Dehydration of Selected Vegetables by Different Drying Methods

Khin Hnin Aye*

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 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 quality of the dried products was examined by their re-hydration ratio, nutritive value and by the determination of microorganism (mold) on the dried products. The storage life of dehydrated products from four different drying methods was also determined in this work.

Keywords: drying time, drying yield, re-hydration ratio, nutritive value, storage life

*Dr., Lecturer, Department of Industrial Chemistry, Dagon University

1. 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). Dehydration involves the application of heat to vaporize water and some means of removing water vapor after its separation from the fruit/vegetable tissues. Hence it is a combined/ simultaneous (heat and mass) transfer operation for which energy must be supplied (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).

Dried and dehydrated foods are more concentrated than any other preserved form of foodstuffs. They are less costly to produce, there is a minimum of labor required, processing equipment is limited, dried food storage requirements are at a minimum, and distribution costs are reduced (one car load of dried, compressed food may equal ten car loads of the fresh commodity). 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 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 vaporized liquid is carried away by the drying medium, i.e. the hot gases. Direct dryers must also be termed convection dryers. The operations of Infra-red or Radiant Heat Dryers depends on the generation, transmission and absorption of infra-red rays. They operate on the principle of heat generation within the solid by placing the latter in a high frequency electric field. Radiant heat dryer might also be termed dielectric heat dryers. In Indirect Dryers, heat for drying is transferred to the wet solid through a retaining wall. The vaporized liquid is removed independently of the heating medium. Rate of drying depends on the contacting of the wet material with hot surface. Indirect dryers might also be termed conduction or contact dryers (Perry, 1949).

Irradiation and microwave heating represent relatively new technologies as applied to foods. Food irradiation is seen primarily as a preservation method, but also has a potential as a more general unit operation to produce specific changes in food materials. Microwave energy, on the other hand, has been employed especially to produce rapid and unique heating effects, one application of which can be food preservation (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

[*]Dr., Lecturer, Department of Industrial Chemistry, Dagon University

to hot air, microwaves can also be combined with freeze drying or vacuum drying. Use of microwave energy in drying offers some advantages as it complements well conventional drying in later stages by targeting specifically the internal moisture of the product (Schubert, 2005).

In this research work, the selected vegetables (i.e. pumpkin, okra and ginger) were dehydrated by four different drying methods. 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, nutritive value and storage life of the dried products were undertaken.

2. MATERIALS AND METHODS

2.1 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.

2.2 Analysis of materials

The crude protein (Kjeldahl, N x 6.25), fat (solvent extraction), crude fibre, ash and moisture were determined according to the recommended methods of the Association of Official Analytical Chemists (AOAC, 1984). The digestible carbohydrate was calculated by difference.

2.3 Dehydration of vegetables

2.3.1 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.

2.3.2 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 drying time required for dehydration of pumpkin by hot air oven was recorded.

The above experiment was again repeated for dehydration of okra and ginger. The dried vegetables were cooled, weighed and stored in air-tight containers.

*Dr., Lecturer, Department of Industrial Chemistry, Dagon University

2.3.3 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 repeated for okra and ginger dehydration, and the time required for the dehydration of each vegetable was recorded.

2.3.4 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 their results were recorded.

2.4 Determination of 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:

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

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

2.5 Determination of 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:

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

2.6 Analysis of dehydrated vegetables

The recommended methods of the Association of Official Analytical Chemists (AOAC, 1984) were adopted to determine the levels of moisture, ash, crude protein, fibre and fat. The digestible carbohydrate was calculated by difference.

2.7 Determination of microorganism (Mold)

Microorganism (Mold) on dried vegetables was tested at Development Centre for Food Technology, Ministry of Industry (1).

*Dr., Lecturer, Department of Industrial Chemistry, Dagon University

3. RESULTS AND DISCUSSION

3.1 Drying time

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

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**.

*Dr., Lecturer, Department of Industrial Chemistry, Dagon University

3.2 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 3**, **4** and **5**. The method of refreshing and cooking will also affect the results. 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.

The determination of nutritional values of dehydrated vegetables obtained from different drying methods was carried out and the results are shown in **Tables 6**, **7** and **8**. These results clearly indicated that the nutritional values of the dehydrated vegetables are very close to that of literature values and that the dried vegetables from the present work were of high quality products.

Table 2 Chemical composition of fresh vegetables

Chemical Composition (wt %)	Pumpkin	Okra	Ginger
Moisture	93.5	89.6	83.9
Ash	0.7	1.0	1.5
Fat	0.1	0.1	0.6
Fibre	1.1	1.6	2.4
Protein	0.9	1.7	1.5
Carbohydrate	3.7	6.0	10.4

[*]Dr., Lecturer, Department of Industrial Chemistry, Dagon University

Table 3 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 4 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 5 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

*Dr., Lecturer, Department of Industrial Chemistry, Dagon University

Heated Dehumidified Air Dryer	4.6	5.93	16.88	5.32

Table 6 Chemical Composition of Dehydrated Pumpkin

Chemical Composition (Wt %)	Dehydrated Pumpkin				
	Literature Value	Sun Drying	Hot Air Oven	Hot Air Oven + Microwave Oven	Heated Dehumidified Air Dryer
Moisture	5	10.8	5.6	5.2	5.3
Ash	-	5.6	5.8	5.5	5.8
Fat	-	1.9	2.1	2.4	2.5
Fibre	-	4.8	4.8	3.2	3.6
Protein	13.6	9.5	10.2	10.5	10.8
Carbohydrate	71.1	67.4	71.5	73.2	72.0

Table 7 Chemical Composition of Dehydrated Okra

Chemical Composition (Wt %)	Dehydrated Okra				
	Literature Value	Sun Drying	Hot Air Oven	Hot Air Oven + Microwave Oven	Heated Dehumidified Air Dryer
Moisture	10.8	11.2	5.5	5.2	5.1

*Dr., Lecturer, Department of Industrial Chemistry, Dagon University

Ash	8.1	11.3	10.3	9.8	10.6
Fat	1.2	0.9	1.9	2.2	2.3
Fibre	18.4	19.2	19.5	18.7	19.2
Protein	10.8	8.8	9.6	10.8	10.5
Carbohydrate	50.7	48.6	53.2	53.3	52.3

Table 8 Chemical Composition of Dehydrated Ginger

Chemical Composition (Wt %)	Dehydrated Ginger				
	Literature Value	Sun Drying	Hot Air Oven	Hot Air Oven + Microwave Oven	Heated Dehumidified Air Dryer
Moisture	6.9	10.5	5.4	4.9	4.6
Ash	5.7	7.2	7.2	7.4	6.5
Fat	6.4	5.8	6.4	6.5	6.8
Fibre	5.9	6.5	6.8	7.1	6.7
Protein	8.6	7.3	8.1	8.3	7.8
Carbohydrate	66.5	62.7	66.1	65.8	67.6

3.3 Storage life of dehydrated vegetables

Table 9 Detection of Mold on Dehydrated Vegetables

Week	Dehydrated Vegetables		
	Pumpkin	Okra	Ginger
1	Negative	Negative	Negative

*Dr., Lecturer, Department of Industrial Chemistry, Dagon University

2	"	"	"
3	"	"	"
4	"	"	"
5	"	"	"
6	"	"	"

Table 10 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	

*Dr., Lecturer, Department of Industrial Chemistry, Dagon University

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 are: 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 3**, **4** and **5**.

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 9**. According to **Table 9** 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 10**. 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.

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.

4. 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. It can be concluded that the combined method was capable of producing products with enhanced flavor, color and low moisture content than the other conventional methods. The present research showed that the keeping quality can be extended to seven months but with modern packaging, the shelf life can be more than seven months. 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.

*Dr., Lecturer, Department of Industrial Chemistry, Dagon University

ACKNOWLEDGEMENTS

The author would like to acknowledge Department of Industrial Chemistry, University of Yangon and Department of Industrial Chemistry, Dagon University for the use of laboratory and research facilities at the department. The author would like to thank Development Center for Food Technology, Ministry of Industry (1), for the assistance in the analysis of the fresh samples and dried vegetable products.

REFERENCES

1. Askari, G.R; Emam-Djomeh, Z and Mousavi, S.M, 2006. "Effect of Combined Coating and Microwave Assisted Hot-air Drying on the Texture, Microstructure and Rehydration Characteristics of Apple Slices", SAGE Publications.

2. Brennan, J.G; Butter, J.R; Cowell, N.D and Lilly, A.E.V, "Food Engineering Operations", 2nd Edition, 1981, Applied Science Publisher.

3. Cruss, W.V, 1958, "Commercial Fruit and Vegetable Products, 4th Edition, Mc. Graw-Hill Book Company.

4. Desrosier, Norman W. (Ph.D), 1970, "The Technology of Food Preservation", 3rd Edition, The AVI Publishing Company, INC.

5. Dauthy, M.E, Fruit and Vegetable Processing, 1995.

6. Foust, A.S; Wenzel, L.A; Clump, C.W; Maus, L; Andersen, L.B, "Principles of Unit Operations", 2nd Edition, 1994.

7. Kirk-Othmar, "Encyclopedia of Chemical Technology", 3rd Edition, Volume (8), 1979.

8. Lopp, L.A, "Drying Food", University of Minnesota, Extension Service.

9. Mc. Cabe, W.L; Smith, J.C; Harriot, P, "Unit Oprations of Chemical Engineering", 5th Edition,1993.

10. Manay, N.S; Shadaksharaswamy, M, "Food Facts and Principles", 2nd Edition, 2001.

11. Potter, Norman N. (Ph.D), "Food Science", 2nd Edition, 1976.

[*]Dr., Lecturer, Department of Industrial Chemistry, Dagon University

12. Perry, John H, “Chemical Engineering Handbook”, Asian Students’ Edition, 1949, Mc. Graw-Hill Book Company.

13. Schubert, H and Reigier, M, “The Microwave Processing of Foods”, 2005.

14. Somogyi, L.P and Luh, B.S, “Vegetable Dehydration: Commercial Vegetable Processing”, 2nd Edition, 1988.

15. Toledo, Romeo T, “Fundamental of Food Process Engineering”, 2nd Edition, CBS Publishers and Distributors.

16. UNIFEM (The United Nations Development Fund for Women), 1993, “Food Cycle Technology Source Book No.6 (Drying)”, Intermediate Technology Development Group,UK.

17. Von-Loesecke, Harry W, “Drying and Dehydration of Foods”, 2nd Edition, 1999.

18. Encyclopedia Britinnica,Volume(10), Hazell Watson and Viney Limited, 1961.

19. Encyclopedia.Britinnica, Volume (11), Haell Watson and Viney Limited, 1961.

20. Encyclopedia Britinnica, Volume (18), Hazell Watson and Viney Limited, 1961.

21. Collier’s Encyclopedia, Volume (11), P.F Collier and Son Limited, 1982.

[*]Dr., Lecturer, Department of Industrial Chemistry, Dagon University