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EFFECT OF DRYING METHODS AND PRETREATMENTS ON THE DRYING CHARACTERISTICS OF GARLIC

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ABSTRACT

Garlic is a semi-perishable vegetable spice and nearly 30% of the crop is wasted due to respiration and microbiological spoilage during storage. Through garlic is produced abundantly and consumed as such, little efforts have so far been made to produce dehydrated garlic and garlic powder. The proper drying techniques are the most important aspect of fruits and vegetables preservation. The use of solar dryer helps not only to reduce losses and improves the quality of product but also helps in conserving the convectional energy sources. A greenhouse type solar dryer was used the experiments were conducted to develop dehydrated garlic slices so as to enhance the availability of garlic slices during off season. In the present study, fresh garlic slices were pretreated in two ways (i) KMS treated samples (ii) NaCl treated samples (ratio of water 1:4 w/w) and untreated garlic slices were also dried as control samples. The slices were dried at different thicknesses of 3.0 mm, 4.5 mm, and 6.0 mm under greenhouse type solar dryer and in open sun. Physico-chemical analysis i. e. moisture content, moisture ratio, drying rate, ascorbic acid, acidity, total sugar, reducing sugar, colour, and pungency were evaluated during the experiment. Experiments were also conducted to study the effect of drying conditions on sensory quality and rehydration characteristics. It was found that total drying time decreased in drying air temperature at 51.63^0C under greenhouse type solar dryer condition. Major drying took place in falling rate period. The average drying rate increased with increase in temperature and decrease with time and thickness. Chemically treated samples dried under greenhouse type solar dryer took lesser time than untreated samples. It was observed that total moisture loss increased with increase in drying temperature. The rehydration ratio for dehydrated garlic increased under greenhouse type solar dryer as compared to open sun drying. The product quality was found to be more acceptable in case of 3.0 mm thickness, KMS treated samples dried under greenhouse type solar dryer.

KEYWORDS: Colour, Garlic, Greenhouse Type Solar Dryer, Open Sun, Dehydration Ratio, Organoteptic Score, Treatments

INTRODUCTION

Garlic (*Allium sativum* Linn.) is a bulbous perennial plant of the lily family liliaceae. The plant's bulbs are used as a flavouring agent. It is a nutritional herbaceous plant known for its medicinal as well as culinary benefits, which originated from the mountains of Central Asian regions globally; China is by far the largest producer of garlic, producing over 75% of world tonnage followed by India. (Korea and the USA (FAOSTAT 2005). The bulb is a very good source of calcium, phosphorus, selenium, manganese, and low in saturated fat, cholesterol and sodium. It is also rich in vitamins C and B_6. A very important health promoting substance in the garlic is allicin, which is formed by an enzymatic reaction on activation of the bulb such as cutting and crushing. By the action of the enzyme alliinase, allyl-S-cysteine sulfoxide (alliin) is converted to diallyl thiosulphate (allicin) and finally disproportional to disulfides and thiosulphates (Krest et al. 2000). Many studies have recently provided strong evidence that most of these biological functions of garlic are attributed to allicin (Li & Xu 2007: Krest et al. 2000; Mousa, 2001). (Li & Xu, 2007) reported that no compound outside the thiosulphate of which allicin is about 60-80% has been found that accounts for a significant protein of the pharmaceutical activities of crushed garlic at levels representing normal human consumption (2-5g/d). And these biological effects of thiosulphates can be related to their strong SH-modifying and antioxidant properties (Rabinkov et al. 1998; Prasad et al. 1996). It is usually used without any preprocessing operation. More recently, it has been used in its dried from, as an ingredient of precooked foods and instant convenience foods including sauces, gravies and soups, which led to a sharp increase in the demand of dried garlic (Sharma and Prasad, 2006). (Afzal and Abe, 2000) reported that air velocity during convective grain drying in thin layers has little influence (would normally increase although may not substantial) on the moisture removal rate, (Jayas and Sokhansanj 1989). Garlic is a semi-perishable vegetable spice and nearly 30% of the crop is wasted due to respiration, microbial spoilage during storage (Anon, 1993).

MATERIALS AND METHODS

Sample Preparation

Fresh garlic were purchased from the local market of Meerut. Care was taken to select the shape size and without having any physical damage on inspection. The garlic bulbs then thoroughly cleaned to remove any dirt or dust particles attached to the surface. Then the sorted cleaned garlics were peeled and cut into required thickness with a hand operated slicer. The uniform thickness of 2.0, 4.5 and 6.0 mm was prepared by adjusting the opening of the slicer (Kumar et al. 2005). Among with these untreated garlic slices with some treated garlic slices were also prepared to observe the difference in drying phenomena for brining.

Experimental Setup

A greenhouse type dryer was used to executing the experiments. The schematic view of dryer is shown in Figure 3. The dryer consists of drying chamber, inlet operating for the entry of warm air, the exhaust system (fan) removing humidity air, during platform.

Figure 1: Pictorial View of Greenhouse Type Solar Dryer

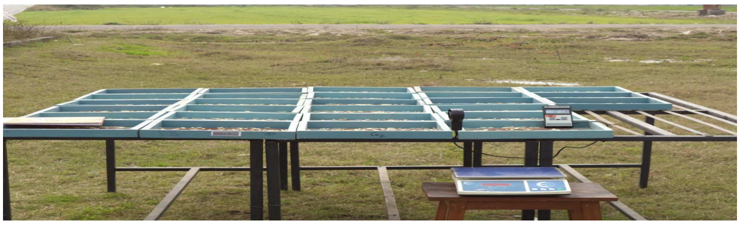

Figure 2: Isometric View of Open Sun Dry

Design of Experiments

Preliminary experiments were conducted on the basis of review of earlier work on drying of high moisture vegetables. It was observed that thickness of garlic slices was mostly preferred for drying of garlic. Hence, it was decided to use samples with a variable thickness of 3.0 mm, 4.50 mm and 6.0 mm of tray area. Time of pretreatment of garlic slices was decided on the basis of literature available. It was found that low temperature drying was preferred to retain the colour and flavour of garlic.

Raw Material and Sample Preparation

Washing

Fresh garlic bulbs were cleaned by manually to remove soil and dust particles if any attached to it. The morphological characteristics of the garlic bulbs were similar to the variety 'G 282', reported by National Horticultural Research and Development Foundation, Nasik, India. The average weight of the bulb and clove was 47g and 4.15g respectively. The initial moisture content of the peeled cloves was 69.24 per cent (wb).

Technical Programme

Drying Process Flow Chart of Dehydrated Garlic

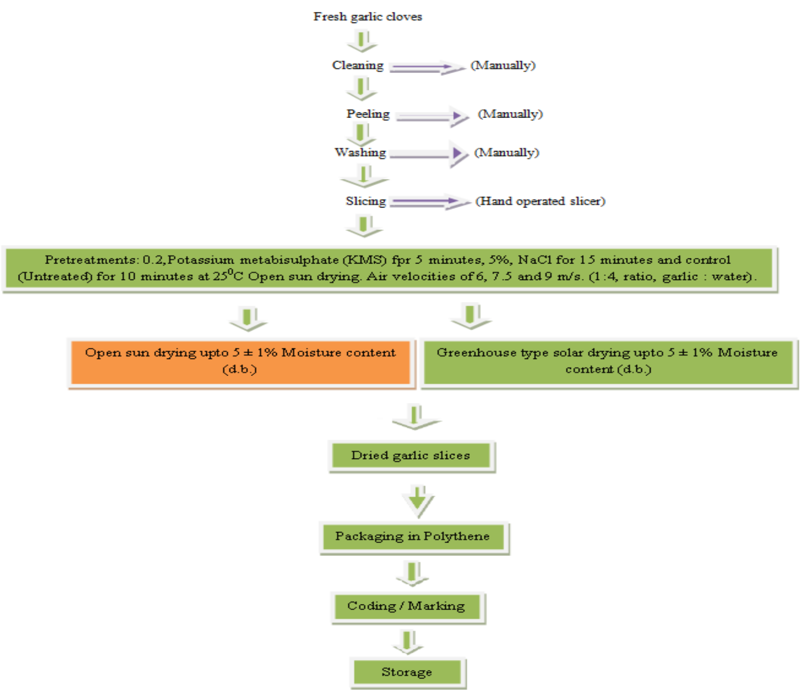

Figure 3: Process Flow Chart of Dehydrated Garlic

Figure 4: Dried Garlic Powder Samples

Equipment/Apparatus Used

Various equipments and apparatus such as trays, digital top pan electronic balance, digital temperature recorder, stop watch, desiccator, beaker, conical flask, measuring cylinder, funnel, volumetric flask, petri dish, Pipette, test tube, sieves etc were used during the experiments. All the equipments were kept in laboratory. They were set and adjusted for the experiments.

Electronic Balance

Weighing of samples for analysis of moisture content was carried out with the help of electronic balance. A top pan electronic balance of high accuracy (Samson, S300) was used which was provided with digital display. It has capacity of 600g and least count 0.1mg. Whereas, larger quantities of products were weighed on another electronic balance (Samson, S500), which was provided with digital display unit having capacity 5 kg and least count 0.1g.

Hot Air Oven

Hot air oven (Instron, IN-301 model) was a double walled chamber of size 78 cm × 27 cm × 116 cm. Outer chamber was made of mild steel while the inner chamber was made of stainless steel. 65 cm glass wool insulation was provided in between the two walls. Heating elements are evenly placed in ribs on both sidewalls and rear wall for uniform heating. Air ventilators were provided on the sidewalls of the oven. A thermometer was provided at the front of the oven. The temperature was controlled by a thermostat.

Measurement of Variables

Methods used to measure different variables are described below:

Air Temperature and Relative Humidity

Air temperature and relative humidity was measured just above the amaranth using digital RH/temperature recorder having the capacity of 0-200^{0}C with least count of 0.1^{0}C.

Air Velocity

Air velocity of air passing through the system was measured by hot wire anemometer (air flow, model TA5). The velocity range of anemometer was 0-15 m/s. air velocity was not controlled as no airflow control valve was provided in the set-up.

Solar Radiation

This was measured by pyranometer (Kipp & Zoner, model CM3) of the range 0-1000 W/m^2 range.

Initial Moisture Content (IMC)

The following method recommended by (Ranganna 1986) was used for determination of moisture content.

A thin layer of asbestos was spread into a flat bottom metallic dish and dried in a hot air oven at 80^{0}C for a period of an hour. It was quickly covered, cooled in a desiccator and weighed (W_1). A sample of 5g was kept over the asbestos layer and weighed as quickly as possible to avoid loss of moisture (W_2). The cover was removed and the samples were kept in hot air oven at 70 ±1^{o}C. The samples were dried for 18 hours until two to three consecutive weights did not vary more than 3-5 mg (0.3-0.5 %). After drying, the dish was taken out of the oven, covered with the lid and cooled into the desiccators containing activated silica gel at room temperature which generally took about one hour and final weight was recorded (W_3). The moisture content was calculated using the following formula:

$$IMC,\ \%\ (d.\ b.) = \frac{[(W2 - W1) - (W3 - W1)] \times 100}{(W3 - W1)} \quad (1)$$

Where,

W1 = Weight of metallic dish with cover, g

W2 = Weight of sample before oven drying plus weight of metallic dish with cover, g

W3 = Weight of dried and desiccated sample plus weight of metallic dish with cover, g

W2 - W1 = weight of sample, g

W3 - W1 = Weight of dried and desiccated sample, g

Moisture Content during Drying Experiment

Moisture content of the samples during drying were computed through mass balance. For this purpose, weight of the sample during drying were recorded at predetermined time interval. The following formulae were used to calculate the moisture content.

$$MC\ \%\ (d.\ b.) = \frac{(W - Wd) \times 100}{Wd} \quad (2)$$

Where,

W = weight of sample at any time, g

Wd = Weight of bone dry matter, g

Weight of bone dry matter were calculated as

$$Wd = \frac{(100 - Mc) \times Wi}{100} \quad (3)$$

Where,

Wi = Initial weight of the sample, g

Mc = Moisture content of the sample, % (w.b.)

Equilibrium Moisture Content (E. M. C.)

The final moisture content was taken as equilibrium moisture content (Pande et al. 2000 and Jain et al. 2000).

Moisture Ratio (M. R)

Moisture Ratio (MR) is calculated as follows.

$$MR = \frac{M - Me}{Mo - Me} \tag{4}$$

Where,

M= Moisture content, % (d. b.) at time t (min.) during drying.

Mo= Moisture content, % (d. b.) at the initiation of drying i.e. at zero time.

Me= Equilibrium moisture content, % (d. b.).

The moisture ratios at different time intervals were calculated by using Equation 4 to study the drying characteristics of garlic slices.

Drying Rate (D. R)

In thin layer drying, the drying process has been represented as follows:

$$\frac{dM}{dt} = -K\,(M - M_e) \tag{5}$$

From the above equation (Brooker et al. 1974), it is clear that for a positive value of constant K, $\frac{dM}{dt}$ would be negative when $M>M_e$ (i.e. the material will lose moisture with respect to time) and for a negative value of constant K, $\frac{dM}{dt}$ would be positive when $M<M_e$ (i.e. the material will gain moisture with respect to time). During drying, there is a loss of moisture with time. Hence, the drying rate indicates the rate of loss of this moisture of the sample.

Average Drying Rate (A. D. R)

The average drying rates at different times were computed using following relationship suggested by (Mishra 1991).

$$\left(\frac{dM}{dt}\right)_{avg} = \frac{M_t - M_{t+\Delta t}}{\Delta t} \tag{6}$$

Where,

$\left(\frac{dM}{dt}\right)_{avg}$ = average drying rate, % d.b. /min

t = time at any instant, min

t+ Δt = time after an interval of Δt, min

Overall Drying Rate (O. D. R.)

The overall rate of drying was calculated as ratio of difference of initial and final moisture content and total drying time.

The overall drying rate was calculated as follows:

$$\left(\frac{dM}{dt}\right) = \frac{M_o - M_F}{t_T} \quad (7)$$

Quality Evaluation of Dehydrated Garlic

Rehydration Ratio, Coefficient of Rehydration

According to (Ranganna 1986), there is no standard time for rehydration of fruits and vegetables. It varies from product to product. Rehydration time should be standardized through trial runs (Kar 1998).

For this purpose, preliminary experiments were carried out to find the time of boiling after which gain by dehydrated garlics stopped and it was found that beyond 25 minutes, there was no weight gain during rehydration using boiled water. For the rehydration ratio test, dehydrated samples (2g each) were dipped in boiling water for 25 minutes and contents were then filtered through Wattman No. 4 filter paper. The rehydrated garlic sample was then weighed and the weight recorded as WR. The rehydration ratio (RR) was computed using the following equation (Ranganna 1986).

$$\text{Rehydration ratio (RR)} = \frac{WR}{WD} \quad (8)$$

Where,

WR = weight of rehydrated garlics, g

WD = weight of dehydrated garlics, g

The coefficient of rehydration was calculated using the following equation.

$$\text{Coefficient of rehydration} = \frac{W_2 \times [100 - M_I]}{[W_1 - M_F] \times 100} \quad (9)$$

Where,

M_F = Amount of moisture present in the dried sample taken for rehydration, g

M_I = Initial moisture content of sample before drying, % db.

Statistical Analysis

The data obtained from the various experiments were recorded during the course of study and subjected to statistical analysis as per method of "Analysis of variance" by Factorial Randomized Block Design (factorial R.B.D). The significance and non-significance of data obtained from various experiments were judged with the help of F (Variance ratio) table. The significance difference between the means was tested against the critical difference at 5% level of significance (Gomez and Gomez 1984). Excel software was used for analyze the recorded data.

Standard Deviation

The standard deviation measures the spread of the experimental values and gives a good indication of how close the values are to each other (Chandel 1998).

The data obtained for selected quality parameters were analyzed for mean and standard deviations using following formula:

$$S.D. = \pm\sqrt{\frac{\sum(x_1 - x)^2}{n}} \quad (10)$$

Where,

X_1 = individual sample values

X = mean of individual samples

N = total population of sample

RESULTS AND DISCUSSIONS

Drying behaviour of garlic slices was characterized under greenhouse type solar dryer and open sun, with three levels of thickness (3.0, 4.5 and 6.0 mm) and two level of chemical treatments (KMS and NaCl). Experiments were also conducted for control (untreated) samples for garlic. The samples were dried from initial moisture content of 912.60-880.35% db to a final moisture content of 5.90-6.815% (d. b.). Drying started at 8.00 AM and terminated at 6.30 PM. The loaded trays were weighed every 30 minutes until the end of the drying period. After 6.30 PM, the samples were collected and kept in air tight plastics covers to induce uniform moisture distribution in garlic slices. Weight of the sample was taken at an interval of 30 minutes during the experiment. The weight loss was converted in corresponding moisture loss for calculating the moisture content (d. b.). The calculated moisture content (d. b.) was used as basic data for further analysis. Quality evaluation of the dried garlic slices was done. Rehydration characteristics of dehydrated samples were studied in terms of rehydration ratio for various drying conditions. The effect of drying methods, thickness and pretreatments on rehydration ratio, colour (in terms of enzymatic browning reaction), pungency, reducing sugar, total sugar and ascorbic acid content were studied during storage. The sensory evaluation for overall acceptability was also studied to optimize the drying conditions.

Drying Characteristics of Garlic Slices

The drying behaviour of garlic slices was analyzed using the experimental data on moisture of product at various time intervals for different drying conditions. The experimental data of the drying behaviour of garlic slices in relation to moisture content, moisture ratio and drying rate are given in (Table 1-4). After applying selected pretreatments, the samples were dried up to the final moisture content safe level of moisture content, which is about 5.90-6.815% on dry basis (d.b.) as reported by the various researchers (Van Arsdel and Copley 1963) for High moisture foods.

Moisture Profile Analysis

The drying behaviour of treated and untreated garlic slices, subjected to different drying methods and thicknesses were analysed. The change in moisture content with drying time for treated and untreated samples are ploted in Figure 5 to 10, exhibiting a non linear decrease of moisture with drying time. Initially, moisture decreasesd slowly during first hour because of low temperature in the morning. Moisture decreased rapidly as drying chamber warmed up, and then slowed down considerably. Initially, material surface was saturated with water, and therefore, with increase in air temperature, faster drying took place between 180 to 210 min. In the falling rate period, the material surface was no longer saturated with water and drying was controlled by diffusion of moisture from the interior of the material to the surface. For example, Table 4. showed the drying behaviour of garlic slices under greenhouse type solar dryer (GSD) and thickness of 3.0 mm for KMS treated samples. The drying time ranged from 480 min (KMS treated It 3.0, 4.5 and 6.0 mm thickness under greenhouse type solar dryer) to 510 min (NaCl treated samples, thickness 3.0, 4.5 and 6.0 mm under open sun), being generally lower at higher drying temperatures. It was observed that drying time decrease with increase in temperature e.g. under open sun drying (540 min at 3.0, 4.5 and 6.0 mm for KMS treated samples, 570 min NaCl treated and 630 min for untreated samples). Again, it was observed in case of greenhouse type solar dryer that KMS treated samples took lesser time (480 min at 3.0, 4.5 and 6.0 mm as compared to NaCl and untreated samples (510 to 540 min). Similar trend was also observed in case of open sun drying. The final moisture content varied from 5.90% to 6.815% (d.b.).

Table 1: Drying Data of Untreated Garlic Slices in Open Sun Drying, Thickness-3.0, 4.5 and 6.0 mm

Moisture Content (db%)	Moisture Ratio (M.R.)	Drying Rate (D.R.)	Time (Min.)
912.60	1.0	-	0
890.55	0.96	0.584	30
815.20	0.92	0.744	60
790.32	0.86	1.413	90
710.12	0.76	1.857	120
666.20	0.63	3.248	150
520.12	0.45	3.687	180
310.15	0.24	3.360	210
210.12	0.13	2.812	240
110.15	0.07	0.932	270
60.25	0.05	0.686	300
55.356	0.04	0.428	330
40.81236	0.03	0.435	360
32.452	0.027	0.368	390
28.371	0.021	0.345	420
25.425	0.018	0.268	450
20.224	0.014	0.198	480
16.172	0.012	0.102	510
13.90	0.009	0.057	540
09.25	0.008	0.045	570
07.12	0.05	0.038	600
05.90	0.00	0.032	630

Table 2: Drying Data of Untreated Garlic Slices in Solar Drying, Thickness-3.0, 4.5 & 6.0 mm

Moisture Content (db%)	Moisture Ratio (M.R.)	Drying Rate (D.R.)	Time (Min.)
912.32	1.00	-	0
898.35	0.960	0.605	30
794.54	0.840	0.650	60
665.31	0.700	0.750	90
445.50	0.480	0.980	120
205.68	0.290	3.560	150
193.84	0.160	4.358	180
94.50	0.080	3.145	210
72.51	0.060	1.985	240
53.21	0.040	0.958	270
38.10	0.030	0.482	300

Table 2: Contd.,

29.15	0.0180	0.399	330
21.50	0.150	0.212	360
18.35	0.0090	0.095	390
15.30	0.0070	0.080	420
11.650	0.0040	0.048	450
9.560	0.0030	0.040	480
7.540	0.0010	0.035	510
6.815	0.00	0.028	540

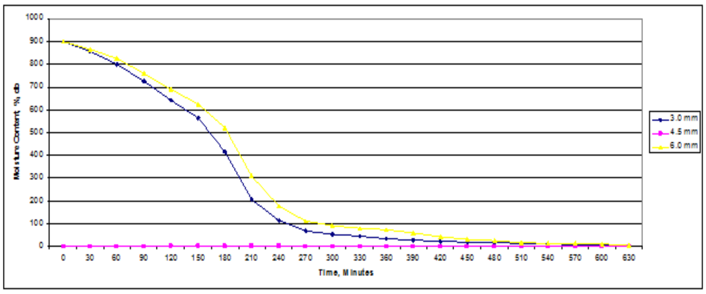

Figure 5: Variation in Moisture Content with Time under Open Sun Drying (Untreated Samples)

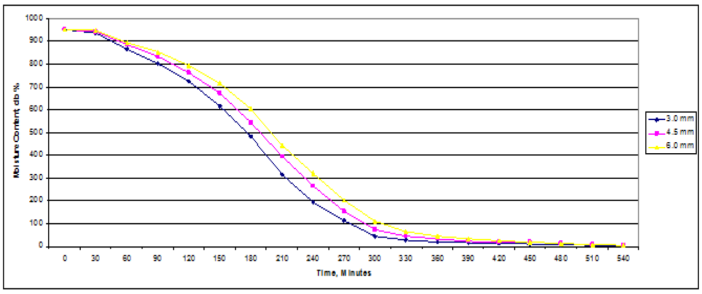

Figure 6: Variation in Moisture Content with Time under Open Sun Drying (KMS Treated)

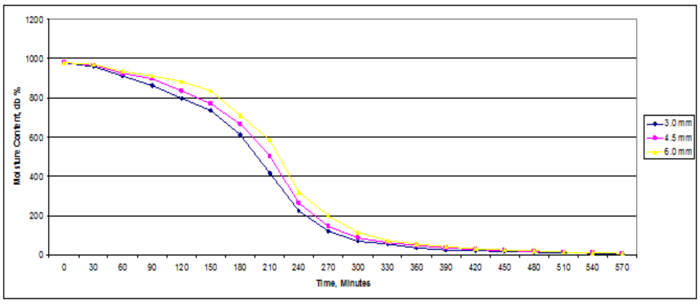

Figure 7: Variation in Moisture Content with Time under Open Sun Drying (NaCl Treated Samples)

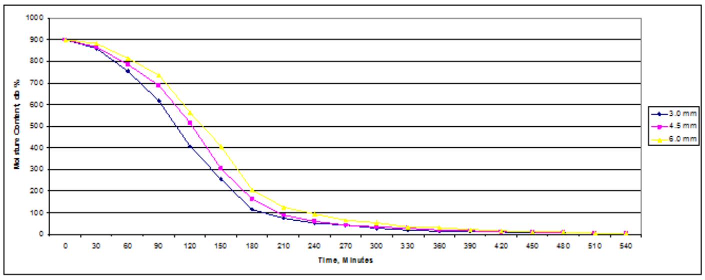

Figure 8: Variation in Moisture Content with Time under Green House Type Solar Dryer (Untreated Samples)

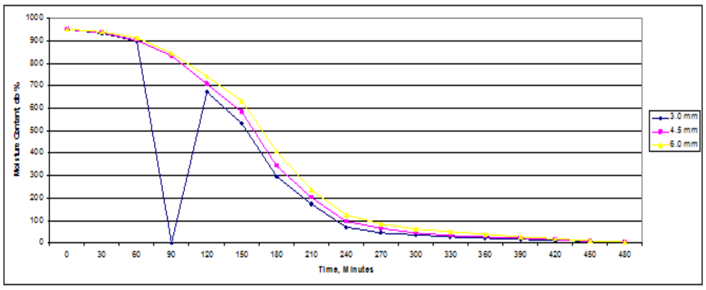

Figure 9: Variation in Moisture Content with Time under Green House Type Solar Dryer (KMS Treated Samples)

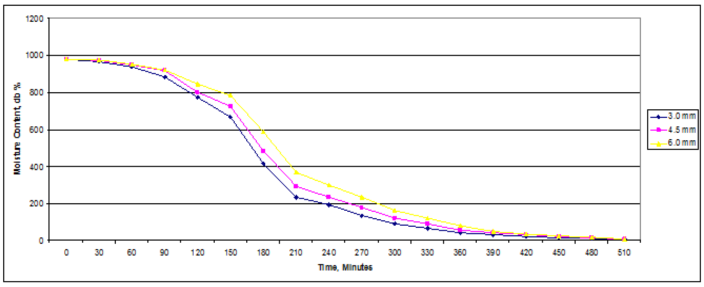

Figure 10: Variation in Moisture Content with Time under Green House Type Solar Dryer (NaCl Treated Samples)

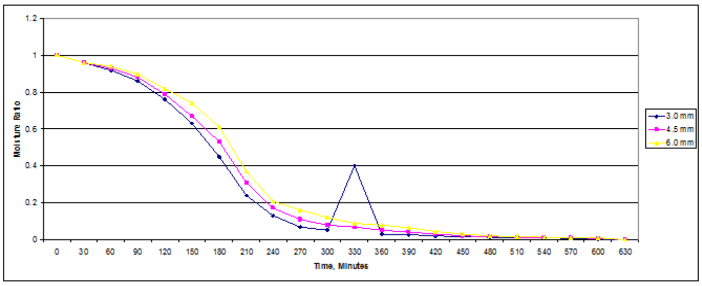

Figure 11: Variation in Moisture Ratio with Time under Open Sun Drying (Untreated Samples)

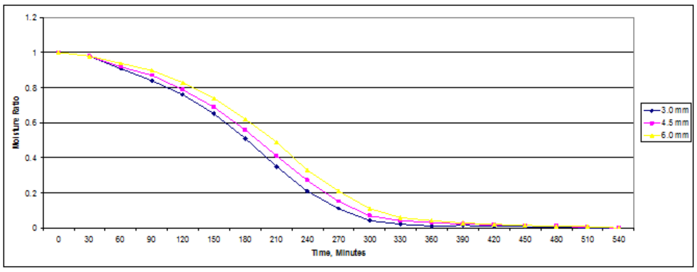

Figure 12: Variation in Moisture Ratio with Time under Open Sun Drying (KMS Treated)

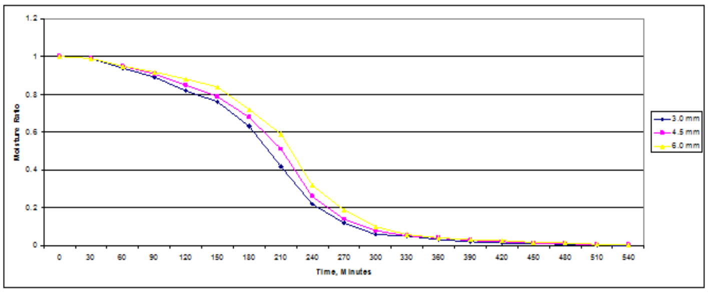

Figure 13: Variation in Moisture Ratio with Time under Open Sun Drying (NaCl Treated Samples)

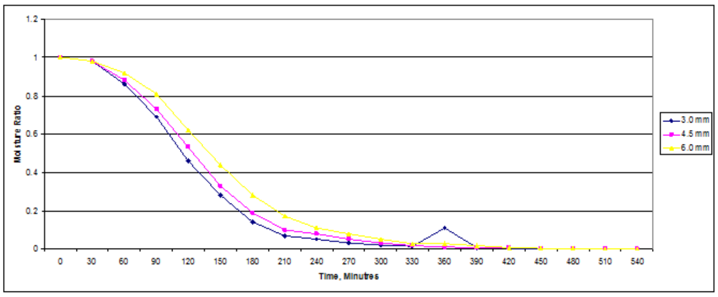

Figure 14: Variation in Moisture Content with Time under Green House Type Solar Dryer (Untreated Samples)

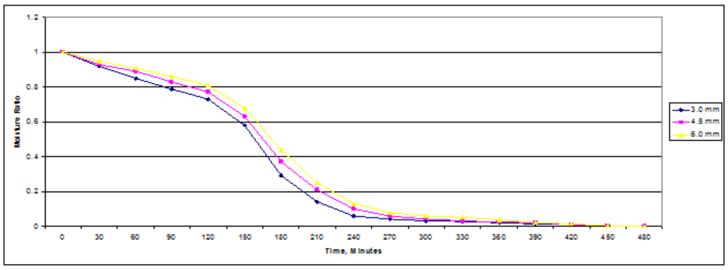

Figure 15: Variation in Moisture Content with Time under Green House Type Solar Dryer (KMS Treated Samples)

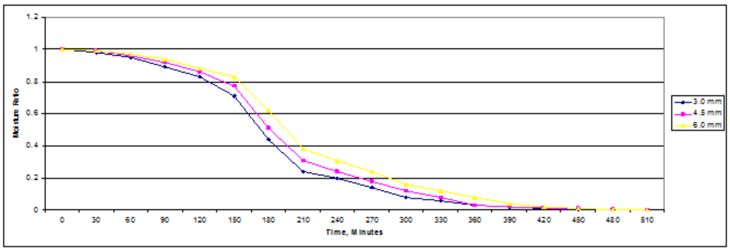

Figure 16: Variation in Moisture Content with Time under Green House Type Solar Dryer (NaCl Treated Samples)

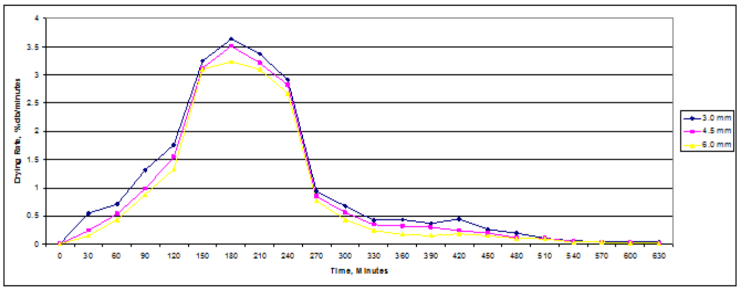

Figure 17: Variation in Drying Rate with Drying Time under Open Sun Drying (Untreated Samples)

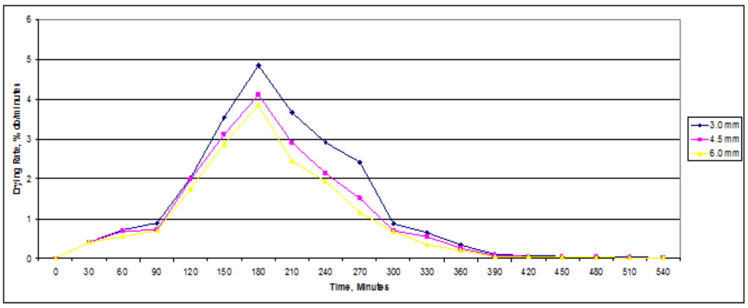

Figure 18: Variation in Drying Rate with Drying Time under Open Sun Drying (KMS Treated)

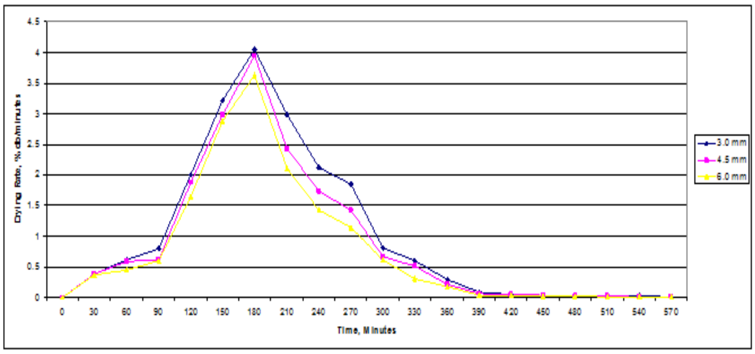

Figure 19: Variation in Drying Rate with Drying Time under Open Sun Drying (NaCl Treated Samples)

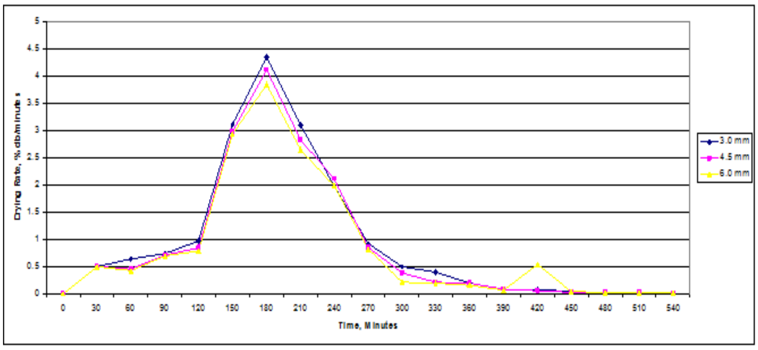

Figure 20: Variation in Drying Rate with Drying Time under Green House Type Solar Dryer (Untreated Samples)

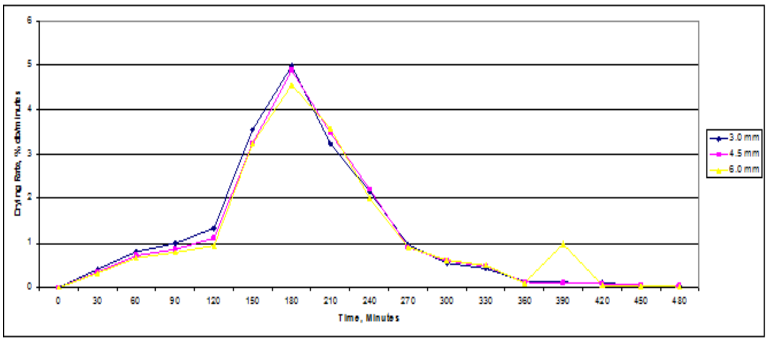

Figure 21: Variation in Drying Rate with Drying Time under Green House Type Solar Dryer (KMS Treated Samples)

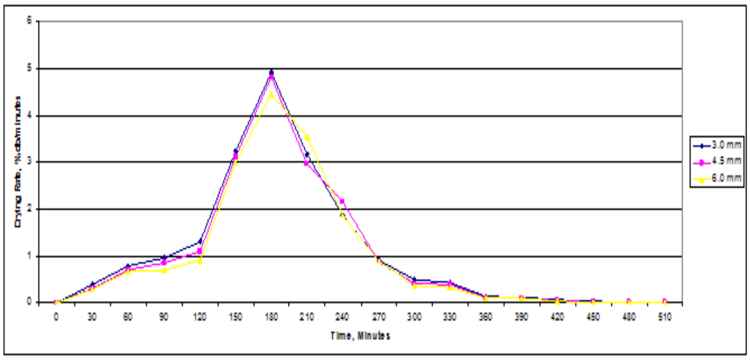

Figure 22: Variation in Drying Rate with Drying Time under Green House Type Solar Dryer (NaCl Treated Samples)

Table 3: Overall Drying Rates at Experimental Drying Conditions

Temperature (^{0}C)	Thickness (mm)	Treatments	Initial Moisture Content (% db)	Final Moisture Content (% db)	Drying Time (min)	Overall Drying Rate
Open Sun Drying (OSD 40.4^{0}C)	3.00 mm	KMS treated	951.20	4.60	540	1.752
		NaCl treated	982.15	5.48	570	1.713
		Control	895.53	5.53	630	1.418
	4.50 mm	KMS treated	953.22	5.41	540	1.749
		NaCl treated	983.18	6.43	570	1.800
		Control	895.55	6.65	630	1.426
	6.00 mm	KMS treated	952.25	6.65	540	1.756
		NaCl treated	985.23	6.99	570	1.709
		Control	897.58	6.86	630	1.417
Green house type Solar Drying (GSD 51.63^{0}C)	3.00 mm	KMS treated	952.20	4.58	480	1.973
		NaCl treated	984.15	6.13	510	1.914
		Control	895.53	6.25	540	1.656
	4.50 mm	KMS treated	954.22	5.14	480	1.968
		NaCl treated	985.18	6.37	510	1.905
		Control	895.55	6.36	540	1.654
	6.00 mm	KMS treated	956.25	6.15	480	1.968
		NaCl treated	985.23	6.43	510	1.909
		Control	896.58	6.87	540	1.653

Table 4: ANOVA for Overall Drying Rate

Source of Variation	SS	Df	MS	F	P-Value	F_{crit}
Rows	0.376803	2	0.1934016	1945.523	1.1456802	4.122821
Columns	0.224118	4	0.0528235	454.9265	1.956833	3.365835
Error	0.001948	8	0.0000987			
Total	**0.584868**	**14**				

CONCLUSIONS

Dehydration of garlic slices was studied in the present work with and without pretreatment using 5% NaCl and 0.2% KMS solution. The drying kinetics, quality characteristics, sensory evaluation of the final product and storability study of the dehydrated garlic slices were studied.

- Total drying time considerably reduced with the increase in drying air temperature from 35.55 to 45.35^{0}C under open sun drying to 45.15 to 58.63^{0}C under greenhouse type solar drying conditions. Average drying temperature in the greenhouse type solar dryer and in the open sun were 51.63^{0}C and 40.4^{0}C, respectively whereas the relative humidity was about 18.04% and 20.85%, respectively.

- Chemical treated (KMS and NaCl) samples dried under green house type solar dryer took average drying time of 8 hours which was 2.50 hours lesser than drying time of untreated samples under open sun drying.

- The initial moisture contents of garlic slices were found in the range between 898.53-981.23% (d.b.). The garlic samples took 480 to 630 minutes drying time depending upon temperature, drying methods, pretreatments and thickness. It was observed that total moisture loss increased with increase in drying temperature and decrease with decreased in drying temperature.

- The best consumer preference in terms of overall acceptability after 90 days of storage was found in sample S1 (8.0) followed by S2 (7.0), S3 (6.8) and sample S4 (6.5). Hence, S1 sample was better on the basis of maximum score obtained for colour, appearance, taste and overall acceptability.
- The product in terms of pungency, colour, acidity, ascorbic acid, total sugar, reducing sugar, rehydration characteristics and sensory evaluation was found to be most acceptable when samples were treated in the solution of potassium metabisulphite (KMS) and dried under greenhouse type solar drying condition using 3.0 mm thickness.
- Increase in temperature and thickness resulted higher colour value. However, chemically treated garlic slices showed less colour development due to sulphite treatment. Thus, the colour value can be minimized by imparting the sulphite treatment and adopting lower drying temperature as thickness, where as colour value was maximum in greenhouse type untreated samples.
- With respect to colour and texture, chutney was well accepted after 90 days as compared to upma, whereas in case of flavour, taste and overall acceptability, the upma was well accepted as compared to chutney.
- Overall the greenhouse type solar dryer was found suitable for drying garlic slices which can be safely stored for 3.0 months.
- The temperature and slice thickness were found to be the significant factors affecting the drying process.
- The effect of air velocity was observed only on the rehydration ratio.
- The drying of garlic slices takes place in the falling rate period.

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