Effect of Pretreatments, Loading Density and Drying Methods on Garlic Leaves

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Abstract: ***The proper drying techniques are the most important aspect of leafy vegetable preservation. The use of solar dryer helps to reduce the losses and improves the quality of product. Fresh amaranth leaves were pretreated in two ways viz. (i) dipping in a solution (leaves to water 1:5 (w/w)) containing 0.1% Mgcl2 + 0.1% NaHCO3 + 2% KMS (T_1) in distilled water for 15 minute and (ii) blanching in boiling water (T_2) containing 3% sodium bisulphate for 2 min. The leaves were dried at 1.5, 2.0 and 2.5 kg/m^2 loading density, under greenhouse type solar dryer and in open sun. Untreated samples (T_3) were also dried as control samples. The samples were dried from initial moisture content of 655.35 to 727.12% db to a final moisture content of 5.381 to 5.79% db. Total drying time considerably reduced with the increase in drying air temperature from 30^{0}C under open sun drying to 44 ^{0}C under greenhouse type solar drying conditions. Major drying took place in falling rate period. The average drying rate increased with increase in temperature and decrease with time and loading density. Chemically treated samples dried under greenhouse type solar dryer took lesser time than blanched and untreated samples. It was observed that total moisture loss increased with increase in drying temperature and decreased with decrease in drying temperature. The product quality was found to be most acceptable of garlic leaves treated in the solution of 0.1% Mgcl2 + 0.1% NaHCO3 + 2% KMS (T_1) dried under GSD using 2.0 kg/m^2 loading density.***

Keywords: Loading Density, Pretreatment, Open Sun Drying, Greenhouse Type Solar drying

1. Introduction

Garlic plant grain was first discovered in Mexico and it gained popularity due to its healing and nutrition value **(Bressani R., 1990).** Garlics plant is a popularly grown leaf vegetable in tropical and subtropical regions of the world including Africa, India, Bangladesh, Sri Lanka and the Caribbean. It is also grown as leaf vegetable through South-East Asia and Latin America. Leafy vegetable have gained commercial importance and form an essential part of diet, providing vitamins and micro-nutrients. As a result of their high moisture and short shelf life, there is the need to process them **(Driscoll, 2004)** that can store for longer periods **(Jayaraman and Das Gupta, 2006)** and so are available all year round **(Mudambi *et al*., 2006)**. Potential advantage of the amaranths is the chemical composition which is source of plant protein and rich source of vitamins and minerals. Garlic leave contains Fat (0.5g), Fibre (1.0gm), Minerals (2.7gm), Protein 4.0 (gm), Carbohydrate (6.3 gm), Thiamin (0.03mg), Riboflavin (0.10mg), Iron (25.5 gm), Vitamin (99gm) and Vitamin A (9300 I.U).

Drying is the most common form of food preservation and extends the food self-life. The major objective in drying agricultural products is the reduction of the moisture content to a level, which allows safe storage over an extended period. Also, it brings about substantial reduction in weight and volume, minimizing packaging, storage and transportation costs **(Okos, Narsimhan, Singh, & Witnauer,1992).** In the Mediterranean countries the traditional technique of fruit and vegetable drying is by using the sun. This technique has the advantages of simplicity and the small capital investments, but it requires long drying times that may have adverse consequences to the product quality: the final product may be contaminated from dust and insects or suffer from enzyme and microbial activity **(Andritsos, Dalampakis, & Kolios, 2003).** In order to improve the quality, the traditional sun drying technique should be replaced with industrial drying methods such as hot-air and solar drying **(Ertekin & Yaldiz, 2004; Diamante & Munro, 1993).** The drying is influenced by processing conditions, sample treatment and composition **(Ahmed *et al*., 2001)**. During drying many changes take place; structural and physic-chemical modifications affect the final product quality, and the quality aspects involved in dry conversation in relation to the quality of fresh products and applied drying techniques **(Baysal, Icier, Ersus, & Yıldız, 2003).** Currently hot air drying is the most widely used method in post-harvest technology of agricultural products. Using this method, a more uniform, hygienic and attractively coloured dried product can be produced rapidly **(Doymaz, 2004).** However, it is an energy consuming operation and low-energy efficiency, so more emphasis is given on using solar energy sources due to the high prices and shortage of fossil fuels. Solar dryers are now being increasingly used since they are a better and more energy efficient option. The solar dryers could be an alternative to the hot air and open sun drying methods, especially in locations with good sunshine during the harvest season **(Pangavhane, Sawhney, & Sarsavadia,** 2002). Many researchers on the mathematical modeling and drying studies have been conducted on the thin layer drying processes of various agro-based products such as green bean green peppers, squash, rice etc. However, very little information is available on thin layer drying behavior of garlic leaves. Therefore, thin layer drying of amaranth under open sun and greenhouse type solar dryer was planned to undertake. Limited scientific information on drying of leafy vegetables under solar dryers are available. As we know that the degree of greenness is important in determining the final quality of thermally processed green vegetables which gets their colour from chlorophyll pigments. The degradation of naturally occurring colour pigments in the food during thermal processing is a major problem. In all green vegetables, the change in colour from bright green to dull olive - green or olive - green colour is due to the conversion of chlorophyll to their respective pheophytins and further breakdown of products such as pheophorbides and Amaranth fits well in a crop rotation because of very short duration and large yield of edible matter per unit area. In recent years, research efforts have been directed towards investigating drying and dehydration characteristics of various products, mostly in relation to process parameters and develop appropriate technologies. In India, studies on drying and quality characteristics of high moisture leafy vegetable like garlic are very few. Considering the advantage of greenhouse type solar dryer, a comparative study of greenhouse type solar dryer and open sun drying for garlic leaves was planned.

2. Materials and Methods

2.1 Sample Preparation

Fresh garlic leaves were washed thoroughly in fresh water so as to remove roots and stem and leaves and soft stem were separated from the rest parts. Care was taken to avoid bruised and discoloured leaves.

Preliminary experiments were planned and conducted on the basis of review of earlier work on drying of high moisture vegetables. The drying of garlic leaves was carried out both under greenhouse type solar dryer and in open sun. The samples of garlic leaves were subjected to two pretreatments viz. dipping in the solution of 0.1% $MgCl_2$ + 0.1% $NaHCO_3$ + 2% KMS (T_1) for 15 min and blanching in boiling water (T_2) in the ratio of 1:5 (leaves: water) containing 3% sodium bisulphate ($NaHSO_4$) for 2 min. The control untreated (T_3) samples were also used for the comparative studies. It was observed that loading density (weight of sample per unit area) was mostly preferred for drying of amaranth leaves. Hence, it was decided to use sample with a variable loading density of 1.5, 2.0 and 2.5 kg/m^2 of tray area. The unblanched samples took less time to dry as compared to blanched one. Time of pretreatment of amaranth leaves was decided on the basis of literatures available. It was found that medium temperature drying is preferred to retain the green colour and flavour of garlic leaves to an acceptable level. Hence, the temperature available in the month of March was selected for the present study. A process flow chart for the experiment is show in Figure-1

2.2 Experimental plan

Sl. No	*Variable Parameters*	*Range/ particulars*	*Levels*	*Observations*
1.	Pre-treatments	T1: Dipping in the solution of 0.1% $MgCl_2$+ 0.1% $NaHCO_3$ + 2% KMS, for 15 min. T2: Blanching in boiling water in the ratio of 1:5 (leaves: water) containing 3% sodium bisulphate ($NaHSO_4$) for 2 min. T3: Control (untreated)	3	1. Measurement of weight of the samples 2. At an interval of 30 min quality evaluation of dried samples viz. sensory and rehydration ratio.
2.	Loading density	1.5, 2.0 and 2.5 kg/m^2	3	
3.	Drying methods	GSD: Greenhouse type solar drying OSD: Open sun drying	2	
4.	Storage	Quality analysis on 0, 30, 60, 75 and 90 days during storage		

2.3 Experimental setup

A greenhouse type solar dryer was used to executing the experiments. The schematic view of drying is shown in Figure 1. The dryer consists of drying chamber, inlet opening for the entry of warm air, the exhaust system (fan) removing humidity air, during platform. The specifications of the greenhouse type solar dryer given in Table 2.

Table 2: Specifications of the Greenhouse Type Solar Dryer

S. No.	*Parameters*	*Specification*
1.	Side height	2.0m
2.	Central height	2.3m
3.	Dimension	5.0m x 3.0m
4.	Shape	Modified Quonset shape
5.	Slope of roof	36.9^0 from south and north wall
6.	Orientation	East-west direction
7.	Dryer frame	38mm square MS pipe
8.	Glazing material	200µ UV stabilized LDPE having 75% transparency
9.	Floor	Cement concrete floor at the bottom, insulated with glass wool and covered with black painted iron sheet (22 gauge)
10.	Inlet opening	5” wide inlet of insect proof net throughout the length on south wall covered with plastics film with the rolling system
11.	Outlet opening (exhaust)	L shape (1.5m length) on north wall
12.	Tray holding frame	Frame (2.0m x 0.7m x 1.0m) made of 30mm square MS pipe, with the provision of 3 steps of racks namely upper, middle and lower
13.	Drying trays	35cm x 30cm x 5cm size wooden framed with perforated stainless steel base

14.	Mode of drying	Natural convection solar drying
15.	Shade system	Provision of black shade net (70%) system below the top glazing material. It is fixed on north side and may be opened towards south depending upon the crop to be dried.
16.	Inside temperature	May be more than 15 ^{0}C above the ambient during summer.
17.	Capacity	55 kg leaves for Amaranths per batch
18.	Efficiency	95%
19.	Evaporation rate of water	0.3 kg/m^2/hr during March
20.	Life	20 yrs of frame and 4 yrs of glazing material
21.	Operation	Inlet and outlet (exhaust) system should be kept open when the device is used as a dryer, during peak hot period of the day

2.4 Equipments/Instruments

2.4.1 Hot Air Oven

Hot air oven (Instron, IN-301 model) was a double walled chamber of size 78cm x 27cm x 116cm. Outer chamber was made of mild steel while the inner chamber was made of stainless steel. Glass wool insulation (65 cm) was provided between the two walls. Heating elements were evenly placed in ribs on both sidewalls and rear wall for uniform heating. Air ventilators were provided on the sidewalls of the oven. A digital display was placed in front of the oven to measure the temperature. The temperature was controlled by a thermostat. The perforated shelves were made of stainless steel provided for the placement of samples over them. Oven was used for drying of samples, so as to determine the moisture content of raw materials and their products.

2.4.2 Electronic Balance

A top pan electronic balance of high accuracy (M/s Eagle Instruments Pvt., New Delhi) with least count of 0.01 g was used for weighing the samples. Another electronic balance (Samson S300) with least count of 0.10 g having capacity of 5 kg was also used for weighing of onion and other raw materials.

2.5 Temperature measurement

The temperatures were measured using copper constantan thermocouples. The thermocouples were calibrated at both boiling and freezing points. The measurements were conducted using digital thermometer (model Omega type J, USA).

2.5.1 Relative humidity measurement

The air relative humidity (%) of the inlet and outlet ducts of the dryer was measured using thermo-hygrometer (model 37200, OKTON).

2.6 Determination of various parameters of drying kinetics

Methods used to measure different variables described blow

2.6.1 Initial Moisture Content

Initial moisture content of onion samples were determined oven drying method as recommended by **(7).** In the determination of the moisture content a thin layer of finely divided asbestos (gooch grade) was spread over a flat bottom metallic dish and dried at 110^o C in hot air oven for one hour then covered, cooled and weighed. Sample of 5 g each was taken and its weight was recorded as initial weight of sample (M_o). Then samples were spread uniformly over the asbestos layer in a metallic dish and weight was recorded as M_1. The dish-containing sample was then placed in the hot air oven maintained at 100 ± 1^{0}C temperature for 16-18 hours.

$$IMC = \frac{M_1 - M_2}{M_0} \times 100 \qquad \ldots\ldots (1)$$

Where,

IMC = Initial moisture content of sample, % (w.b.)

M0 = Initial weight of sample taken, 5 g

M1 = Weight of sample before oven drying plus weight of dish with cover, g

M2 = Weight of dried and desiccated sample plus weight of dish with cover, g.

2.6.2 Moisture content during drying experiment

Moisture content of the samples during drying was computed through mass balance. For this purpose, weight of the sample during drying was recorded at predetermined time interval. The following formulae were used to calculate the moisture content according to the **(7).**

$$MC = \frac{W - W_{d'}}{W_{d'}} \times 100 \qquad \ldots\ldots\ldots. (2)$$

Where

M.C. = Moisture content, % (d.b.)

W = Weight of sample at any time, g

Wd′ = Weight of bone dry material, gm

2.6.3 Moisture ratio and drying rate

Moisture Ratio (MR) is defined as followed by **(7)**

$$MR = \frac{M - Me}{Mo - Me} \qquad \ldots\ldots\ldots. (3)$$

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.).

2.6.4 Drying rate

In thin layer drying, the drying process is represented as followed by **(7)**

$$\frac{dm}{dt} = \frac{M_2 - M_1}{\Delta t} \qquad \ldots\ldots.. (4)$$

Where

M1 = Moisture Content (%db) at time t1

M2 = Moisture Content (%db) at time t2

Δt = difference in time

3. Result and Discussion

The drying behavior of chemical treated (T_1) blanching in boiling water (T_2) untreated (T_3) amaranths , subjected to different drying methods and loading density were statically analyzed. The change in moisture content with drying time for treated (T_1), blanching in boiling water (T_2) and untreated (T_3) samples are plotted in Fig. 1 to 6 from these figures it is observed that the moisture content decreases with increase in time for different loading density.

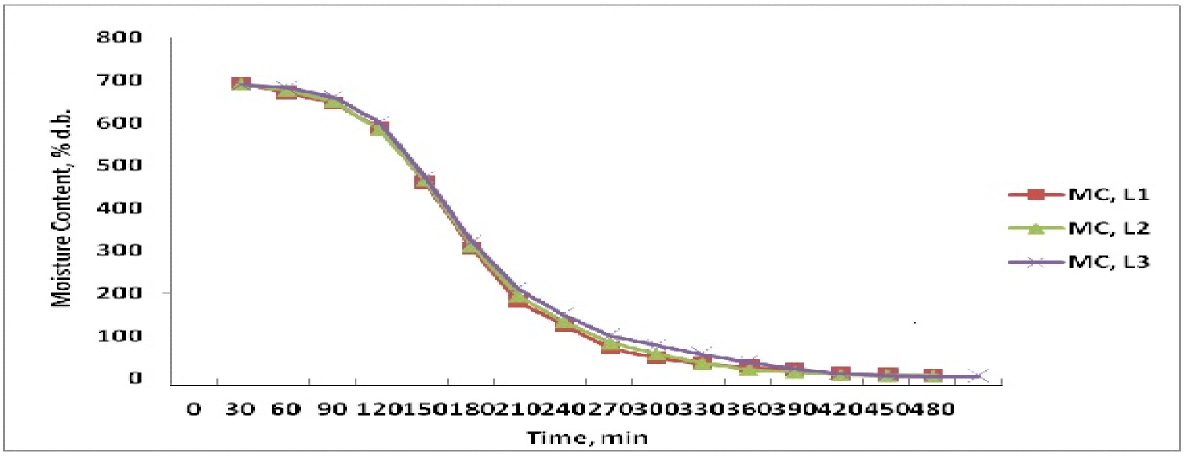

Figure 1: Variation of moisture content with time under GSD for chemically treated samples

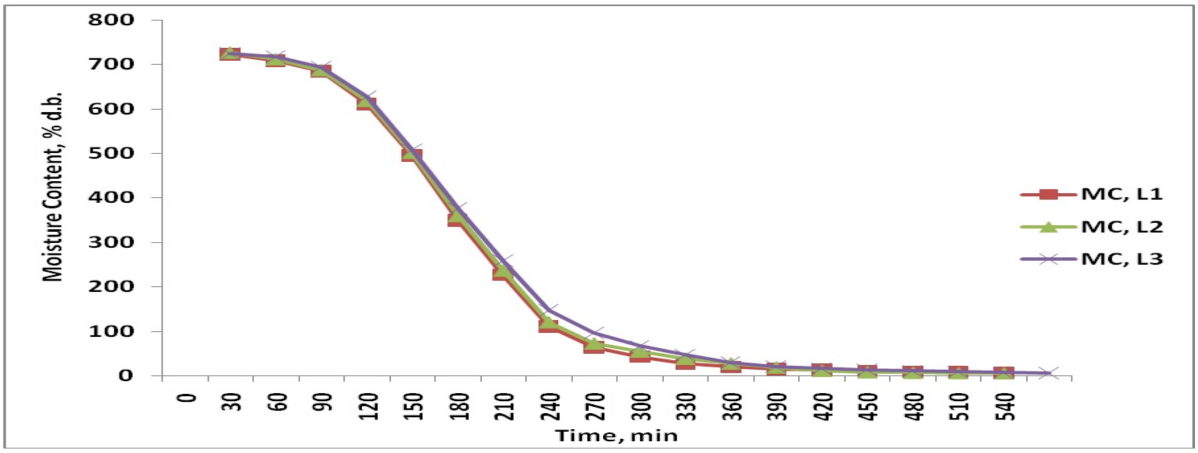

Figure 2: Variation of moisture content with time under GSD for boiling water blanched samples

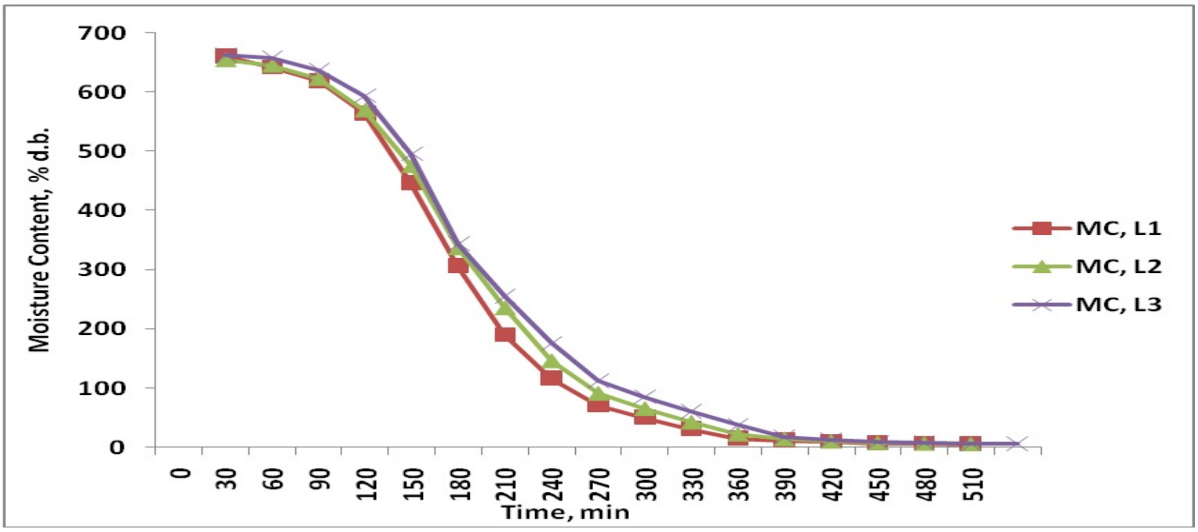

Figure 3: Variation of moisture content with time under GSD for untreated samples

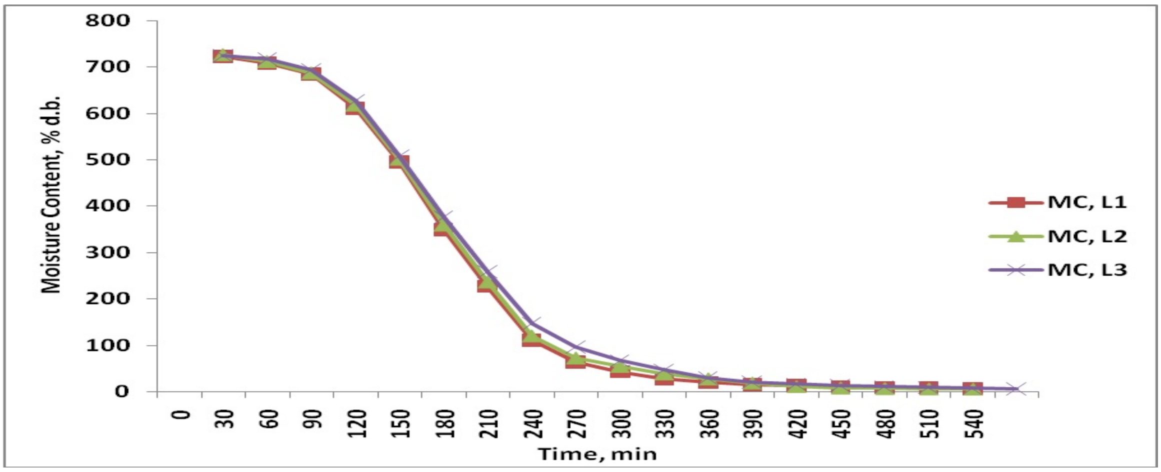

Figure 4: Variation of moisture content with time under GSD for boiling water blanched samples

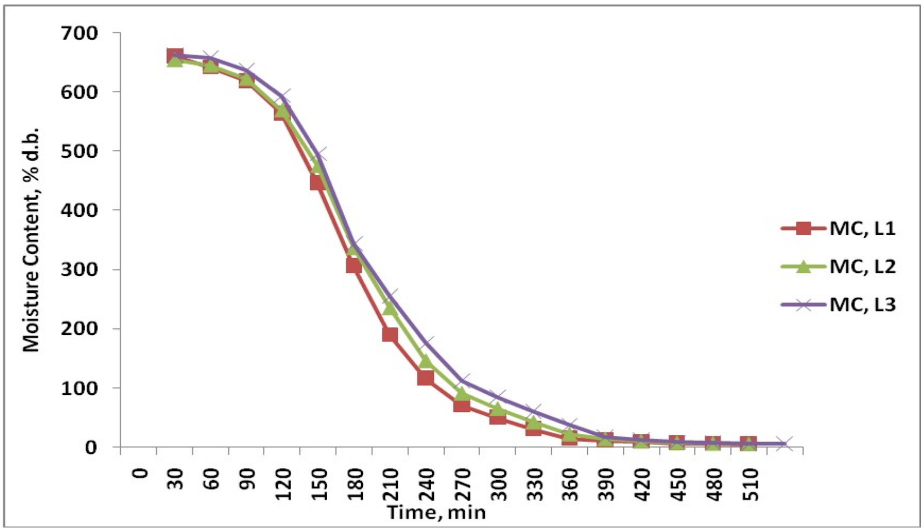

Figure 5: Variation of moisture content with time under GSD for untreated samples

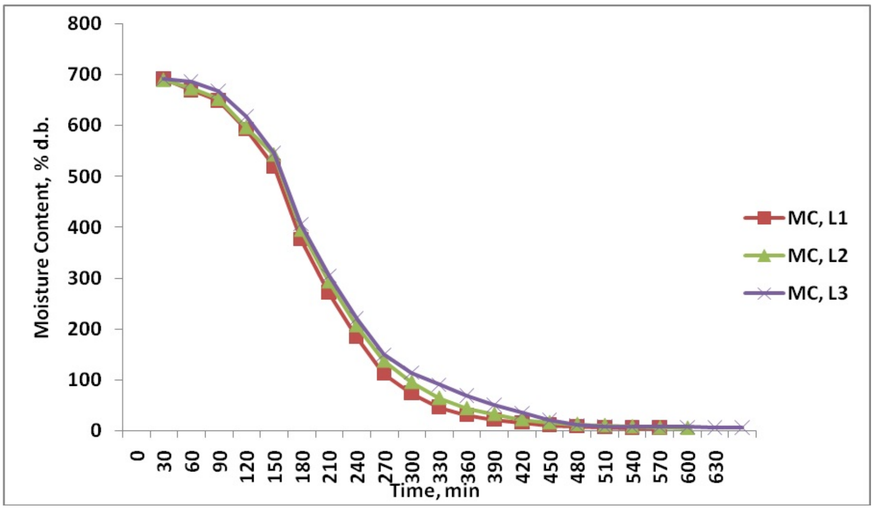

Figure 6: Variation of moisture content with time under OSD for chemically treated samples

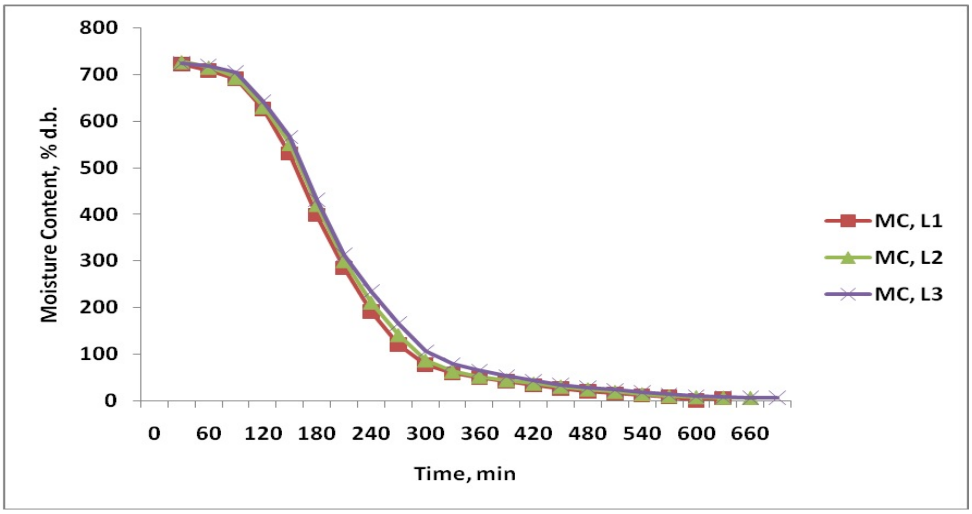

Figure 7: Variation of moisture content with time under OSD for boiling water treated (blanched) samples

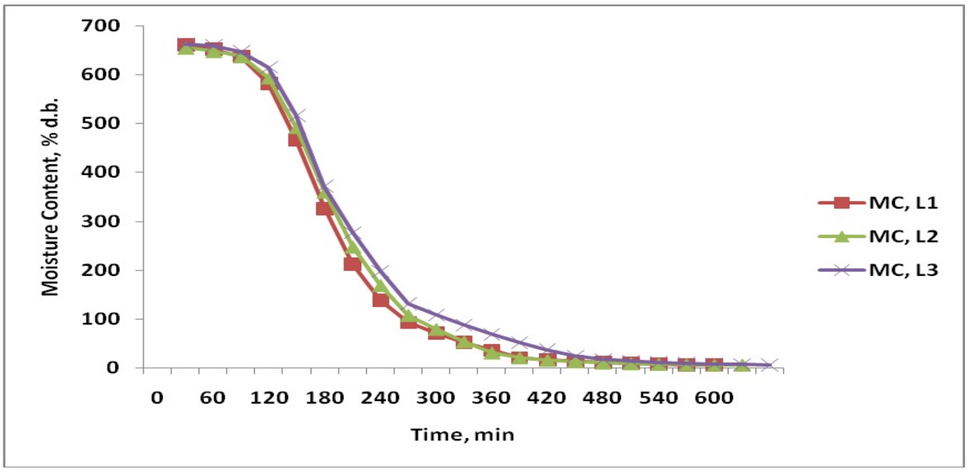

Figure 8: Variation of moisture content with time under OSD for untreated samples

3.1 Drying Rate

Normally, it can be expected that the overall drying rate should be higher at higher temperature from 30^{0}C (open sun) to 44^{0}C (greenhouse type solar dryer). Overall drying rate increased with increase in average temperature. It is seen that the overall drying rate decreased with increase in loading density in each drying methods. It is also seen that the overall drying rate was slightly lower for boiling water blanched (T_2) and untreated sample (T_3) than for chemically treated (T_1) at almost all experimental samples. The amaranth treated chemically, dried faster than the others, as chemicals used in chemical treatment (T_1) resulted into more expansion of amaranth pores caused faster heat and mass transfer between amaranth surface and air, and therefore, increased drying rate. **Sodha, Dang, Bansal, and Sharma (1985)** found that the rate of drying (moisture evaporation) depends on a number of external parameters (solar radiation, ambient temperature, wind velocity and relative humidity) and internal parameters (initial moisture contents, type of crops, crop absorptivity, mass of product per unit exposed area etc.).

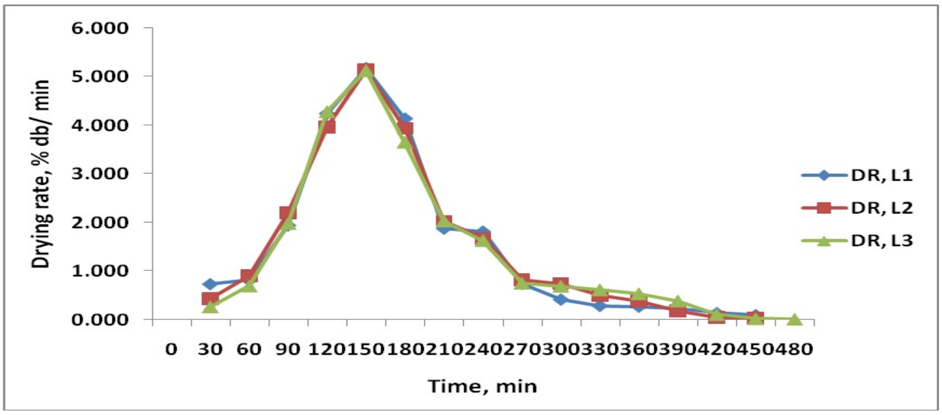

Figure 9: Variation of drying rate with drying time under GSD for chemically treated samples

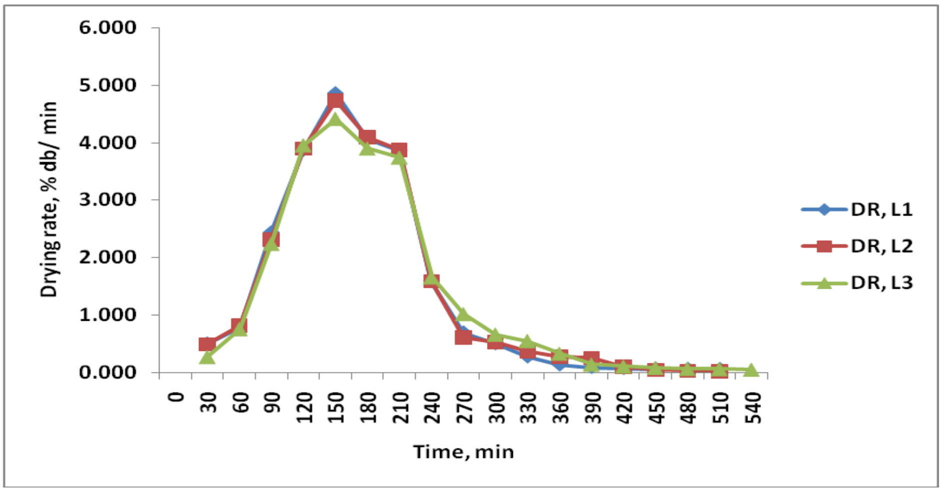

Figure 10: Variation of drying rate with drying time under GSD for boiling water treated (Blanched) samples

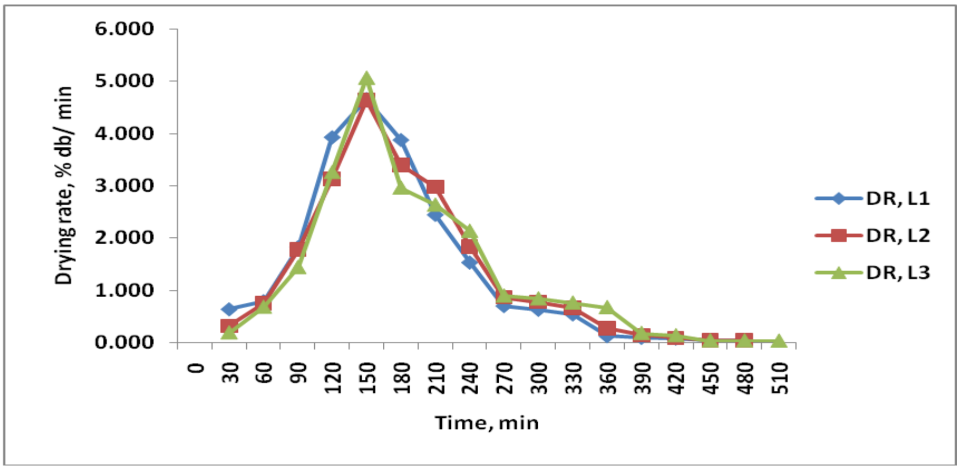

Figure 11: Variation of drying rate with drying time under GSD for untreated samples

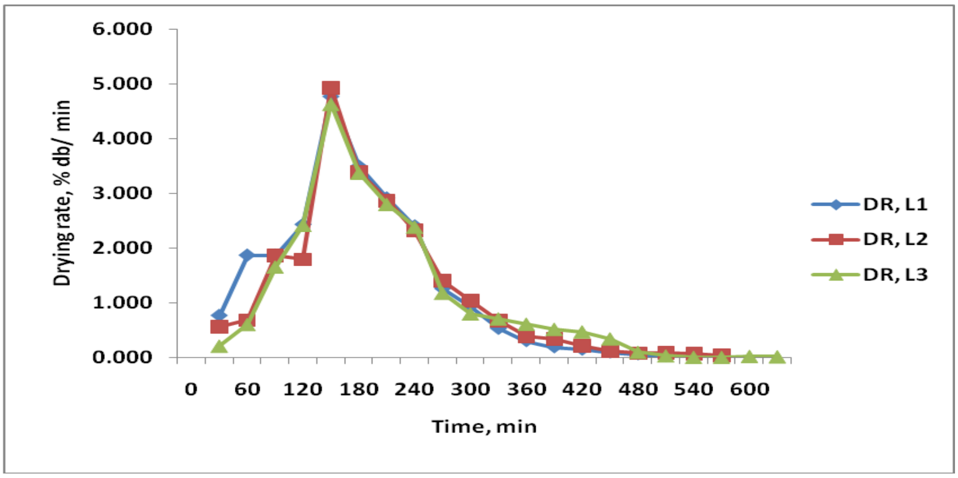

Figure 12: Variation of drying rate with drying time under OSD for chemically treated samples

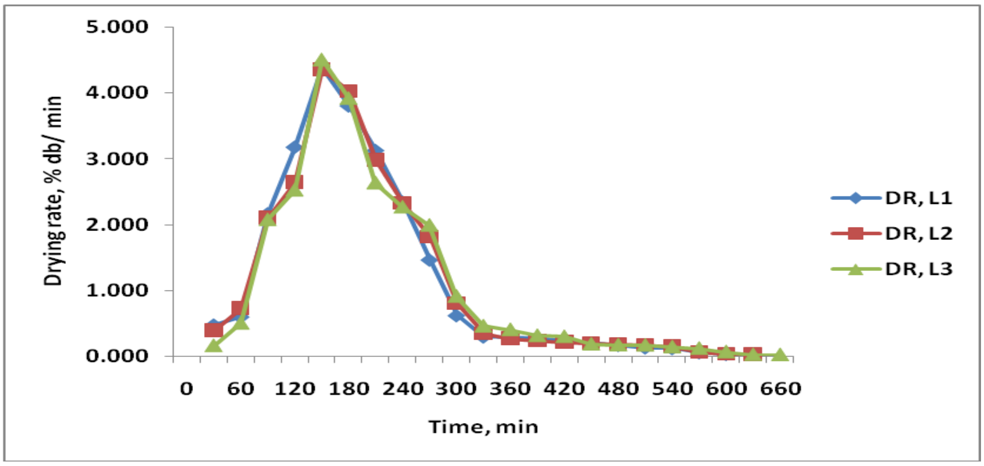

Figure 13: Variation of drying rate with drying time under OSD for boiling water treated (Blanched) samples

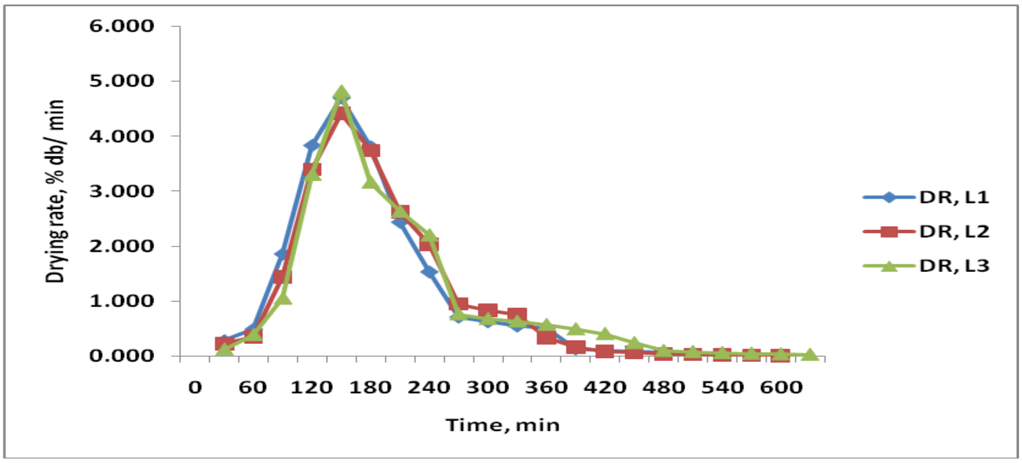

Figure14: Variation of drying rate with drying time under OSD for untreated sample.

3.2 Moisture Ratio

The variations in moisture ratio with time under greenhouse type solar dryer and under open sun are shown in Fig 15 to Fig 20. The moisture ratio value at zero time of drying was one in all the cases and in successive drying it decreases nonlinearly. So, moisture ratio versus drying curve could better describe the drying phenomena than the curves of moisture content verses drying time (fig. 1 to 6), because the former had same initial value of moisture ratio (MR=1) but latter had different initial moisture content.

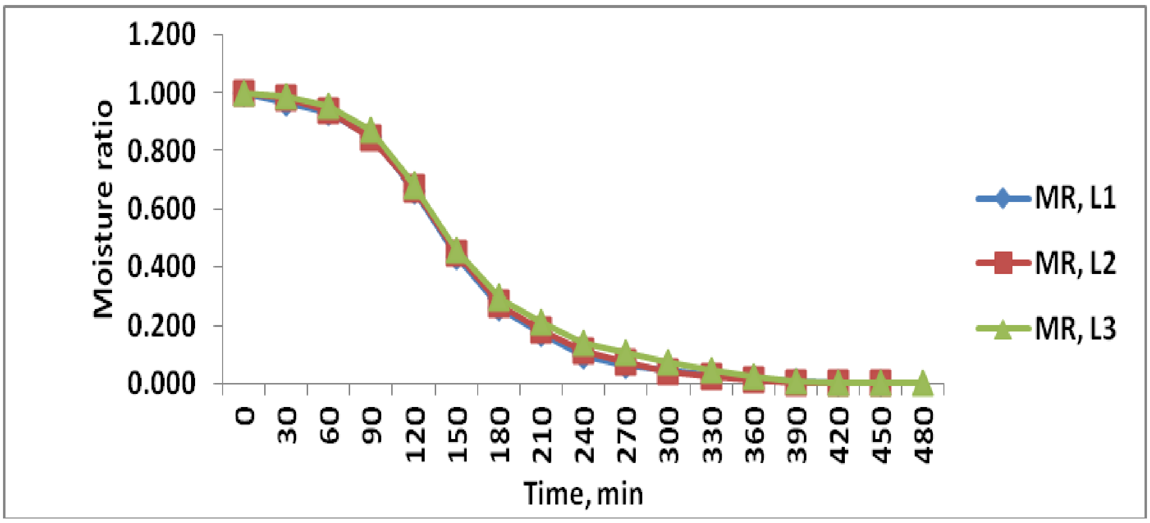

Figure 15: Variation in moisture ratio with drying time under GSD for chemically treated samples

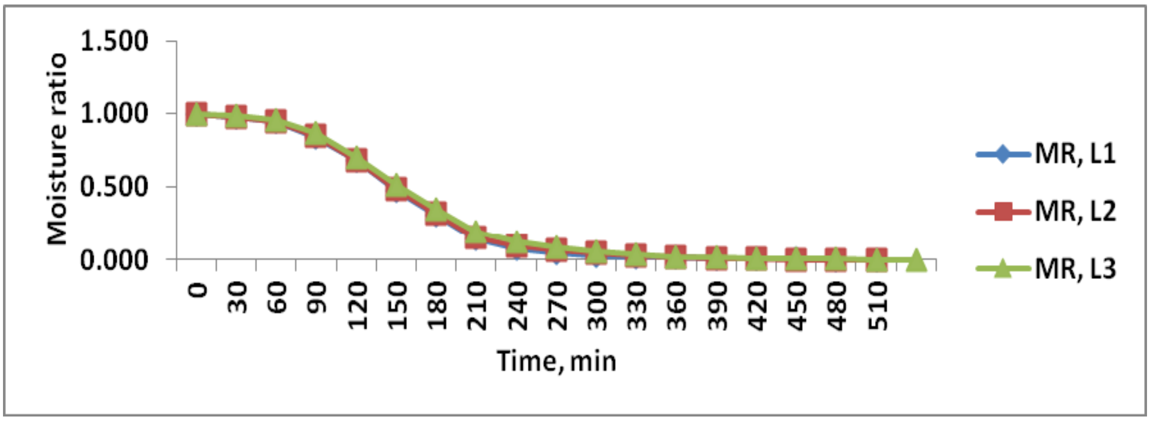

Figure 16: Variation in moisture ratio with drying time under GSD for boiling water treated samples

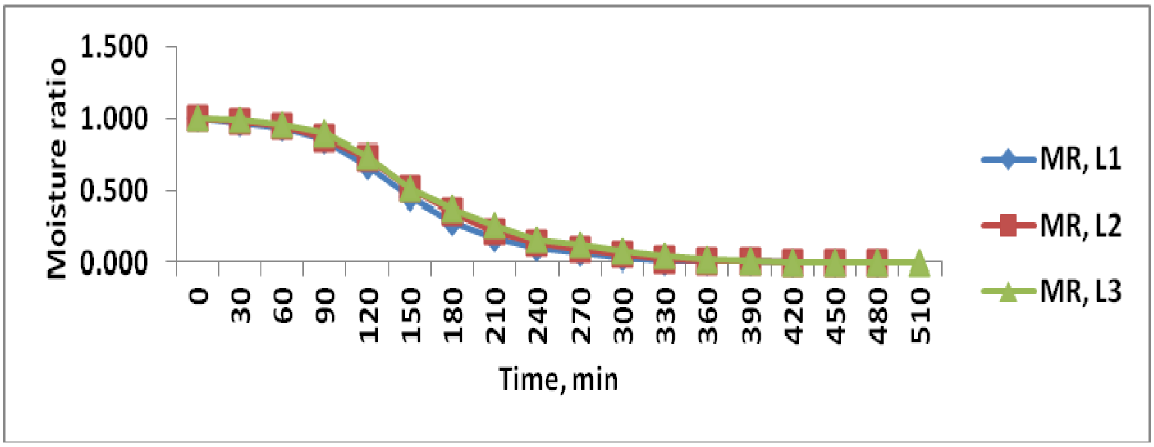

Figure 17: Variation in moisture ratio with drying time under GSD for untreated samples

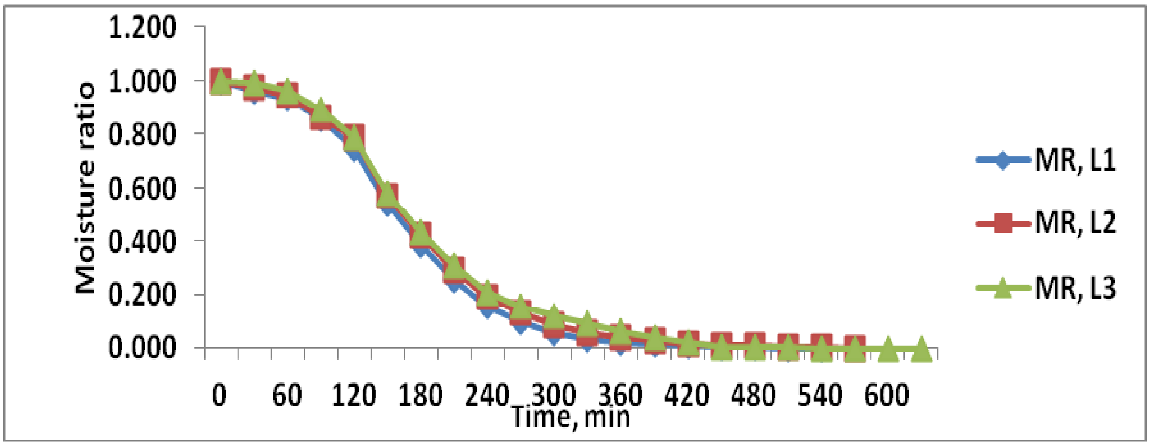

Figure 18: Variation in moisture ratio with drying time under OSD for chemically treated samples

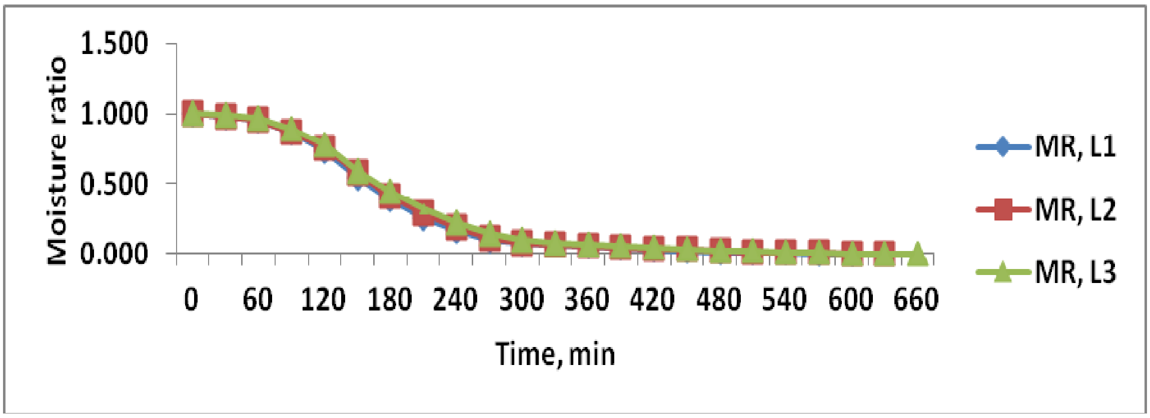

Figure 19: Variation in moisture ratio with drying time under OSD for boiling water treated (blanched) samples

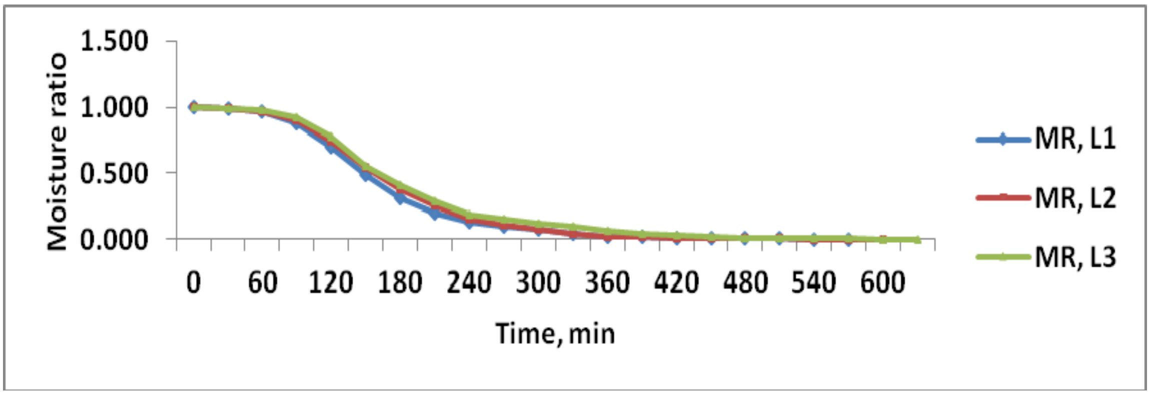

Figure 20: Variation in moisture ratio with drying time under OSD for untreated samples

4. Conclusion

Drying rate should a positive correlation with temperature while it showed a deceasing trend with increasing loading density. The average drying rate increased with increase in temperature and decreased with increase in time and loading density. Total drying time considerably reduced with the increase in drying air temperature from 30 ^{0}C under open sun drying to 44^{0}C under greenhouse type solar drying conditions. Average drying temperature in the greenhouse type solar dryer and in the open sun were 44^{0}C and 30^{0}C, respectively whereas the relative humidity was about 34.13 % and 36.29 % respectively. Chemically treated samples dried under greenhouse type solar dryer took average drying time of 7.666 hrs which was 3 hrs lesser than drying time of blanched samples under open sun drying. The chemically blanched samples took less time in dehydration as compared to blanched and untreated leaves.

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