

An Investigation on Drying Efficiency of Four Different Drying Methods

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Abstract

In this research work, selected vegetables (i.e. pumpkin, okra and ginger) were dehydrated by four different drying methods: by hot air oven, by the combination of hot air oven and microwave oven, by heated dehumidified air dryer, by sun drying. Drying characteristics such as drying time, drying yield and drying ratio of four different drying methods were studied for each selected vegetable. Comparative study of the four different drying methods showed that drying by combination of hot air oven and microwave oven had decreased the drying time of vegetables with higher energy and drying efficiency. The storage life of dehydrated products from four different drying methods was also determined in this work.

Keywords: drying method, drying time, drying yield, drying ratio

Introduction

The technique of drying is probably the oldest method of food preservation practised by mankind. The removal of moisture prevents the growth and reproduction of micro-organisms causing decay and minimizes many of the moisture mediated deterioration reactions (Dauthy, 1995). Foodstuffs may be dried in air, superheated steam, in vacuum, in inert gas, and by the direct application of heat (Desrosier, 1970). A current of air is the most common medium for transferring heat to a drying tissue and convection is mainly involved (Dauthy, 1995).

An acceptable dehydrated food should be competitive pricewise with other types of preserved foods, have a taste, odor and appearance comparable with the fresh product or with product processed by other means, reconstitute readily, retain nutritive values, and have good storage stability (Desrosier, 1970).

There are many types of dryers used in the dehydration of foods, the particular type chosen being governed by the nature of the commodity to be

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dried, the desired form of the finished product, economics, and operating conditions (Desrosier, 1970). There are mainly three groups of dryers used for producing a dry, solid product from a wet feed. They are direct dryers, infra-red or radiant heat dryers and indirect dryers. In Direct Dryers, heat transfer for drying is accomplished by direct contact between the wet solid and hot gases. The operations of Infra-red or Radiant Heat Dryers depends on the generation, transmission and absorption of infra-red rays. In Indirect Dryers, heat for drying is transferred to the wet solid through a retaining wall (Perry, 1949).

Irradiation and microwave heating represent relatively new technologies as applied to foods (Potter, 1976). An advantage of using microwave energy is the possibility of combining multiple drying methods. Combination of convection hot air drying with microwaves offers reduced drying times and improved food quality. In addition to hot air, microwaves can also be combined with freeze drying or vacuum drying (Schubert, 2005).

In this research work, the selected vegetables (i.e. pumpkin, okra and ginger) were dehydrated by four different drying methods. The aim of this work has been undertaken with a view to compare the drying efficiency of the four different drying methods to produce high quality dried products. In this study, particular emphases on drying time, drying yield, drying ratio, re-hydration ratio and storage life of the dried products were undertaken.

The objectives of the work were:

- To determine the effect of drying methods on drying behaviours of selected vegetables;
- To evaluate the quality of dried products produced by different drying methods; and
- To investigate the most effective method for each selected vegetables.

Materials and Methods

Preparation of Materials

Pumpkin (*Cucurbita pepo*), okra (*Hisbiscus esculentus*) and ginger (*Zingiber officinale*) were used for dehydration in this study.

Pumpkin: Pumpkin was cut into pieces; seeds and cavity pulp were removed, and washed thoroughly with water to remove all adhering dirt. It was then peeled and sliced into 1/8 inch pieces.

Okra: Okra pods were washed thoroughly with water until the dirt and foreign matters were removed. It was then placed on a plastic screen for (10) minutes and most of the water were drained off. The washed pods were trimmed and cut into half crosswise.

Ginger: Ginger was peeled and washed thoroughly with water to remove all adhering dirt, sand, mud and undesirable matter. The washed ginger was strained for (10) minutes and then sliced into 1/8 inch thick slices.

Dehydration of Vegetables

Sun Drying

(500) g each of previously prepared samples were spread uniformly on perforated trays and exposed to the sun until the samples were completely dry. The dried samples of pumpkin, okra and ginger were weighed, and the drying time required for each samples were recorded.

Hot Air Oven Drying

(500)g of pumpkin slices were weighed in a previously weighed container and transferred to the trays of hot air oven which was preset at a temperature of (60°C). Then, the pumpkin slices were dehydrated in hot air oven until the samples were completely dry.

The above experiment was again repeated for dehydration of okra and ginger. The time required for dehydration of each selected vegetable was recorded.

Combined Hot Air Oven and Microwave Oven Drying

(500)g of prepared pumpkin slices were weighed in a previously weighed container and dried in trays of hot air oven preset at (60°C) until its moisture content reached 20%. And then, this partially dried pumpkin slices were further dehydrated in a microwave oven at a temperature of (50°C) until completely dry sample of pumpkin was obtained.

The same procedure was carried out for okra and ginger dehydration, and the time required for the dehydration of each vegetable was recorded.

Drying by Heated Dehumidified Air Dryer

(500)g of pumpkin slices were weighed in a previously weighed container and placed evenly on the tray of heated dehumidified air dryer preset at (60°C). Then the pumpkin slices were dehydrated until the samples were completely dry.

Similarly, okra and ginger were dehydrated in the same manner as in pumpkin drying, and drying time for each sample was recorded.

Determination of Drying Characteristics

Drying Ratio and Drying Yield

Calculation of drying ratio and drying yield of dehydrated vegetables (pumpkin, okra and ginger) obtained from different drying methods were carried out by using the following formulae:

$$\text{Drying ratio} = \frac{\text{Weight entering dryer}}{\text{Weight leaving dryer}}$$

$$\text{Drying yield} = \frac{\text{Weight leaving dryer}}{\text{Weight entering dryer}}$$

Re-hydration Ratio

About (10) g of dried sample was cooked with (300) ml of water for (20) minutes. After cooking, the sample was cooled for (45) minutes and the excess water was drained off. Finally, the reconstituted product was weighed, and its rehydration ratio was determined as follows:

$$\text{Re-hydration ratio} = \frac{\text{Weight of reconstituted product}}{\text{Weight of dehydrated material}}$$

Determination of Moisture Content

Moisture contents of dried samples were determined according to the recommended method of the Association of Official Analytical Chemist.

Determination of Mold on Dried Vegetables

Microorganism (Mold) on dried vegetables was tested at Development Centre for Food Technology, Ministry of Industry and the results are shown in Table (5).

Determination of Storage Life

In order to examine the storage life, the dried vegetables were placed in air tight plastic bags and examine under ambient condition at every two weeks interval and the results were recorded in Table (6).

Results and Discussion

Drying Time

In the present work, selected vegetables (i.e. pumpkin, okra and ginger) were dehydrated by four different drying methods; by sun drying, by hot air oven, by combination of hot air oven and microwave oven, and by heated dehumidified air dryer. The important steps undertaken prior to dehydration of vegetables include producing desired thickness, size and

form of the materials as the uniformity of the sample individually or collectively influenced the drying time and the product quality. From the results of **Table 1**, it was found that different methods require different drying time for dehydration of selected vegetables. It is quite clear that drying time vary considerably depending on the type of food, its moisture content and method of drying. The dehydration of vegetables by natural drying (sun drying) is relatively slow because the sun does not cause rapid evaporation of moisture. Drying under controlled temperature condition in conventional methods (i.e. drying by hot air oven and, drying by heated dehumidified air dryer) was found to have shorter drying time than sun drying. Comparative study between drying by hot air oven and drying by heated dehumidified air dryer showed that drying time required by the heated dehumidified air dryer was shorter than that of hot air oven because the dryer was fitted with dehumidifier unit, heat exchanger unit and exhaust fan to dry food more efficiently. Amongst the four different drying methods used in this work, the application of combined hot air and microwave oven dehydration was found to be the most effective method for the dehydration of vegetables as the vegetables were effectively dehydrated within a short period as indicated in **Table 1**.

Table (1) Time Required for Dehydration of Vegetables by Different Drying Methods

Vegetables	Method				
	Sun Drying	Hot Air Oven	Hot Air Oven + Microwave Oven		Heated Dehumidified Air Dryer
			Hot Air Oven	Microwave Oven	
Pumpkin	14 hr	12 hr	6 hr	1 min	10.5 hr
Okra	14 hr	11 hr	5 hr	2 min	9.5 hr
Ginger	12 hr	8 hr	4.5 hr	2 min	6 hr

Quality of Dehydrated Vegetables

The main aim of food dehydration is to extend the storage life of food material without microbial spoilage and loss of quality. It is important to preserve as much of the product's nutritive value, natural flavour and cooking quality. One of the most obvious changes during drying of cellular or non-cellular food is shrinkage. Severe shrinkage reduces bulk density and re-hydration capacity. Less dense dehydrated product absorbs water, reconstitute quicker and more closely resembles the original material. On reconstitution of dried vegetables obtained from this work, the size and shape of re-hydrated vegetables were very similar to those of the fresh vegetables used for dehydration. More precisely, re-hydration is expressed as re-hydration ratio as shown in **Tables 2, 3 and 4**. It is predictable that the general bacterial content of product will be reasonably low because there is no development of the undesirable flavor after reconstitution of dried vegetables.

Table (2) Drying Data for Dehydrated Pumpkin

Method of Dehydration	Moisture Content, (Wt %)	Drying Ratio	Drying Yield, (Wt %)	Rehydration Ratio
Sun Drying	10.8	13.72	7.29	5.16
Hot Air Oven	5.6	14.52	6.89	5.35
Hot Air Oven + Microwave Oven	5.2	14.59	6.86	5.41
Heated Dehumidified Air Dryer	5.3	14.57	6.86	5.37

Table (3) Drying Data for Dehydrated Okra

Method of Dehydration	Moisture Content, (Wt %)	Drying Ratio	Drying Yield, (Wt %)	Rehydration Ratio
Sun Drying	11.2	8.54	11.71	4.61
Hot Air Oven	5.5	9.09	11.01	4.65
Hot Air Oven + Microwave Oven	5.2	9.11	10.97	4.78
Heated Dehumidified Air Dryer	5.1	9.12	10.96	4.94

Table (4) Drying Data for Dehydrated Ginger

Method of Dehydration	Moisture Content, (Wt %)	Drying Ratio	Drying Yield, (Wt %)	Rehydration Ratio
Sun Drying	10.5	5.56	17.99	4.87
Hot Air Oven	5.4	5.88	17.02	5.21
Hot Air Oven + Microwave Oven	4.9	5.91	16.93	5.28
Heated Dehumidified Air Dryer	4.6	5.93	16.88	5.32

Storage life of dehydrated vegetables

A major advantage of dehydrated and dried food is that they do not spoil easily. The low level of moisture in the foods limits the growth of bacteria and other microorganisms that cause decay. A product should be dried until its moisture reaches the level recommended for long term storage. The highest water content at which microbial spoilage does not occur in the case of dried foods is: dehydrated vegetables, 14-20%;

dehydrated fruits, 18-25%. According to these literature values, all dehydrated vegetables obtained from the different drying methods have moisture content well below that of the accepted range as shown in **Tables 2, 3 and 4**.

Generally, bacteria and yeast require more moisture than molds, and so molds often will be found on semi-dry foods where bacteria and yeasts find this condition unfavorable. Deterioration of dried foods is particularly concerned with molds. The detection of mold on dried vegetables was carried out at the Development Center for Food Technology, Ministry of Industry (1) and the results obtained were shown in **Table 5**. According to **Table 5** it was noted that all vegetables were sufficiently dehydrated and that the dehydrated vegetables have appreciable moisture content for safe storage.

Storage life of dehydrated vegetables packed in plastic bags and kept under ambient condition was recorded in **Table 6**. According to literature value, the maximum storage life for dehydrated foods is one year. Except for sun dried vegetables, other dehydrated vegetables have appreciable storage life. Storage life of sun dried vegetables is too short and it should be noted that its shelf-life could be extended by finish drying. On the other hand, the moisture content of dried vegetables is not constant because of their hygroscopicity and is always in equilibrium with relative humidity of air in storage rooms. The storage temperature should be below 25°C (and preferably 15°C); lower temperature (0 – 10 °C) help maintain taste, color and water rehydration ratio.

Table (5) Detection of Mold on Dehydrated Vegetables

Week	Dehydrated Vegetables		
	Pumpkin	Okra	Ginger
1	Negative	Negative	Negative
2	Negative	Negative	Negative
3	Negative	Negative	Negative
4	Negative	Negative	Negative
5	Negative	Negative	Negative
6	Negative	Negative	Negative

These tests were carried out at Development Center for Food Technology

Table (6) Storage Life of Dehydrated Vegetables under Ambient Condition

Dehydrated Vegetables	Drying Method	Storage Life (Month)	Remark
Pumpkin	Sun Drying	2	Needs finished drying
	Hot Air Oven	6	
	Hot Air Oven + Microwave Oven	7	
	Heated Dehumidified Air Dryer	6	
Okra	Sun Drying	2	Needs finished drying
	Hot Air Oven	6	
	Hot Air Oven + Microwave Oven	6	
	Heated Dehumidified Air Dryer	6	
Ginger	Sun Drying	2	Needs finished drying
	Hot Air Oven	7	
	Hot Air Oven + Microwave Oven	7	
	Heated Dehumidified Air Dryer	7	

Conclusion

Important feature of the research work involved using microwave oven in combination with hot air oven in the dehydration of vegetables. The results indicated that combining of the two methods of heating and drying avoids skinning effect while providing quick processing. From energy and environmental points of view as well as the global requirement regarding the improvement in the food supply for the growing human population, it is important that drying technology be enhanced in order to reduce spoilage and thus contribute to a higher quality of dried products. The present research will eventually encourage the agricultural production of these vegetables and then also allow exporters to find foreign markets. With the increasing population all over the world, the consumption of fruits and vegetables is ever on the increase. This laboratory scale research will eventually lead to large scale dehydration of fruits and vegetables in Myanmar.

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