Effect of Different Drying Methods on Physicochemical Properties and Antioxidant Activities of Postharvest Okra Pods

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Abstract: Effects of hot-air drying (HD) and microwave drying (MD) methods on the physicochemical properties and antioxidant activities of postharvest okra was investigated. The weight loss rate and the contents of vitamin C, chlorophyll a, protein, soluble pectin as well as antioxidant activities of okra pods were determined. The results showed that HD and MD methods had significant influences on the physicochemical properties and antioxidant activities. The weight loss rate of okra treated by HD method was 87.45%, and it was 75.04% treated by MD. Both of them presented lower contents of chlorophyll a with a ranges of 0.33 ± 0.01 mg/g and 0.23 ± 0.02 mg/g. The protein contents of the HD was 16.38 ± 0.49%, and 9.16 ± 0.11% for MD method. The soluble pectin contents were 29.1 ± 0.76 mg/g and 28.26 ± 0.57 mg/g for HD and MD methods, respectively. It indicated that the nutrients in okra pods are susceptible to thermal processing, and the high temperature will significantly reduce the nutritional value. The specific conditions for different thermal processes should be studied and optimization.

Keywords: Okra pods; Hot-air drying; Microwave drying; Physicochemical properties; Antioxidant activities

1. Introduction

Okra (*Abelmoschus esculentus* (L.) Moench), also known as lady's finger, gumbo, guinogombo, guibeiro and bhindiin[1], belongs to the family Malvaceae[2], which is an annual flowering plant grown in tropical and Mediterranean climates especially in southeast Asia, Africa, southern states of the USA, and the Middle East[3,4]. It is a rich source of nutrients like protein, vitamin C, pectin, fiber, calcium, iron and zinc, furthermore with great amount of bioactive components[5]. The main edible part of okra is tender fruit with unique taste and rich nutrition, due to which okra is popular by the general consumes[6].

Drying refers to the process of vaporizing and evaporating water in food under natural or artificial conditions. It plays an important role in the food preservation, effectively preserving the fresh vegetables and fruits, preventing the growth of spoilage microorganisms and prolonging their quality guarantee period[7]. If vegetables and fruits are effectively dried, the products will be provided for people even when they are off-season[8].

On account of the high water contents and respiration rate, okra has a short shelf-life and extremely perishable[9].Therefore, drying has become one of the important means of processing and preserving okra. In this paper, the effects of hot-air drying (HD) and microwave drying (MD) procession on the change of weight loss rate and the contents of vitamin C, chlorophyll a, protein, soluble pectin as well as antioxidant activities of okra were studied. The aim of this study was to optimize the drying and processing technology of okra, improve its quality and prolong its storage period.

2. Materials and methods

2.1. Plant materials

The fresh okra fruits were purchased from a supermarket (Zhanjiang, China) in July 2018. Fruits were selected for uniformity of size, shape and color, with no plant diseases and insect pests. Then cleaned and blotted up with

filter paper to remove the excess water. Separating the okra randomly into three groups for the drying experiments.

2.2. Drying experiments

Hot-air drying (HD):The okra fruits were spread on trays to a single layer, which were placed in the dryer using parallel air flow at 60 °C .The drying lasted for 40 h.

Microwave drying (MD): Lay fresh okra neatly on a microwave plate adopting a piecewise drying method to dry the okra at 1 300 w for totally 8 min .

2.3. Scanning electron microscopy (SEM) analysis

The samples were cut into slices to observe the micro-structure of okra, using a scanning electron microscopy (SEM). The acceleration voltage is 3000 V, and the image magnification factor is 2000 times.

2.4. Weight loss rate

Weight loss was measured according to the following formula, and expressed by fresh weight:

$$\text{Weight loss}\,(\%) = \frac{\text{original weight - weight after drying}}{\text{original weight}} \times 100\%$$

2.5. Chlorophyll a

The chlorophyll a content of okra was determined according to the method of Arnon[10],and expressed as mg/g by dry weight.

2.6. Protein

The protein content of okra was determined by automatic Kjeldahl analyzer, and expressed by dry weight.

2.7. Vitamin C

Vitamin C content of okra was determined by 2,6-dichlorophenol indophenol titration, and expressed as mg/100 g of vitamin by dry weight.

2.8. Soluble pectin

The content of soluble pectin was determined by spectrophotometer method (NY/T 2016-2011**)** and the results was expressed as mg/g of soluble pectin by dry weight [11].

2.9. Total antioxidant capacity

The total antioxidant capacity was determined with T-AOC kit, and the OD value was measured with ultraviolet spectrophotometer and the wavelength of 520 nm. At 37 °C, per minute per mg tissue protein increase the reaction system of absorbance value (OD) 0.01 total antioxidant capacity unit (U/mg).

2.10. Statistical analysis

Statistics as well as analysis all experimental data using Origin 9.0. Results were presented as means ± SD for three replications.

3. Results and discussion

3.1. Effects of different drying methods on the micro-structure of okra pods

The microstructure of okra dried with different methods were analyzed using a scanning electron micrograph, and the results were displayed in Figure 1. Dry treatment has a great influence on the microstructure of the samples, which cause the cell tissue to shrink, and thus there are many holes improving the drying efficiency. The HD samples had many holes and trastructure like honeycomb, therefore it had a higher degree of dehydration. Because of the high power and the non-uniform heating, the internal local temperature was quite high, which destroyed the cell structure and made it interweave together. Otherwise, the pore structure shrinks and deforms, and the degree of drying was not complete.

3.2. Effect of different drying methods on weight loss rate of okra pods

As showed in the Figure 2, two drying methods were used in the experiment. Treated by hot-air drying (HD), the weight loss rate of okra reached 87.45%,which of the microwave drying (MD) was only 75.04%. The reason of the difference is that the performance of the drying equipment is different so as to the efficiency is not the

same too. Hot-air drying is defined as a process of moisture loss along with mass and energy transfer, usually removes water by evaporation[12]. It has advantages of high production capacity and convenient operation, but takes a lot of time to dry the okra. Compared with what above mentioned, owing to the same transfer direction of temperature and moisture, microwave drying (MD) can offer many advantages such as great energy efficiency and high heat transfer rate[13].Though microwave drying (MD) cost only a little time, it also has its own disadvantages. On the one hand, it's difficult to control the drying process. On the other hand, since its local temperature can easily rise to a level that causes scorching, it has frequently appeared phenomenon of local coke if dry too many samples at the same time. As a result, it's better to adopt a piecewise drying method to dry the okra pods.

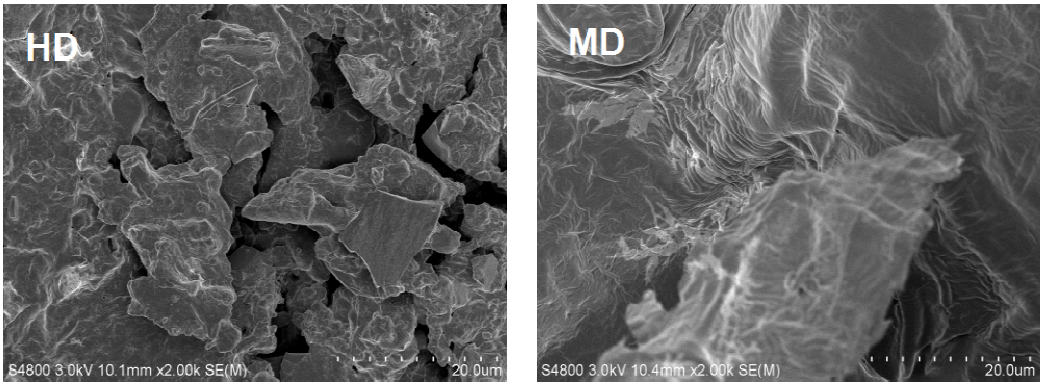

Fig. 1 Scanning electron micrographs (× 2000) of okra dried with different methods (HD, hot-air drying; MD, microwave drying)

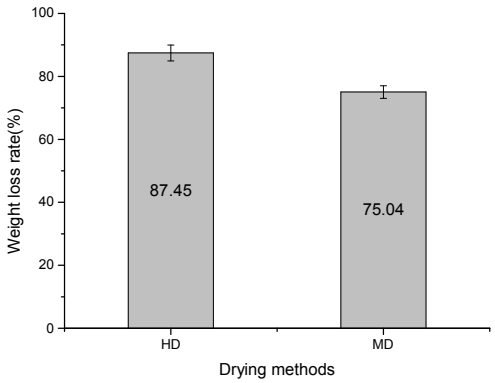

Fig. 2 Effect of different drying methods on weight loss rate of okra pods

3.3. Effect of different drying methods on chlorophyll a, protein, vitamin C and soluble pectin contents of okra pods

The contents of chlorophyll a, protein , vitamin C, and soluble pectin of different drying methods of okra are presented in Table 1. As we can see, the content of chlorophyll a of fresh fruit was 1.00 ± 0.07 mg/g, protein content was 20.18 ± 0.32%, vitamin C content was 11.55 ± 0.11 mg/100g, and the soluble pectin content was 65.64 ± 0.81 mg/g.

Samples subjected to hot-air drying and microwave drying presented lower chlorophyll a content of 0.33 ± 0.01 mg/g and 0.23 ± 0.02 mg/g, respectively. Compared with fresh fruits, the content of chlorophyll a reduced by 67.00% and 77.00% after hot-air drying and microwave drying. It indicated that heating decreased the content of the chlorophyll a.

A significant effect was noted on the protein content in all samples. The protein content of the hot-air drying (16.38% ± 0.49%) sample was higher than microwave drying (9.16% ± 0.11%). Compared with fresh fruits, the content of protein decreased by 18.83% and 54.61% after hot-air drying and microwave drying. Heating damages the structure of the protein cells, and then weakens the three-dimensional conformation of the protein cells, eventually leading to the loss of the protein and the reduction of the protein content in the sample[14,15].

Vitamin C is a very important vitamin in plant tissues. From Table 1,the content of hot-air drying was 8.25 ±

0.39 mg/100g and the microwave drying was 8.04 ± 0.34 mg/100 g. Compared with fresh fruits, the content of Vitamin C reduced by 28.57% and 30.39% after hot-air drying and microwave drying. These results indicated that vitamin C was easy to be decomposed at higher temperature and higher microwave power[16].

Pectin is one of the main ingredients of okra. The soluble pectin content of fresh okra was as high as 65.64 ± 0.81 mg/g. However, samples subjected to hot-air drying and microwave drying presented lower soluble pectin contents of 29.1 ± 0.76 mg/g and 28.26 ± 0.57 mg/g, respectively. Compared with fresh fruits, the content of soluble pectin decreased by 55.67% and 56.95% after hot-air drying and microwave drying.

It can be concluded from the above that the nutrients in okra are susceptible to temperature, and the high temperature will reduce the content of each component. When selecting drying method, the effect of specific conditions in each process on the sample should be considered.

Table 1. Effect of different drying methods on chlorophyll a, protein, vitamin C and soluble pectin contents of okra pods

Drying methods	Chlorophyll a (mg/g)	Protein(%)	Vitamin C (mg/100 g)	Soluble pectin (mg/g)
Fresh fruit (FF)	1.00 ± 0.07	20.18 ± 0.32	11.55 ± 0.11	65.64 ± 0.81
Hot-air drying (HD)	0.33 ± 0.01	16.38 ± 0.49	8.25 ± 0.39	29.10 ± 0.76
microwave drying (MD)	0.23 ± 0.02	9.16 ± 0.11	8.04 ± 0.34	28.26 ± 0.57

3.4. Effects of drying methods on total antioxidant capacity of okra pods

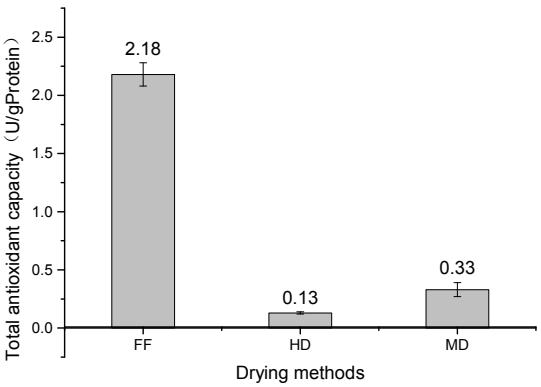

Fig. 3 Effect of different drying methods on total antioxidant capacity of okra pods

Figure 3 showed that different drying methods had certain effect on total antioxidant capacity of okra. The total antioxidant capacity of HD sample was 0.13 ± 0.01 U/g protein while the MD sample was 0.33 ± 0.06 U/g protein. Compared with HD and MD samples, FF samples had the strongest antioxidant capacity (2.18 ± 0.1 U/g protein), which was 16.77 and 6.61 times as much as HD and MD samples.

4. Conclusions

In summary, the present study demonstrated that drying methods, like hot-air drying and microwave drying, had noticeable influences on the physicochemical properties of okra. The weight loss rate of okra treated by hot-air drying (HD) was 87.45% whereas treated by microwave drying (MD) was 75.04%. Hot-air drying and microwave drying presented lower chlorophyll a content of 0.33 ± 0.01 mg/g and 0.23 ± 0.02 mg/g. The protein content of the hot-air drying was 16.38 ± 0.49%, while microwave drying was 9.16 ± 0.11%. The soluble pectin content of the hot-air drying was 29.1 ± 0.76 mg/g, which was higher than microwave drying of 28.26 ± 0.57 mg/g. It can be concluded from the above that the nutrients in okra are susceptible to temperature, and the high temperature will reduce the content of each component. When selecting drying method, the effect of specific conditions in each process on the sample should be fully considered.

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