zhang *et al.*, 2002). Data were calculated on a dry basis and expressed as micrograms per 100 g solids. The analyses were carried out in duplicate. Vitamin C content of the dried carrot was converted to the vitamin C content per 100 g fresh carrot. Vitamin C value of carrot pieces after blanching was used as the control value.

Rehydration ratio

About 2 g were weighed and then poured into water. The carrot pieces were taken out after a certain time of immersion at 50 °C. After vacuum filtration for 10 s, the sample was weighed. R (rehydration ratio) was obtained as following formula:

$$R = \frac{M_2 - M_1}{M_1} \quad (1)$$

where M_1 is the initial weight of the carrot pieces, M_2 is the final weight of carrot pieces after immersion and vacuum filtration.

Colour

Sample colour was measured by CR-400 model colourimeter (Dnica minolt Co., Chiyoda-ku, Tokyo, Japan). The measurement was replicated five times. The colour values were expressed as *L* (whiteness/darkness), *a* (redness/greenness) and *b* (yellowness/blueness). Additionally, the total colour difference from the FD carrot pieces ΔE, as defined below, was used to describe the colour changes during the other combination drying process:

$$\Delta E = \sqrt{(L_o - L)^2 + (a_o - a)^2 + (b_o - b)^2} \qquad (2)$$

where subscript "*o*" refers to the colour reading of FD carrot pieces. FD carrot pieces were used as the reference and larger ΔE values denote greater colour change from the reference material.

Sensory evaluation

The sensory qualities of different carrot slices were analysed in terms of its appearance (1–4 points), colour (1–3 points), flavour (1–3 points) and texture (1–3 points). A twelve-number panel, all of whom were experienced in the sensory evaluation of fish snack foods, scored the three parts. The sum score (total of 13 points) of the four characteristics was used to evaluate the product's sensory characteristic. Carrot slices with at least 9 points were accepted as good products.

Energy consumption evaluation

The total energy consumption during drying was calculated from an ampere meter reading (unit: kw h), 1 kW h = 1 kw × 3600 s = 3600 kJ. Unit of energy consumption was expressed as kJ h per kg H_2O, which expressed power consumption required per kilogram of evaporation of water in carrot.

Statistical analysis

An ANOVA procedure for the statistical analysis of the results was done by using the SAS software. Least significance difference test was used to determine difference between means. Significance was assumed at $P \leq 0.05$.

Analysis and results

Drying characteristics

Typical drying curves of three different methods are shown in Fig. 4. The drying time of MWFD was 3, 4.3, 6, times longer than in MWVD, MWSD at 2.0 W g^{-1} and 3.5 W g^{-1}, respectively. The low drying rate in MWFD could be explained that the dielectric constant value of ice was lower than liquid water, which resulted in lower conversion of microwave energy to thermal energy in MWFD. In addition, the high drying rate in MWSD should be attributed to constant movement of carrot pieces within the MW cavity, which allowed the different parts of the carrot pieces to receive a relative uniform MW radiation over a period of time. Moreover, heat and mass transfer of carrot pieces were faster under constant fluidisation condition, which resulted in the fast drying rate. It is necessary to note that drying time at 2.0 W g^{-1} power in MWSD was longer than 3.5 W g^{-1}. In fact, several higher MW powers had been tested and the results showed that the total drying time changed little when the MW powers were higher than 3.5 W g^{-1}. However, to date there were no available data to explain the effect. Maybe it is related to the distribution of MW radiation in the drying cavity or the drying intensity of the laboratory-scale microwave spouted dryer, just like the intensity of spray drying (Mujumdar, 2001).

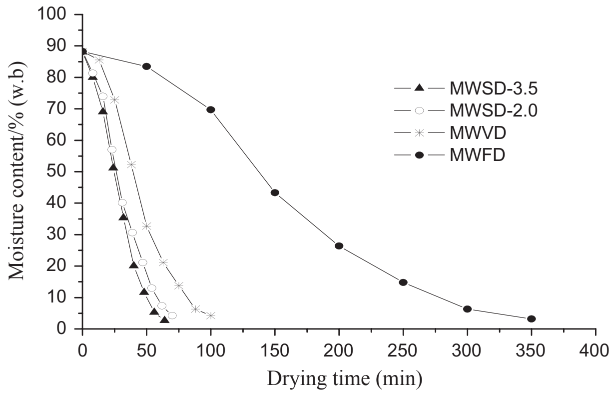

Figure 4 Drying curves of three combined MW drying methods.

The average drying rates of carrot in different drying period are shown in Table 1. It can be observed that the drying process consisted of three stages (Zhang *et al.*, 2006). The drying rate varied form slow to fast and then getting slow again. In the first stage, MW energy was converted into thermal energy within the carrot pieces, and the temperature of the product increased with drying time. After the heating-up stage, a stable temperature profile was established and thermal energy that came from MW energy was used for the vaporisation of moisture. In porous food materials, the resistance of mass transfer can be neglected. Therefore, the rates of moisture vaporisation at different locations, to a large extent, depend on the energy conversion rates from MW to thermal. So the drying rate was very fast in the second stage. The last drying stage was the falling rate drying period, during which the local moisture content was reduced to a lower level. If the energy needed for moisture vaporisation is less than thermal energy came from MW, which may cause overheating or charing (Lu *et al.*, 1999).

According to Fig. 4 and Table 1, it can be seen that heating-up and falling rate drying periods were relatively short in the whole drying processing, which could be

Table 1 Average drying rate of carrot in different drying period by different combined MW drying

Drying period		MWFD	MWVD	MWSD, 2.0 w g^{-1}	MWSD, 3.5 w g^{-1}
Heating-up period	Time (min)	65	12	8	6
	Drying rate (% w.b min^{-1})	0.18	0.67	1.12	1.33
Faster drying period	Time (min)	190	55	37	31
	Drying rate (% w.b min^{-1})	0.32	1.18	1.84	2.33
Falling rate drying period	Time (min)	80	25	18	12
	Drying rate (% w.b min^{-1})	0.09	0.37	0.78	0.83
Total average drying rate (% w.b min^{-1})		0.26	1.22	1.41	1.80

MW, microwave; MWFD, microwave-assisted freeze drying; MWVD, microwave-assisted vacuum drying; MWSD, microwave-enhanced spouted bed drying.

attributed to quick energy conversion from MW to thermal. In fact, it also could be used to explain that the drying rate of MWVD, MWFD and MWSD is faster than conventional drying methods.

Effect of different combined microwave drying on rehydration ratio

The rehydration characteristics of the dried product were used as a quality index because they could indicate the physical and chemical changes of samples during drying. The effect of the three combined MW drying on rehydration ratio is shown in Fig. 5. It shows that compared with other methods, the carrot dried by MWFD had a good rehydration capability, even nearly the same with the rehydration capacity of FD products. The rehydration ratio of carrot pieces dried by MWSD and MWVD were almost same. In addition, the products dried by MWSD with higher microwave energy showed a relative high rehydration capacity ($P \le 0.05$). After a period of time, the dehydration ratio of the three combined MW-drying products were the same, which indicated that the rehydration capacity of combined microwave dried products were good. The rapid evaporation of moisture in the carrot pieces induced a porous structure, which in favour of the rehydration of products. Feng & Tang (1998) reported that apples dried by MWSB had higher rehydration capacity compared to spouted bed–dried and hot-air-dried apples, which was in agreement with this study.

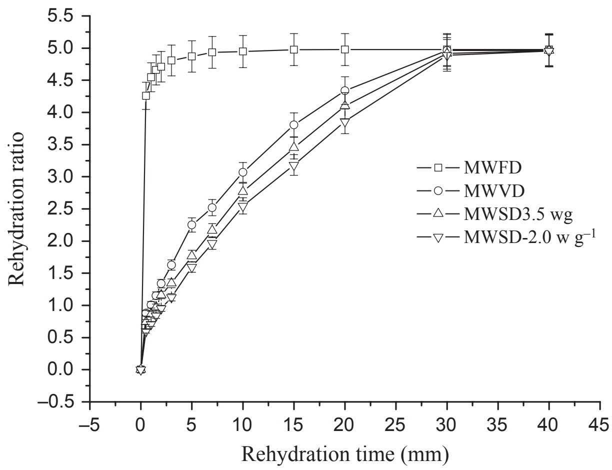

Figure 5 Rehydration ratio of carrot pieces dried by different drying method.

Colour and drying uniformity

The colour differences of the dried carrot slices between combined MW drying and FD drying methods are shown in Table 2. The MWFD products had the best colour ($P \le 0.05$). Other combination drying processes resulted in lower values of L ($P \le 0.05$). MWVD only induced a decrease in yellowness ($P \le 0.05$). However, for the MWSD carrot pieces, there was a decrease not only in redness but also in yellowness. There was no significant difference about the L, a, b and ΔE values ($P > 0.05$) among the MWSD carrot pieces dried with different microwave power. The result indicated that the carrot slices colour dried by MWFD and MWVD methods were very close to those dried by FD method. And combined MW drying can be able to maintain the colour of products well after blanching.

There was no significant difference among three MWSD dried carrot pieces, which not means that all products have the same colour. Drying uniformity was expressed as the numbers of charring carrot slice per 100 random carrot slices and the results are shown in Table 3. It was observed that some charring appeared in MWVD experiments and relatively low in MWFD. This was in good agreement with the results reported in Feng & Tang (1998). The main cause was the nonuniformity of microwave absorption in MWVD, which can induce overheating in the last stage of drying process. However, this phenomenon was not observed in MWSD products. The carrot pieces in MWSD can evenly absorb microwave energy in the microwave field because of the effect of fluidisation. Therefore, the MWSD products had the best uniformity.

Table 2 Colour parameters of carrots dried and rehydrated by different drying methods

Drying method	L	a	b	ΔE
FD	42.72 ± 1.12[a]	26.35 ± 0.87[a]	24.23 ± 1.03[a]	0.00
MWFD	41.23 ± 0.94[a]	25.84 ± 1.02[a]	23.65 ± 1.32[a]	1.71[c]
MWSD-3.5	36.65 ± 1.45[b]	23.56 ± 0.95[b]	21.76 ± 0.69[c]	7.18[a]
MWSD-2.0	35.94 ± 2.03[b]	22.86 ± 0.86[b]	20.12 ± 1.43[c]	8.69[a]
MWVD	37.27 ± 0.99[b]	23.93 ± 0.74[b]	22.37 ± 0.97[b]	6.31[b]
Rehydration				
FD	39.13 ± 1.32[a]	25.87 ± 0.84[a]	25.42 ± 1.22[a]	0.00
MWFD	38.44 ± 1.08[a]	24.75 ± 1.03[a]	24.57 ± 0.89[a]	1.58[c]
MWSD-3.5	33.82 ± 2.01[c]	23.98 ± 1.67[c]	19.30 ± 1.45[b]	8.34[a]
MWSD-2.0	32.77 ± 1.04[c]	23.13 ± 1.23[c]	18.47 ± 1.06[b]	9.86[a]
MWVD	34.20 ± 1.25[b]	24.95 ± 0.79[a]	22.63 ± 0.97[b]	5.71[b]

FD, freeze-dried; MWFD, microwave-assisted freeze drying; MWVD, microwave-assisted vacuum drying; MWSD, microwave-enhanced spouted bed drying.
[abc]different letters in the same column indicate a significant difference ($P \leq 0.05$).

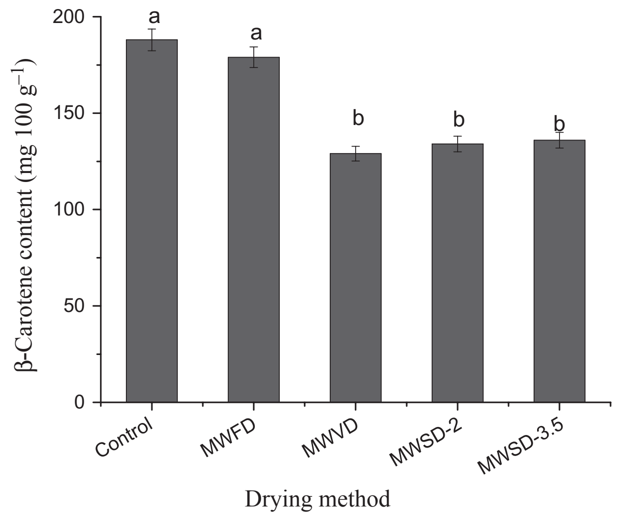

Figure 6 β-Carotene content (based on original sample weight) of carrot pieces dried by different drying method, control mean the value of carrot pieces after blanched. Note: Different letters indicate a significant difference ($P \leq 0.05$).

Effect of different combined microwave drying on β-carotene and vitamin C content

Carotenoids are widely known as pro-vitamin A and have many physiological functions, such as the anti-cancer activity, protection against cardiovascular disease, cataract prevention. (Beveridge, 2002). Some researches had indicated that heat, oxidation and other conditions can cause the carotene degradation (Kalt *et al*., 1999). Pesek & Warthesen (1987) observed the carotene degradation in vegetable juice system and the degradation following first-order kinetics. Therefore, carotene content was an important quality index for evaluating the effect of MW-related drying.

The β-carotene content changes in carrots dried by different combined MW drying methods are shown in Fig. 6. It can be seen that the β-carotene content in MWFD carrot pieces was the highest and the value was close to the number of fresh carrot (control value). However, compared to the fresh carrot, the β-carotene contents of MWSD and MWVD carrot pieces decreased to the similar level (about 70% of the control). This result can be explained that the temperature of MWFD was low and carrots were dried under a high vacuum condition which reduces the oxidation and degradation of β-carotene. On the other hand, in MWVD and MWSD, samples were exposed to the higher

Table 3 The numbers of charring dried carrot slices among 100 pieces by different drying methods

	MWFD	MWVD	MWSD, 2.0 w g^{-1}	MWSD, 3.5 w g^{-1}
The numbers	1.1[b]	5.6[a]	0[c]	0[c]

MWFD, microwave-assisted freeze drying; MWVD, microwave-assisted vacuum drying; MWSD, microwave-enhanced spouted bed drying. Sampled randomly 100 dried carrot slices of different drying methods and observed charring carrot pieces by eyes, five parallel experiments were carried out.
[abc]different letters in the same line indicate a significant difference ($P \leq 0.05$).

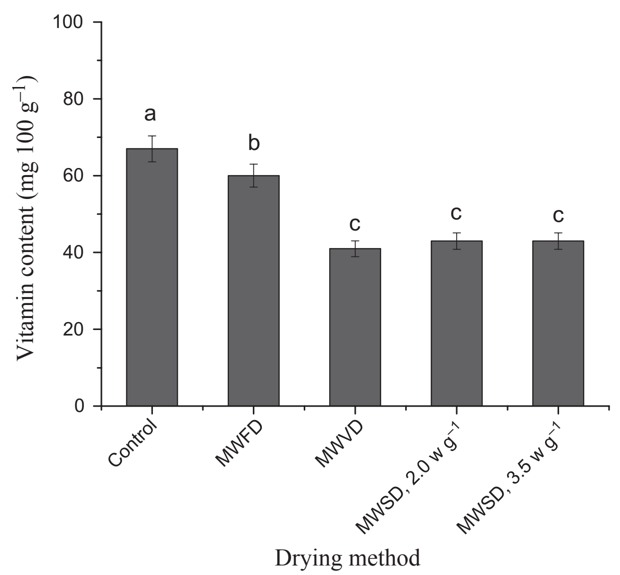

Figure 7 The retention of vitamin C (based on original sample weight) in carrot slices by different drying methods. Note: Different letters indicate a significant difference ($P \leq 0.05$).

temperature and the hot air. Although more degradation and oxidation of β-carotene existed in MWVD and MWSD products, the retention rate of β-carotene in carrot pieces dried by the two methods were about 70% because of the relatively shorter drying times.

Compared to β-carotene, vitamin C is more sensitive to heat, oxygen and light. Therefore, the retention of vitamin C was used as one indicator of the dried carrot pieces quality. The retention of vitamin C in carrot pieces by different drying methods is shown in Fig. 7. It can be seen the vitamin C content was highest in MWFD samples and it was close to the content of the control. ($P > 0.05$), while the vitamin C content was relative low in MWVD and MWSD samples and the value of these two were very close ($P > 0.05$). It suggested that vitamin C content in dried products would decrease significantly with drying temperature, because drying temperature in MWVD and MWSD was higher than MWFD. Some researches also reported that the negative effect of temperature on vitamin C (Lin *et al.*, 1998 and Yen *et al.*, 2008).

Sensory evaluation

The data of the sensory scores of the finished products can be observed in Table 4. It can be seen that the total score of carrot slices dried by MWFD was the highest followed by MWVD and MWSD. There were significant differences in appearance and texture among different drying methods ($P \leq 0.05$), while no significant differences in colour and flavour ($P > 0.05$). This result was in agreement with the Table 4. It was worthy to mention that although the score of carrot slices dried by MWVD and MWSD were not as high as that of MWFD products, these scores were also high to exceed nine points, which means that these carrots slices also can be accepted by consumers.

Table 4 The result of sensory evaluation on carrot slices dried by different drying methods

Drying method	MWFD	MWVD	MWSD, 2.0 w g^{-1}	MWSD, 3.5 w g^{-1}
Appearance	3.6^{a}	2.9^{b}	2.8^{b}	3.0^{b}
Colour	2.8^{a}	2.7^{a}	2.5^{a}	2.6^{a}
Flavour	2.4^{a}	2.5^{a}	2.3^{a}	2.7^{a}
Texture	2.7^{a}	2.4^{b}	2.5^{b}	2.3^{b}
Total scores	11.5^{a}	10.8^{b}	10.6^{b}	10.8^{b}

MWFD, microwave-assisted freeze drying; MWVD, microwave-assisted vacuum drying; MWSD, microwave-enhanced spouted bed drying.
^{ab}different letters in the same line indicate a significant difference ($P \leq 0.05$: $n = 12$).

Energy consumption

The energy consumptions during different drying processes are summarised in Fig. 8. It can be seen that the energy required by MWFD was very high, while MWVD and MWSD were lower. This may because the drying time for MWFD was long, about five times longer than MWVD and MWSD, and more energy was needed to maintain a high vacuum and low temperature situation in the cold trap. By comparison, among the three combined MW drying, energy consumption of MWVD and MWSD can save about 75% energy than MWFD. There was no significant difference of energy consumption between MWVD and MWSD ($P > 0.05$). The results were the same to the conclusion drawn by Chen *et al.* (2001) and Mujumdar (2001).

Conclusions

MW-related drying could shorten the first and the last drying period. Compared with the traditional drying methods, combined microwave drying can significantly shorten the drying time. By comparing the three MW-related drying methods, the drying rate in MWSD was the fastest, and the rehydration ratio and nutritional content of MWFD carrot pieces were the best, while the energy consumption in MWFD was the highest. In addition, the uniformity of colour was the best in MWSD carrot and it was the worst in MWVD carrot. It suggested that MWSD is a very valid method for overcoming the uneven characteristics that was occurred in alone MW drying.

Finally, the three MW-related drying methods were all better than alone MW drying. However, every MW-related drying method has its limitation on energy

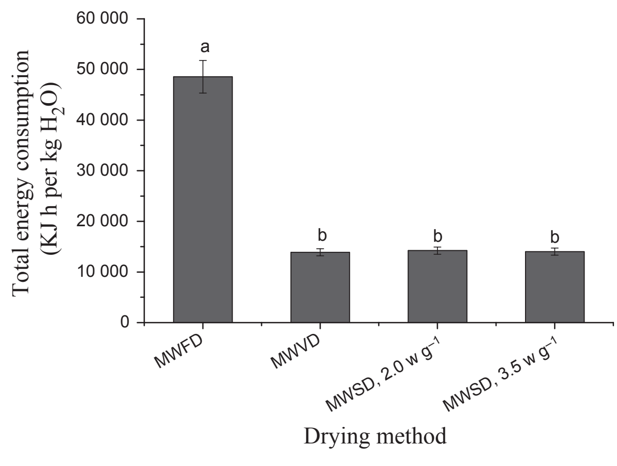

Figure 8 Comparison of the energy consumption of different drying methods. Note: Different letters indicate a significant difference ($P \leq 0.05$).

consumption or colour and nutrients maintaining. How to choose a suitable drying method depends on the different specific demand of the industry.

Acknowledgments

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