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Effect of different drying techniques and packaging materials on garlic (*Allium sativum*) powder

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ABSTRACT

Garlic (*Allium sativum* L.) powder is a convenience product commonly used in domestic and commercial food preparations. The present study was carried out in 2019–20 at Enthkedi, Bhopal, Madhya Pradesh to demonstrate the effect of different drying techniques, viz. shade drying (~32ºC), S_1; oven drying (50ºC, 6–8 h), S_2; microwave drying (800W, 4 min), S_3; and solar drying (10 h), S_4, on (un)treated garlic cloves with respect to quality characteristics of garlic powder. The garlic cloves were blanched in boiling water for 10–15 sec followed by dipping in 0.2% potassium-meta-bisulphite (KMS) for 5 min at room temperature, this was the treated sample (T_1). The treated samples and untreated samples (T_2) were subjected to different drying techniques followed by evaluation in terms of product recovery, rehydration ratio, cutting strength, colour, titratable acidity and ascorbic acid content. Full factorial completely randomized design was adopted for the experiments. It was observed that across all the responses S_1 and S_4 did not have any significant ($P<0.05$) effect, while T_1 and T_2 rendered significant ($P<0.05$) difference to the responses. The hardness of shade dried (51.87N) garlic clove was significantly ($P<0.05$) more than that of microwave dried (32.48N). Dried garlic cloves were evaluated for quality parameters (ascorbic acid, acidity) and overall acceptability which was found best with T_1 under S_1 condition. Microbiological parameters, viz. total viable fungal colony in different packaging material (LDPE, PE, multilayered) was evaluated for garlic powder stored over a period of 60 and 90 days. Multilayered packaging for T_1 sample (S_2) garlic powder was found to be the most acceptable and safe.

Keywords: Drying, Garlic cloves, Garlic powder, Microbiology, Packaging, Texture

Garlic (*Allium sativum* L.) is a compound bulb, which comprises small bulbs called cloves, enclosed within a white membranous outer casing. It is a rich source of carbohydrates, proteins and phosphorous. The fresh peeled garlic cloves approximately contain about 60% moisture (w.b.), 10% protein, 1.0% fat, 1.5% mineral matter, 2.0% fiber and 25% carbohydrates (Lawal *et al.* 2018).

Nearly 20% of the crop is wasted due to respiration, transportation and microbiological spoilage during ordinary storage of garlic bulbs. The garlic cultivars need drying and value addition. Garlic pickle, powder, paste, flavour and flakes are a few value-added products. Peeled garlic cloves are a convenient minimally processed vegetable and their amount has increased in retail and food service markets. Garlic is mainly processed in the form of dehydrated product for use in curries and soup powder. Low cost drying techniques by maintaining quality of dried garlic can be a bonus for the farmers.

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Dehydration is a major food processing operation in the food industry for the removal of water (responsible for many deteriorative reactions) from a product. The optimization of such an operation leads to an improvement in the quality of the output product, a reduction in the cost of processing (Jayas 2016).

Powder prepared from the dehydrated or dried garlic slices can be used for seasoning of Indian dishes apart from using it as a spice. Garlic powder is used as a flavoring agent for condiments and processed foods. In recent years, the improvement of quality retention of dried products by altering drying process and pretreatment has been a research goal. In this respect, drying techniques like shade drying, oven drying, microwave and solar drying of garlic have been the subject of extensive research. The present research work was thus planned to assess physical characteristics of garlic in bulk, study the quality parameter of garlic slices produced by different drying methods (shade drying, microwave drying, oven drying, solar drying) and to verify the storage stability of garlic.

MATERIALS AND METHODS

Raw material: Garlic (*Allium sativum* L. var. Yamuna safed-3, G-282) was procured from the RAK College of Agriculture, Sehore, Madhya Pradesh for the present experiment. The fresh garlic was manually peeled and washed. The entire study was conducted at Fruit Research Station, Enthkhedi, Bhopal in 2019–20.

Physico-chemical parameters of fresh garlic samples: The parameters of fresh garlic samples were recorded in terms of physical parameters, quality parameters and microbiological parameters.

Pretreatment: The cloves were subjected to blanching by steeping the slice in boiling water for 10–15 sec followed by immersing in 0.2% KMS solution for 5 min at room temperature (Xiao *et al.* 2017). These garlic cloves were called treated (T_1) garlic cloves.

Drying methods: Treated (T_1) and untreated (T_2) garlic cloves were dried by four different drying methods, viz. (i) shade drying, 100 g garlic cloves were dried in shade at room temperature; (ii) oven drying, 100 g garlic cloves were subjected to a dryer temperature of 60±5°C and drying was carried for a time period of 6–8 h; (iii) microwave drying, 100 g garlic cloves were dried at a power and time of 800W and 7 min, respectively; (iv) solar drying, at 54±2°C for 6–8 h. The cloves obtained after drying were pulverized in a domestic grinder (2 min) to obtain garlic powder.

Product recovery: This parameter helps in estimation of the final amount of dried matter obtained from the raw garlic cloves. A sample of 100 g garlic cloves was dehydrated and the product recovery (PR) of sample at constant drying rate was expressed as:

$$\text{Product recovery} = \frac{\text{Final weight of dried sample (g)}}{\text{Initial weight of sample (g)}} \times 100 \qquad (1)$$

Rehydration ratio: Rehydration ratio of dried garlic cloves was estimated as per the method described by Ranganna (1986). Dried garlic cloves (W_D) were put in boiling water for 25 min and the contents were passed through whatman no. 4 filter paper. The rehydrated garlic sample was weighed (W_R), and rehydration ratio (RR) was computed as:

$$RR = \frac{W_R}{W_D} \qquad (2)$$

Cutting strength: It was determined instrumentally by using a texture analyser (TA XT2i, Stable Microsystems, Surrey, England) with Texture Expert Exceed 2.46 version software. Cutting strength (CS) was recorded as the peak force (N) required to snap the material by the downward moving probe of texture analyser.

Titratable acidity: Determination of acidity was calculated by using the following formula and expressed in percent (AOAC 1988).

$$\text{Acidity (\%)} = \frac{1 \times \text{Eq. wt. of acid} \times \text{Normality of NaOH} \times \text{Titre value}}{10 \times \text{Weight of sample}} \times 100 \qquad (3)$$

Ascorbic acid content: Ascorbic acid or vitamin C of the garlic cloves was estimated by employing the standard method of analysis (AOAC 1995).

$$\text{Ascorbic acid (mg/100 g)} = \frac{0.5 \times V_2 \times 100 \text{ ml} \times 100}{V_1 \times 5 \text{ ml} \times \text{weight of sample}} \times 100 \qquad (4)$$

where, V_1 is the dye volume; V_2 is the titre volume of the dye (ml)

Microbial study by standard plate count method (SPC): About 23.5 g of potato dextrose agar (PDA) was taken in a conical flask and 1000 ml distilled water was added to it. It was heated in steam at 12°C under 15 psi atmospheric pressure for 15 min and then cooled to about 40°C. A series of dilution was made using 9 ml blanks.

In this way, the dilution was made up to 10^{-6} times. About 15–20 ml PDA media was taken in each of six petri dishes. 1 ml of the diluted sample was then pipetted into each of these sterile petri dishes in triplicate. After solidification of the media the plates were incubated at 25°C for 48 to 96 h. The plates containing bright, clear and countable colonies were selected for easy counting of colonies.

$$\text{Number of colony forming unit cfu/g or ml} = \text{average cfu/plate} \times \text{dilution factor} \qquad (5)$$

Sensory analysis: The sensory quality of the developed powders in respect of colour, appearance, flavour and texture were analysed using 9-point hedonic scale (Wichchukit and O'Mahony 2014) and reported as overall acceptability (OA).

Storage studies for Garlic powder: The microbial population in garlic powder samples in different packaging material made by the drying methods were assessed. The total fungal count in fresh and packed garlic powder (2 g) at 60 and 90 days was analyzed in three different packaging materials, viz. polyethylene (PE) 100 gauge, multilayered (ML) 300 gauge and low-density polyethylene (LDPE) 200 gauge.

Data analysis: Individual and interactive effect of variables on the responses was assessed by Factorial Completely Randomized Design (FCRD), the statistical significance was understood by the procedure given by Panse and Sukhatme (1967). The values of the responses recorded under different drying conditions was analyzed with SAS (SAS Institute Inc., 2001), and least significant difference ($LSD_{0.05}$) with no preliminary ANOVA was used for comparison between means of responses.

RESULTS AND DISCUSSION

The physico-chemical parameters of fresh garlic were observed in terms of physical parameters— bulb weight (g) 24±3.41, number of bulbs per kg 53±5.21, number of cloves per bulb 17±4.33, weight of bulb before peeling (g) 1.68±2.01, weight of bulb after peeling (g) 1.28±2.13, moisture content (%, wet basis) 67.60±1.9, hardness (N) 7.25±3.61; and quality parameters— acidity (%); 2.57±0.99; ascorbic acid (mg/100 g) 11.51±2.11; no microbial count (cfu/g) was observed in the samples.

Physical parameters of dried garlic cloves: The product recovery (%) of dehydrated garlic clove was affected by the choice of the drying technique. Drying technique had a significant (P<0.05) effect on the product recovery. Steep temperature difference across the food microstructure resulted in the maximum removal of water during oven drying followed by microwave drying, where again the dipolar movement imparted enough energy for the water to move out of the cloves. Moisture loss was less in case of milder drying processes like shade and solar drying. This trend was independent of the treatments. Similar observations have been reported by Bozkir *et al.* (2019) while working with these drying techniques over vegetable matrices.

Rehydration ratio differed significantly ($P<0.05$) with respect to the drying technique (S) and treatment (T). KMS treatment resulted in higher value of rehydration ratio. Similar results have been reported by Davoodi *et al.* (2007) for tomato. Rehydration ratio was higher in microwave drying followed by other drying methods in the experiment. This might be due to water loss and heat generated due to dipolar movement resulting in breakdown of cellular structure. The cutting strength for the treated samples was more than it was for untreated samples. Blanching improves texture by strengthening pectin present in the vegetable matrix, this can be the reason for the increased cutting strength of treated samples. Microwave dried garlic cloves had minimum cutting strength, this can be attributed to the disruption of cellular structure caused as a result of the incidence of microwaves and the oscillatory dipolar movement of water molecules present abundantly inside the raw garlic clove. During drying process, influenced by high temperatures, cell walls undergo modifications in terms of their macrostructure and microstructure properties (Niamnuy *et al.* 2014).

Parameters of garlic powder: Pulverized dried cloves collected as underflow of IS 70 mesh sieve were considered for the study. Since the garlic powder was made out of the dried cloves, they followed the same trend as was followed by the cloves (Table 1). Here also the moisture content was least in case of oven drying followed by microwave, solar and shade drying. However, the treatment (T) and drying technique (S) both had significant effect on the moisture content of garlic powder. These results are in agreement with the findings of Rathor and Mathur (2001) and Bondre *et al.* (2016). Across all the drying methods, the treated samples exhibited lesser final moisture content. This can be attributed to the use of 0.2% potassium meta-bisulphate (KMS) during treatment. The hygroscopic nature of KMS might have resulted in water being absorbed from inner tissues of the slice through osmosis (Chakraborty *et al.* 2018) resulting in lesser final moisture content in treated samples. Also, sulphiting displaces air from the tissue in plant materials, softens cell walls so that drying occurs more easily.

The highest acidity (0.76%) was recorded in S_1 (shade drying) under T_2 (untreated), whereas the lowest acidity (0.52%) was recorded in S_4 (solar drying) under T_1 (treated). This is due to low effectiveness of moisture removal under shade drying conditions coupled by the long period in the shade (approximately 8–9 days). Similar results have been reported by Casado *et al.* (2004) while working with garlic pickle. The titratable acidity values were significantly ($P<0.05$) affected by drying method as well as treatment. The highest ascorbic acid content (6.60 mg/100g) was recorded under solar drying (S_4) conditions with untreated

Table 1 Effect of treatment and drying methods on various parameters of dried garlic cloves and powder

Parameter	Treatment	S_1	S_2	S_3	S_4	Mean standard error (±SEM)			CD (P=0.05)		
						T	S	T × S	T	S	T × S
Product recovery (%)	T_1	66.9	70.3	69.8	68.1	0.53	0.75	1.02	ns	2.29	ns
	T_2	64.8	69.0	68.6	67.0						
Rehydration ratio	T_1	2.06	2.66	2.46	2.23	0.05	0.08	0.11	0.17	0.24	ns
	T_2	2.00	2.33	2.2	2.1						
Cutting strength (N)	T_1	54.4	31.3	29.6	40.4	2.6	3.7	5.3	8.05	11.39	ns
	T_2	49.34	56.4	35.3	56.4						
Moisture content (%)	T_1	3.47	3.25	3.30	3.35	0.02	0.01	0.03	0.07	0.05	0.01
	T_2	3.90	3.48	3.52	3.71						
Titratable acidity (%)	T_1	0.69	0.59	0.62	0.52	0.01	0.02	0.03	0.06	0.04	ns
	T_2	0.76	0.67	0.69	0.61						
Ascorbic acid (mg/100 g)	T_1	5.45	4.02	5.10	5.96	0.01	0.02	003	0.06	0.04	ns
	T_2	6.19	4.52	6.13	6.60						
Overall acceptability	T_1	7.38	7.33	6.5	7.1	0.17	0.24	0.35	ns	ns	ns
	T_2	6.90	6.94	7.0	6.6						

Reported values are an average of three replications.

T_1, Treated; T_2, Untreated; T, individual effect of treatment; S, individual effect of drying technique; T × S, interactive effect of treatment and drying technique; ns, non-significant; S_1, shade drying; S_2 , oven drying; S_3, microwave drying; S_4, solar drying.

Table 2 Microbial count in packaged garlic powder under various packaging conditions

Drying method/Treatment		Fungal count (cfu/g)					
		Packaging material					
		LDPE		PE		ML	
		60 days	90 days	60 days	90 days	60 days	90 days
S_1	T_1	4×10^{-5}	8.5×10^{-5}	4×10^{-5}	11×10^{-5}	3.5×10^{-5}	7.5×10^{-5}
	T_2	4×10^{-5}	13×10^{-5}	5×10^{-5}	19×10^{-5}	4×10^{-5}	11.5×10^{-5}
S_2	T_1	2×10^{-6}	5.5×10^{-6}	3×10^{-6}	9×10^{-6}	3×10^{-6}	4.5×10^{-6}
	T_2	4×10^{-6}	9.5×10^{-6}	5×10^{-6}	14.5×10^{-6}	3×10^{-6}	8.5×10^{-6}
S_3	T_1	3×10^{-5}	6.5×10^{-6}	4×10^{-5}	10×10^{-5}	3×10^{-5}	7.5×10^{-5}
	T_2	4×10^{-5}	10×10^{-6}	4×10^{-5}	18.5×10^{-5}	4×10^{-5}	10×10^{-5}
S_4	T_1	4×10^{-6}	8.5×10^{-6}	4.5×10^{-6}	12.5×10^{-6}	3×10^{-6}	9×10^{-6}
	T_2	5×10^{-6}	12×10^{-6}	6×10^{-6}	18×10^{-6}	4×10^{-6}	12.5×10^{-6}

LDPE, low density polyethylene; PE, polyethylene; ML, multilayered.

(T_2) garlic cloves, whereas the lowest ascorbic acid (4.02 mg/100g) was recorded in oven drying (S_2) under treated (T_1) condition, relatively high temperature in oven perhaps led to the destruction of heat sensitive ascorbic acid present in the garlic clove. Bondre *et al.* (2016) and Sangwan *et al.* (2010) have also reported lower values of ascorbic acid in oven dried garlic powder.

Cumulative effect of drying technique and treatment on responses was gauged by least significant difference method ($P<0.05$). Among all the drying techniques PR was observed to be minimum (i.e. maximum removal of water) with shade drying and it was significantly ($P<0.05$) different from rest of the three drying techniques. Rehydration ratio (2.60) was significantly ($P<0.05$) best with oven dried samples followed by microwave drying (2.40) as close second. CS was desirably lowest for microwave drying. Retention of vitamin C was observed to be best with solar drying. OA was maximum for oven dried samples followed closely by shade drying. Across garlic clove drying and garlic powder making, T_1 and T_2 samples varied significantly ($P<0.01$) for all the responses except OA. Treatment (T_1) was not able to bring any significant change.

Microbiology of packed garlic powder: Total number of fungal counts in treated (T_1) and untreated (T_2) dried garlic powder at different drying techniques packed in low density polyethylene (LDPE) of 200-gauge, polyethylene (PE) of 100 gauge and multilayered (ML) of 300-gauge thickness was evaluated. Packaging was estimated at 60 and 90 days interval stored under room temperature. Fungal count across the days exhibited an increase for all the packaging materials (Table 2). Hence, recommended days of storage is 60 days in packaged form for the garlic powder. It could be inferred that T_1 samples exhibited less fungal load as compared to the T_2 samples. This can be attributed to the fact that blanching inactivates enzymes, reduces microorganisms and displaces entrapped air in the plant tissues.

It was also observed that T_1 and T_2 samples stored in PE as compared to LDPE and ML exhibited maximum number of total fungal count, this can be attributed to the higher water vapour transmission rate (WVTR) of PE than the other two materials. In other words, polyethylene (PE) is not recommended to be used as packaging material for packing garlic powder.

Drying of garlic cloves can be carried out under all the four drying techniques, viz. shade drying, oven drying, microwave drying and solar drying. Garlic powder can be produced from dried cloves. Blanching and sulphiting had significant effect on the responses, final moisture content, rehydration ratio and cutting strength. Oven dried samples were found to exhibit better results. The quality parameters (ascorbic acid, acidity) and over all acceptability of dried garlic powder were found best for shade dried treated samples. Microbiological parameters, viz. total viable fungal colony in different packaging material were found the best in multilayer (ML) packaging under treated sample (T_1) and the recommended days of storage under room temperature conditions should not exceed 60 days.

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