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RESEARCH PAPER

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Drying characteristics of Bijapur white onion (*Allium cepa* L.) using solar tunnel dryer

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SUMMARY :

Fresh Bijapur white onion (*Allium cepa* L.) were treated with 10 per cent NaCl for 1 h, 0.2 per cent KMS for 15 min and 10 per cent NaCl + 0.2 per cent KMS for 15 min and dried in solar tunnel dryer (STD) and open yard sun drying (OYSD). A comparative study was conducted to evaluate two drying methods with respect to temperature and time combinations. The sample of Bijapur white onion required 18 to 21 h to dry under open yardsun drying and 16 to 18h in solar tunnel drier to bring down initial moisture content ranging from 599.30–774.13 per cent (d.b.) to final moisture content of 4.56-5.25 per cent (d.b.). Drying took place in the falling rate period and the Midilli and kocuck model was found to be the best fit to describe the drying behaviour of Bijapur white onion.

KEY WORDS : Bijapur white, STD and OYSD, Pre-treatment, Drying, Drying models

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Onion (*Allium cepa* L.) is considering one of the main crops under Allium family, cultivated mainly in the tropical countries since long time. Besides imparting a characteristic taste and flavour to food, it also has significant therapeutic values (Augusti, 1996). Onion serves as a good medicinal compound for cataract, cardiovascular disease and cancer due to its hypocholesterolemic, thrombolitic and antioxidant effects (Nuutila *et al*., 2003). It has been in cultivation for more than 4000 years (Brewster, 1994). Onion contains vitamin B and a trace of vitamin C and also traces of iron and calcium. The outstanding characteristic of onion is its pungency, which is due to a volatile oil known as allyl-propyl disulphide. Onions when compared with other fresh vegetables are relatively high in food energy, intermediate in protein content and rich in calcium and riboflavin.

Eating raw onions helps to reduce cholesterol levels because they increase levels of high density lipoproteins. Several antioxidant compounds, mainly polyphenols such as flavonoids and sulfur-containing compounds have been described in onion and garlic (Gorinstein *et al*., 2005). Onions help in controlling coronary heart disease, thrombosis and blood pressure. Sulphur compounds present in onion help to prevent the growth of cancer cells (Mitra *et al*., 2011). Onion is dried or dehydrated to increase its shelf-life. Dehydrated onion is used mainly for making soup in Europe and USA (*www.newdesignworld.com*). But in India, the dehydrated onion mainly used in ketchup, pickle, sauce and in some spicy foods.

In India, onions (mostly red onions) are grown for fresh market. White onions are grown on commercial scale in few states like Maharashtra, Gujarat and some parts of Karnataka. Red onions are not suitable for dehydration and for export primarily due to their poor quality, low productivity, low solids, low pungency level and high reducing sugars (>17 %); even upto 22-26 per cent total soluble solids (TSS) in some hybrids; comparatively low moisture content (< 84 %), globe shaped, having small root base with a minimum of 70 mm diameter. These onions usually have longer shelf-life and free from diseases (*www.jains.com*). The *Bijapur white* onions were selected for the present study, since this variety having more total soluble solids but less shelf-life, hence with this technology can enhance the shelf-life and quality of this onion.

The common preservation techniques followed for onion worldwide are mostly sun or solar drying (Sarsavadia, 2007), and hot air drying (Kaymak-Ertekin and Gedik, 2005). Solar drying is the best alternative as a solution to all drawbacks of natural drying and artificial mechanical drying. Open sun drying has several disadvantages like spoilage of product due to adverse climatic condition like rain, wind, moisture, dust, loss of material due to birds and animals, deterioration of the material by decomposition, insects and fungus growth. The purpose of the study was to find such a model to describe solar tunnel drying characteristics of onion slices. A few selected models are described below.

EXPERIMENTAL METHODS

The present study on drying of Bijapur white onion was carried out in the solar tunnel dryer of one tone capacity installed at the Department of Processing and Food Engineering, Raichur. The dryer has tunnel shape made of semi cylindrical metallic (galvanized pipe) structure covered with UV-stabilized transparent thermic polyethylene sheet of 200 micron. Fresh onion (*Allium cepa* L.) of Bijapur white onion was purchased from the local market of Bijapur district of Karnataka. The onions were washed in tap water to remove the soil and dirt adhered to the onion. The onions were pre-treated in selected preservatives and dried in STD and under OYSD. The treatment combinations were laid out in two Factorial Randomized Block Design with three replications.

The details of pre-treatments selected for the investigation are as given below :

P_1 = Untreated

P_2 = 10 per cent NaCl for 1 h

P_3 = 0.2 per cent KMS for 15 min

P_4 = 10 per cent NaCl + 0.2 per cent KMS for 15 min.

The temperature and relative humidity of ambient air and air inside STD were recorded at an interval of one hour during drying period. Initial weight of onion samples and hourly physiological loss in weight during drying period were taken to study the drying characteristics onions in STD and under OYSD. The experimental data were tested for fitting in two drying models. The drying rate was calculated by using the following equation :

$$\text{Drying rate } (\%\text{d.b. h}^{-1}) \ Z \ \frac{dM}{dt} \qquad ....(1)$$

where,

dM= Difference in moisture content (% d.b.),

dt= Difference in drying time (h).

The mathematical models *viz*., Page, Midilli-Kucuk and logarithmic models were selected for fitting the experimental data and these selected models were the best models to describe the drying curve equations of onion slices during drying (Derya and Mehmet, 2010). These are explained here under.

Page model: $MR = \exp(-k\times\bar{\ }^{n}) \qquad ....(2)$

Midilli-Kucuk model: $MR = a\times\exp(-k\times\bar{\ }^{n})+b\bar{\ } \qquad ....(3)$

Logarithmic model: $MR = a\times\exp(-k\times\bar{\ }^{n})+c \qquad ....(4)$

where,

MR = Moisture ratiowhich is denoted by $\left(\frac{M - M_c}{M_o - M_e}\right)$

M_e = equilibrium moisture content, per cent (d.b.)

M = moisture content at any time θ, per cent (d.b.)

M_o = initial moisture content, per cent (d.b.)

k = drying rate constant

θ = drying time (min)

n = dimensionless empirical co-efficient

a, b, c = empirical constants in drying models.

The difference between observed and predicted moisture ratio values at various drying times under different drying methods and chemical treatments were defined as residuals. The residuals were plotted against predicted values of moisture ratios. A model was considered acceptable if the residual values fell in horizontal band centered around zero, displaying no systematic tendencies (*i.e.*, random in nature) towards a clear pattern. If the residual plots indicated clear pattern, the model was not considered acceptable (Chen and Morey, 1989).

The constants of the selected models were estimated by non-linear regression (Ramachandra and Rao, 2009).The parameters of all the models were estimated by using MATLAB version 7.0 software packages. The fit quality of the proposed models on the experimental data was evaluated using linear regression analysis using curve fitting tool in MATLAB 7 Software. The statistical parameters standard square error (SSE) and root mean square error (RMSE) were calculated employing the following equations :

$$\mathbf{RMSE} = \sqrt{\frac{\sum_{i=0}^{N}\left(\mathbf{MR_o} - \mathbf{MR_p}\right)^2}{\mathbf{df}}} \qquad ....(5)$$

$$\mathbf{SSE} = \frac{\mathbf{1}}{\mathbf{N}}\sum_{i=1}^{N}(\mathbf{MR_o} - \mathbf{MR_p})^2 \qquad ....(6)$$

where,

MR_o = observed moisture ratio

MR_p = predicted moisture ratio

df = degrees of freedom

N = number of data points

z = number of constants

SST = sum of squares total

SSE = sum of squares error.

EXPERIMENTAL FINDINGS AND ANALYSIS

The effects of different pre-treatments on moisture content of Bijapur white onion under different drying methods are shown in Fig. 1. Drying required 17-20 h of drying in open yard sun drying to dry the different pre-treated onion samples from moisture content of 599.30-774.13 per cent (d.b.) to a safe storage moisture content of 4.56-5.21 per cent (d.b.), In case of solar tunnel dryer, the drying required 15-17 h of drying time for various pre-treated onion samples from moisture content of 599.30-774.13 per cent (d.b.) to attain a safe moisture content of 4.77-5.25 per cent (d.b.). The variation in drying time was due to climatic changes *i.e.* variation in temperature and relative humidity. The present results are in good agreement with Kadam *et al.* (2008) who reported that the pre-treated onion slices required 19 sunshine hours in green house/solar dryer. This difference probably might be due to the different cell arrangements and water activity in the food materials.

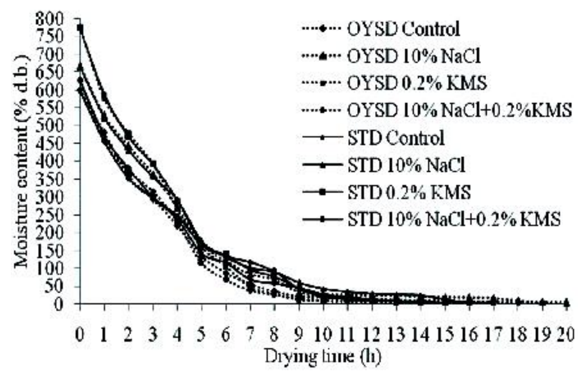

Fig. 1 : Effect of different pre-treatments and drying methods on reduction in moisture content of *Bijapur white* onion

The drying rate of Bijapur white onion dried under OYSD with pre-treatments 10 per cent NaCl, 0.2 per cent KMS, 10 per cent NaCl + 0.2 per cent KMS and untreated (control) samples was varied from 137.66, 197.90, 169.03 and 119.09 per cent m.c. (d.b.)h^{-1} in the first hour to 0.92, 0.45 and 0.15 and 0.28 per cent m.c. (d.b.)h^{-1}, respectively during the final stage of drying. In OYSD, the drying rate is mainly depends on varying drying temperature and relative humidity. The temperature and relative humidity varies with climatic condition. Whereas in STD the drying rate was varied from 145.81, 186.92, 158.09 and 144.30per cent m.c. (d.b.).h^{-1} in the

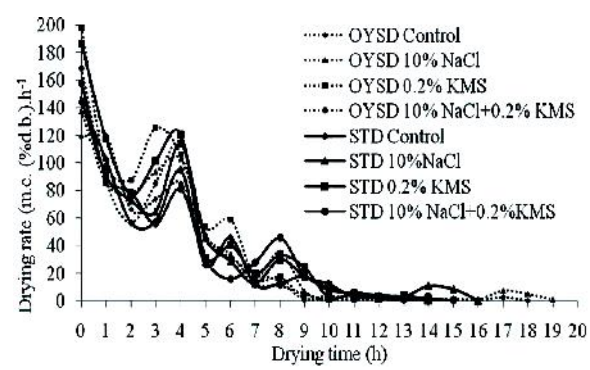

Fig. 2 : Effect of different pre-treatments and drying methods on drying rate of *Bijapur white* onion

first hour to 0.15, 0.35, 2.48 and 0.42 per cent m.c. (d.b.) h^{-1} during the final stage of drying are shown in Fig. 2. This is due to fact that the moisture content of the material was very high during the initial phase of the drying which resulted in high drying rates due to the higher moisture diffusion. The entire drying process for the samples occurred in the range of falling rate period as reported by Derya and Mehmet (2010).

The moisture ratio for different pre-treatments was varied from 1.0 to 0.0078, 0.0059, 0.0079 and 0.0079 in 17-20 h of open yard sun drying in samples pre-treated with 10 per cent NaCl, 0.2 per cent KMS, 10 per cent NaCl + 0.2 per cent KMS and untreated (control) samples, respectively. Whereas in solar tunnel dryer the moisture ratio was varied from 1.0 to 0.0076, 0.0062, 0.0083 and 0.0086 for samples treated with 10per cent NaCl, 0.2 per cent KMS and 10 per cent NaCl + 0.2 per cent KMS and untreated (control) samples, respectively

Table 1 : Estimated values of statistical parameters of page model used for different drying methods and pre-treatments

Method	Variety	Pre-treatements	K	n	SSE	R^2	RMSE
OYSD	V_1	P_1	0.201	1.228	5.079×10^{-3}	0.9970	0.0165
		P_2	0.177	1.227	9.733×10^{-3}	0.9944	0.0226
		P_3	0.198	1.273	1.241×10^{-2}	0.9922	0.0278
		P_4	0.213	1.238	1.808×10^{-2}	0.9885	0.0336
STD	V_1	P_1	0.233	1.092	6.263×10^{-3}	0.9957	0.0204
		P_2	0.199	1.120	7.271×10^{-3}	0.9953	0.0213
		P_3	0.218	1.148	6.889×10^{-3}	0.9952	0.0221
		P_4	0.238	1.051	7.186×10^{-3}	0.9950	0.0218

Table 2 : Estimated values of statistical parameters of Midilli and Kucuk model used for different drying methods and pre-treatments

Method	Variety	Pre-treatements	K	b	a	n	SSE	R^2	RMSE
OYSD	V_1	P_1	0.188	5.99×10^{-4}	0.987	1.27	4.320×10^{-3}	0.9974	0.0164
		P_2	0.153	1.09×10^{-3}	0.977	1.32	7.040×10^{-3}	0.9959	0.0203
		P_3	0.172	-6.54×10^{-5}	0.965	1.34	1.119×10^{-2}	0.9930	0.0282
		P_4	0.184	5.61×10^{-5}	0.963	1.31	1.681×10^{-2}	0.9893	0.0346
STD	V_1	P_1	0.227	-5.51×10^{-4}	0.987	1.09	5.826×10^{-3}	0.9960	0.0281
		P_2	0.187	3.49×10^{-4}	0.985	1.15	6.995×10^{-3}	0.9955	0.0223
		P_3	0.212	-8.41×10^{-4}	0.984	1.14	6.136×10^{-3}	0.9957	0.0226
		P_4	0.243	-1.85×10^{-3}	0.990	1.00	5.166×10^{-3}	0.9964	0.0199
		P_4	0.206	-2.75×10^{-3}	0.999	1.00	3.769×10^{-3}	0.9975	0.0170

Table 3 : Estimated values of statistical parameters of Logarithmic model used for different drying methods and pre-treatments

Method	Variety	Pre-treatements	a	c	K	SSE	R^2	RMSE
OYSD	V_1	P_1	1.005	-1.286×10^{-2}	0.2816	1.373×10^{-2}	0.9918	0.0284
		P_2	1.045	-7.859×10^{-3}	0.2562	1.94×10^{-2}	0.9888	0.0328
		P_3	1.057	-3.217×10^{-2}	0.2780	2.142×10^{-2}	0.9866	0.0377
		P_4	1.046	-2.73×10^{-2}	0.2854	2.599×10^{-2}	0.9839	0.0410
STD	V_1	P_1	1.027	-2.503×10^{-2}	0.2524	6.412×10^{-3}	0.9956	0.0214
		P_2	1.033	-2.037×10^{-2}	0.2335	9.574×10^{-3}	0.9938	0.2526
		P_3	1.047	-3.496×10^{-2}	0.2503	7.644×10^{-3}	0.9947	0.0242
		P_4	1.021	-3.247×10^{-2}	0.2351	4.897×10^{-3}	0.9966	0.0187

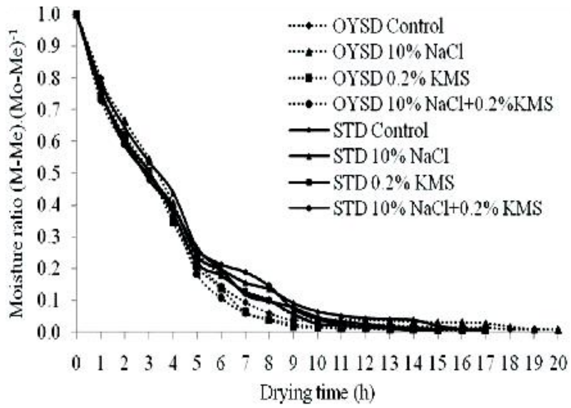

Fig. 3 : Effect of different pre-treatments and drying methods on moisture ratio of *Bijapur white* onion

for 15-17 h are shown in Fig. 3. This is quite obvious because as temperature increased, the vapour pressure inside the sample also increased and in turn the pressure gradient between the surface and inner side of the sample increased resulting in higher drying rate. The similar behaviour was also found by Mitra *et al.* (2011).

Statistical results such as the co-efficient of determination (R^2), sum of square error (SSE), root mean square error (RMSE) and the constants obtained from different drying models are presented in Table 1-3. The Midilli-Kucuk model gave the best fit to the experimental data with higher R^2 value of 0.9975 and lowest root mean square error (RMSE) and sum of square error (SSE) values of 0.017 and 3.769×10^{-3}, respectively. The page model described a poor fit to the experimental data with lowest R^2 value of 0.9970, higher root mean square error (RMSE) and sum of square error (SSE) values of0.0165 and 5.079×10^{-3}, respectively and the Logarithemic model described a very poor fit to the experimental data with lowest R^2 value of 0.9966, higher root mean square error (RMSE) and sum of square error (SSE) values of 0.0187 and 4.897×10^{-3}, respectively. These results were in good agreement with Derya and Mehmet (2010) who reported that the page, modified page and Midilli-Kucuk models exhibited high co-efficient of determination (R^2) values for all the drying methods used in the assay, ranging between 0.9992 and 0.9999.

Conclusion :

The drying characteristics of Bijapur white onion in two drying methods with different pre-treatments were investigated from the present investigation it is concluded that the onion dried in STD was of good quality over OYSD. The time required for drying onion from initial moisture content in the range of 599.30-774.13 per cent (d.b.) to final moisture content of 4.77-5.25 per cent (d.b.) was 17-20 and 15-17 hours for OYSD and STD, respectively. The Midilli-Kucuk model was found to be the best fit to describe the drying characteristics of Bijapur white onion.

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