American Journal of Food Technology

ISSN 1557-4571

Academic Journals Inc.

www.academicjournals.com

American Journal of Food Technology 7 (5): 311-319, 2012
ISSN 1557-4571 / DOI: 10.3923/ajft.2012.311.319

Effect of Different Drying Techniques on the Quality of Garlic: A Comparative Study

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ABSTRACT

The demand for spices and extracts is growing all over the world, although the spices are exported in a variety of forms in the international spice trade, about 80-85% are sold in the whole ungrounded state. The rest are marketed as ground spices or in mixes and as spice essential oils and oleoresins. Dehydrated garlic as spice is of considerable importance in world trade. The quality of dehydrated product is affected by number of factors and is dependent on the quality of raw material used, method of preparation, processing treatments and drying conditions. The freeze drying applied to the manufacturing of certain foods can result in economically unprofitable products. The difficulties encountered in the heat transfer can be avoided by combining other dehydration methods. The garlic cloves for maximum possible Moisture Loss (ML) and retention of volatile oils (VOR) with minimum changes in sensory quality scores (SQS maximum 20) were subjected to hot air drying (13.3% mL, 17.1/20 SQS, 60% VOR, at 60°C for 3 h), Fluidized Bed Drying (FBD) (17.1% mL, 14.2/20 SQS, 65% VOR at 55°C for 2 h), microwave heating (9.75 mL, 16.9/20 SQS , 75% VOR for 14 sec) and freeze drying treatment (58.8% mL, 19.3/20 SOS, 98.7% VOR). By analyzing their effect on the loss of moisture, volatile oil retention and sensory quality, it could be concluded that Freeze drying operation could be combined with fluidized bed drying to get a product with desirable quality attributes and maximum moisture removal at minimum processing cost.

Key words: Volatile oil retention, moisture loss, sensory quality

INTRODUCTION

India is the land of spices and it accounts for about 35% of the global trade. It is emerging as a global major to export derivatives of spices with a yearly spices production of about 2.5 million tones (Hussain, 1996). Spices and extracts is growing all over the world, although the spices are exported in a variety of forms in the international spice trade, about 80-85% are sold in the whole ungrounded state. The rest are marketed as ground spices or in mixes and as spice essential oils and oleoresins (Edison, 1995). Spices play an important role both in domestic market and in international trade but demand for spice derivatives is more steadily growing than natural spices due to natural flavor, existence of natural antioxidants, cost less by 50%, long shelf life, contamination free, including filth less, moisture less, space requirement and portability (Sethi and Meena, 1971). Garlic (*Allium sativum*) have been used since antiquity for both medicinal as well

Table 1: Chemical composition of garlic

Particulars	Percentage
Moisture	62.00
Protein	06.30
Fat	0.10
Total sugars	4.00
Carbohydrates	29.00
Fibre	0.80
Total ash	1.00
Acid soluble ash	0.52

as culinary purpose. Garlic (*Allium sativum*) has acquired in the folklore of many cultures as a therapeutic agent. According to folk medicine, garlic was used to treat cardiac disease (Khan *et al.*, 2008).

It is a perennial with an underground bulb (head) composed of pungent bulblets commonly called cloves (Bibi *et al.*, 2008). It is used in many biochemical researches (Avci *et al.*, 2005; Aksu *et al.*, 2006; Khataibeh *et al.*, 2006) and agricultural researches (Bhyan *et al.*, 2007; Habibullah Bahar *et al.*, 2007). It has been shown in studies that garlic has different applications as antimicrobial, antitumor, antithrombotic, hypolipidaemic, antiarthritic and hypoglycemic agent (Abdel-Salam *et al.*, 2008; Bali *et al.*, 2011).

The garlic bulbs are valued for their flavor and have wide applications in food (Mishra *et al.*, 2011; Puranik *et al.*, 2011; Dewi *et al.*, 2011) and their antimicrobial, antifungal, insecticidal and antioxidative properties (Kalra, 1987). The proximate composition of garlic is given in Table 1. Dehydrated garlic is of considerable importance in world trade. Dehydrated garlic differs from fresh garlic in respect of antibacterial activity, allicin, allylsulphide, color, flavor, etc. The quality of dehydrated product is affected by number of factors and is dependent on the quality of raw material used, method of preparation, processing treatments and drying conditions (Pruthi, 1994).

Spices used primarily in food not only to make bland diet tasty but also to provide variety to the food in which they are added. So, the need to preserve or maintain the quality and safety of spices is of paramount importance. Since the methods of preserving foods effects the nutritional content and taste of the food, preservation has always been a challenging topic and extensive research is needed from processing point of view, to obtain desired quality in terms of flavor and pungency in the final products such as dry spice, spice powder etc. (Pruthi, 1992).

Thermal processing causes degradation of nutritional content and give a cooked flavor to food, while non-thermal processes have emerged as a sound approach for preservation of foods with little induced degradation of nutritional and sensory properties (Barbosa-Canovas and Swanson, 1994). Out of various dehydration techniques used freeze dehydration typically results in biological products with a porous crust and of superior rehydration capability whereas hot air drying results in a dense product with an impermeable crust. The nutrients are lost during different processing conditions while freeze drying in which the nutrient loss are minimized has the advantage over other methods and also it retains the flavor, sensory quality, wholesomeness and original structure of product. This is an improved method of preparing stable water-soluble product from aroma and flavor bearing materials (Kylink, 1990).

The objective of the research is to develop a dehydration process for the preservation of garlic with little induced degradation of nutritional and sensory properties while having higher retention of flavor/essential oils.

MATERIALS AND METHODS

Indian varieties of garlic bulbs were obtained from the local market (Kanpur). Sartorious electronic top loading balance (Model-1213 MP, Sartorius GMBH, Gottingen, Germany) was used for weighing the sample. Yorco hot air steriliser (oven) [Model-YS1431, Yorco Sales Pvt. Ltd., New Delhi, India],: "Radarange' Microwave oven [Model RG5-145, Amana Refrigeration Inc. Amana IOWA, U.S.A.), Fluidised bed dryer Belt type)[SMST, SM SCIENTECH, Calcutta, India] and freeze dryer (http://www.go-dove.com/event-15883/Abbott-Laboratories-Ltd-Tablet-and-Capsule-Production and-Test-Equip/lot-41/CHRIST-ALPHA-2-4-Laboratory-Freeze-Dryer-Gefriertrockner) were used for drying operations. Glass petriplates were used for drying of cloves in various types of driers.

Selection: The garlic bulbs were sorted and selected for the following characteristics like uniform shape and size, full matured with no greenness without sprouts and firm texture. The selected bulbs were cleaned to remove dust/earth, chaff, dry stalk and any foreign materials.

Separation: The clean bulbs were manually separated into cloves and winnowed to remove dust and dirt. The cloves were graded for their size and only medium sized cloves were taken in the experiment.

Peeling: The outer skin of the cloves was removed off by hand while taking care of the surface of clove to remain undamaged. Whole cloves were used for all the drying operations except freeze-drying. In the latter case, the cloves were into 2-3 mm thick slices to increase the surface area for quick drying. In each case, 100 g of cloves/slices were taken for the drying operations.

Chemical characteristics

Moisture determination: Moisture content in 15 untreated clove samples was estimated as per the standard procedure of ISI 1797 (1973) (Methods of sampling and test for spices and condiments) by Entrainment.

Volatile content determination: The volatile oils in 15 untreated and each treated (after drying) samples were determined by IS standard method as in IS 1797-1973(ISI 1797, 1973).

Sensory evaluation: The sensory analysis of untreated and treated cloves/slices was carried out by a trained panel of 5 members on 5 point scale from excellent to poor. Each time a control sample was used for comparison of samples.

Drying methods

Hot air drying: One hundred gram of garlic cloves were spread evenly in a petridish and kept in the oven for 1, 2 and 3 h at 45, 50, 55, 60, 70 and 75 °C. After each drying period samples were taken out of the oven and put into a dessicator and after sometime, the loss in weight was measured as the moisture loss. The samples were evaluated by a sensory method as earlier and analyzed statistically.

Microwave heating: One hundred grams of cloves were placed in a petridish and dried in microwave oven for 8, 14 and 20 sec. After each drying period, sample were taken out off the microwave oven and put into a desiccator till the constant weight was obtained. The samples were evaluated by a sensory method as describe earlier and analyzed statistically.

Fluidized bed drying: One hundred grams of cloves were dried in the fluidized bed dryer to form a bed for 1 and 2 h at 50, 55, 60, 65 and 70°C. The air velocity was maintained constant throughout the experiment. After each drying period samples were taken out of drier and put into a desiccator, till a constant weight was obtained. The samples were evaluated by sensory methods as described earlier and analyzed statistically.

Freeze drying : Whole garlic cloves (peeled), pricked garlic cloves and slices of garlic cloves each in 50 g quantity were taken into the dish of freeze dryer (Model Alpha 2-4) and dried as per the procedure described in the operating manual under the following conditions: Pre freezing temperature-30°C Main drying vacuum-0.370 mbar. The final drying was done till the product attained 20°C temperature.

Statistical analysis: Statistical analysis was carried out as described by Steel and Torrie (1980).

RESULTS AND DISCUSSION

Chemical characteristics

Moisture and volatile oil content: Moisture content and Volatile content in Control Sample are presented in Table 2. The mean moisture content and volatile oil content in untreated 15 garlic cloves samples found to be 61.2 and 0.22%, respectively. The same was used for the comparison purpose. The result shows that the data obtained by the method were quite reproducible as indicated by the very low value of coefficient.

Table 2: Moisture content and volatile content in control sample

	Characteristics	
S. No.	Moisture content (%)	Volatile content (%)
1	61.4	0.22
2	61.8	0.21
3	59.7	0.23
4	60.9	0.24
5	62.1	0.20
6	60.8	0.19
7	62.4	0.25
8	61.3	0.22
9	59.9	0.21
10	61.7	0.22
11	60.4	0.24
12	62.0	0.21
13	61.6	0.22
14	61.5	0.20
15	60.9	0.23
Statistical analysis		
Mean	61.2	0.22
Std.Dev	0.789	0.017
df	0.14	0.14
C.V. (%)	0.581	0.006

Table 3: Effect of hot air drying on moisture loss and sensory quality of garlic cloves

Treatment			Sensory quality				
Temp (°C)	Time (h)	Moisture loss (%)	Appearance	Hand feel	Aroma	Texture	Overall quality
45	1	4.2$^{a\,A}$	5.0^{a}	5.0^{a}	5.0^{a}	5.0^{a}	20.0
	2	6.8$^{b\,A}$	5.0^{a}	5.0^{a}	5.0^{a}	5.0^{a}	20.0
	3	8.3$^{c\,A}$	5.0^{a}	5.0^{a}	5.0^{a}	5.0^{a}	20.0
50	1	4.6^{aA}	5.0^{a}	5.0^{a}	5.0^{a}	5.0^{a}	20.0
	2	7.6^{bA}	5.0^{a}	5.0^{a}	5.0^{a}	5.0^{a}	20.0
	3	9.9^{cA,B}	5.0^{a}	5.0^{a}	5.0^{b}	5.0b	18.9
55	1	5.5^{aA}	5.0^{a}	5.0^{a}	5.0^{a}	5.0^{a}	20.0
	2	8.5b^{A,B}	5.0^{a}	5.0^{a}	4.3^{b}	3.6^{c}	17.9
	3	11.3^{cC}	5.0^{a}	3.8^{b}	4.8^{a}	3.9^{b}	17.5
60	1	5.7^{aA}	5.0^{a}	5.0^{a}	4.6^{a}	5.0^{a}	19.6
	2	10.2^{bB}	5.0^{a}	3.9^{b}	4.7^{a}	3.8^{b}	17.4
	3	13.3c^{C}	5.0^{a}	3.7^{b}	4.6^{a}	3.8^{b}	17.1
65	1	6.2a^{A,B}	5.0^{a}	5.0^{a}	4.2^{a}	5.0^{a}	19.2
	2	10.7^{bB}	5.0^{a}	3.1^{b}	4.3^{a}	3.3^{b}	15.7
	3	14.5$^{c\,C,D}$	4.0^{b}	2.8^{c}	3.2^{b}	2.4^{c}	12.4
70	1	6.7a^{A,B}	5.0^{a}	3.3^{a}	3.2^{b}	3.0^{a}	14.5
	2	10.9$^{b\,B}$	4.0^{b}	3.1^{a}	3.8^{a}	3.7^{b}	13.6
	3	15.4$^{c\,D}$	4.1^{b}	2.4^{b}	3.1^{a}	2.3^{c}	11.9
75	1	8.9$^{a\,B}$	4.2^{a}	2.8^{b}	3.3^{a}	2.6^{a}	12.9
	2	17.5$^{b\,C}$	3.6^{b}	3.1^{a}	2.3^{b}	2.4^{a}	11.4
	3	22.4$^{c\,E}$	3.3^{c}	2.1^{c}	2.0^{b}	2.2^{b}	9.5
SEM		±0.796/0.693	±0.216	±0.312	±0.426	±0.516	

Means in the same column followed by different letter differ significantly ($p<0.05$), df = 4, Small letter denotes the effect of time at same temp. Whereas capital letter denotes the effect of temp. at the same time

Effect of various drying processes on the quality of garlic cloves

Hot air drying: Moisture removal in garlic clove by hot air drying is found to be quite effective but reduced the quality to a greater extent. At the same temperature a significant change has been observed upon increasing the duration of time. This was found to be true for all the drying temperatures studied. On the other hand on increasing the drying temperature for the same drying period, the -moisture loss did not increase significantly up to 60°C (for 1 h 55°(2 h) and 50°C for 3 h). Afterwards highly significant changes were observed and higher moisture losses were observed at 75°C with respective different periods same as the results by Abano *et al.* (2011).

Very small changes in sensory attributes were observed at the lower temperatures of drying but quite significant changes were at higher temperatures. Except the sample dried at 70 and 75°C, the change in appearance was found almost insignificant. The deterioration in textural qualities as well as in aroma has been started just after increasing the temperature from 50°C and the trend was similar up to 75°C) (Rasouli *et al.*, 2011; Sacilik and Unal, 2005; Fernando *et al.*, 2008). By comparing the moisture loss and overall sensory quality score with respect to temperature for a constant drying period of 3 h, it was observed that 60°C temperature was judged optimum for drying of garlic cloves with higher moisture loss and minimum damage to overall quality. The effect of Hot air drying on moisture loss and sensory quality of garlic cloves is given in Table 3.

Microwave heating: The garlic cloves were subjected to microwave heating for 8, 14 and 20 sec exposure however in 20 sec treatment the tips of the cloves were burnt and therefore the rest of the sensory attributes were not accessed (Rao *et al.*, 2007).

Table 4: Effect of microwave heating on moisture loss and sensory quality of garlic cloves

		Sensory quality				
Time (sec)	Moisture loss (%)	Appearance	Hand feel	Aroma	Texture	Overall quality
8	4.12^{a}	5.0^{a}	4.1^{a}	4.8^{a}	4.6^{a}	18.5
14	9.70^{b}	5.0^{a}	3.6^{b}	4.2^{a}	4.1^{b}	16.9
20	14.16^{c}	Tips were brown and burnt	-----	-----	-----	-----
SEM	±0.496	±0.181	±0.413	±0.276	±0.334	

Means in the same column followed by different letter differ significantly ($p<0.05$), df = 4

Table 5: Effect of fluidized bed drying on moisture loss and sensory quality of garlic cloves

	Moisture loss (%)		Sensory quality				
Temp (°C)	1 h	2 h	Appearance	Hand feel	Aroma	Texture	Overall quality
50	9.3^{a}	14.5^{a}	5.0^{a}/5.0^{a}	4.7^{a}/3.2^{a}	5.0^{a}/4.2^{a}	5.0^{a}/3.1^{a}	19.7/15.5
55	9.8^{a}	17.1^{b}	5.0^{a}/5.0^{a}	3.6^{b}/2.5^{a}	5.0^{a}/4.0^{a}	3.6^{b}/2.7^{b}	17.2/14.2
60	12.8^{b}	22.0^{c}	4.4b/4.0^{b}	3.6^{b}/2.3^{b}	4.3^{b}/3.3^{b}	3.0^{c}/2.0^{c}	15.3/11.6
65	17.2^{c}	27.4^{d}	4.1c/4.0^{b}	3.1^{c}/2.0^{d}	3.5^{c}/3.0^{c}	2.5^{d}/2.0^{c}	13.2/11.0
70	20.7^{d}	33.5^{e}	4.0c/4.0^{b}	2.0^{d}/2.0^{d}	3.0^{d}/2.5^{d}	2.0^{e}/2.0^{c}	11.0/10.5
SEM	±1.651	±1.274	±0.034/0.012	±0.051/0.041	±0.024/0.027	±0.053/0.049	

Means of the same column followed by different letter differ significantly ($p<0.05$), df = 4

The moisture loss increased from 4.12 to 14.1% on the increase of exposure to microwave for 8 to 20 sec as expected. After exposure the skins of cloves was found to be shrunken and the cloves were less hard than the normal ones. The aroma was slightly lost in 8 sec treatment but 14 excusers caused slightly more loss due to more evaporation of volatiles (Murthy and Prasad, 2005; Figiel *et al*., 2010).

The overall quality score decreased from 18.5 to 16.9 for 8 and 14 sec treatments respectively but the 14 sec treatment was found suitable due to more moisture loss and hence optimum. The effect of Microwave drying on moisture loss and sensory quality of garlic cloves is given in Table 4.

Fluidized bed drying: Fluidized bed drying greatly affected the loss of moisture at the higher temperature whereas did not show any significant change at low temperature range (50-55°C) for 1 h but significantly increase for 2 h treatment as shown in Table 4. It is clearly evident that for 1 h treatment the maximum increase occurred between 60 and 65°C. On the other hand maximum difference (from 2.6 to 4.9) for 2 h treatment was observed for the range of 55-60°C than in that of 50-55°C. Analyzing the sensory quality not much change was observed at 50°C for 1 h treatment. The pattern is followed up to 65°C for which there was no significant change, however the quality greatly reduced at 70°C. Treatment for 2 h greatly reduced the quality while increasing the temperature as the garlic cloves were shrunken and became soft and soggy probably due to oozing out of the volatile oil from the interior. Taking into account optimum sensory score as well as higher moisture loss, the treatment at 55°C for 2 h can be judged optimum with 17.1% moisture and 14.2 overall quality score. The effect of Fluidized bed drying on moisture loss and sensory quality of garlic cloves is given in Table 5.

Freeze-drying: The effect of freeze-drying on various garlic samples is given in Table 6. Whole garlic cloves were having 14% moisture (moisture loss 47%) at the end of drying probably due to

Table 6: Effect of freeze drying on moisture loss and sensory quality of whole, pricked and sliced garlic

		Sensory quality				
Type	Moisture loss (%)	Appearance	Hand feel	Aroma	Texture	Overall acceptability
Cloves	47	2.0	2.0	4.0	2.0	10.0
Pricked	98	4.0	3.0	4.0	3.0	14.0
Slice	98	4.2	4.8	5.0	5.0	19.0

Table 7: Effect of various drying processes on the moisture loss, sensory quality and volatile retention of garlic cloves

Treatment	Moisture loss (%)	Overall quality score (Max. 20)	Volatile retention
Hot air drying (60°C for 3 h)	13.3	17.1	60
Microwave heating (14 sec)	9.7	16.9	75
Fluidized bed drying (55°C for 2 h)	17.1	14.2	65
Freeze drying	98.0	19.0	93

impermeability of the garlic skin and hence the restricted mobility of the moisture from the interior of the garlic. This is especially true of vegetables whose external cover makes removal of water difficult (Condori *et al*., 2001; Sablani *et al*., 2007). Also some undesirable changes were observed in these cloves like shedding of the skin, light brown and sticky. On the other hand the pricked garlic cloves and slices could be dried for the final moisture content of 2.2 and 2.2%, respectively. However, the dried slices showed better sensory quality score (19) than that of pricked cloves quality (14). The reason for inferior quality of pricked garlic cloves lied in the stickiness due to oil droplets coming out of the cloves.

Volatile oil retention: The volatile oil retention was found to be maximum (93%) in freeze dried samples followed by (75%) in microwave dried (14 sec), (65%) in fluidized bed dried (55°C for 2 h) and then (60%) in hot air dried (60°C for 3 h) samples (Kubra *et al*., 2012). The effect of various drying processes on the moisture loss, sensory quality and volatile retention of garlic cloves is given in Table 7.

CONCLUSION

An overview of the prime methods applied hitherto to garlic cloves has been shown in Table 3. As expected, the freeze dried sample had maximum moisture loss of 58.8% with superior quality score (19) followed by fluidized bed drying, oven drying and microwave heating having moisture losses of 17.1, 13.3 and 9.7%, respectively. The overall quality score among the above three were higher in oven drying method. However, the low processing time of 2 h in fluidized bed drying makes it superior than that of oven drying having 3 h treatment. These results suggest that the fluidized bed drying can successfully be combined with freeze drying to obtain dehydrated garlic with maximum moisture loss and desirable qualities.

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