Current Trends in Technology and Science
ISSN: 2279-0535. Volume: 3, Issue: 3 (Apr-May. 2014)

Dehydration of Onions with Different Drying Methods

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Abstract - The present work was aimed to study the drying behaviour of different onion varieties namely, *Arka kalyan, Bijapur white* and *Arka pragati* which were dried under open yard sun drying, solar tunnel drying and dehumidified air drying methods. The onions were pre-treated with 0.2% potassium metabisulphite for 15 minutes before drying. The samples of *Arka kalyan, Bijapur white* and *Arka pragati* onions required 17 h to dry under open sun, 15 h in solar tunnel drier and 12 h in dehumidified air drier to bring down initial moisture content ranging from 774.13-891.08% (d.b.) to final moisture content of 4.34-5.10% (d.b.). Thin layer drying models namely, Page, Midilli-Kucuk and Logarithmic models were applied to the experimental moisture loss data with respect time to to predict the drying pattern of onions. The higher coefficient of determination (0.9991) with the lowest root mean square error (0.010) and sum of square error (1.001×10^{-3}), indicated Logarithmic model a better fit to the experimental data compared to other models.

Keywords - Arka kalyan, Bijapur white, Arka pragati, pre-treatment, drying, drying models.

1. Introduction

Onion (*Allium cepa L.*) is 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 [1]. Onion serves as a good medicinal compound for cataract, cardiovascular disease and cancer due to its hypocholesterolemic, thrombolitic and antioxidant effects [2]. Onion contains vitamin B, 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. Eating raw onions helps to reduce cholesterol levels because they increase levels of high density lipoproteins. Onions help in controlling coronary heart disease, thrombosis and blood pressure. Onion is one of the important vegetable crops grown in India. Globally, the country occupies the second position after China in onion production with a share of around 14%. In India, during the year 2009-10, the total area under onion cultivation was around 755 thousand hectares with a production of 12166 thousand tonnes.

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% 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.

In Karnataka, Dharwad, Chitradurga, Bijapur, Bellary, Gulbarga and Chikkamagalore are the major districts occupying an area of 141 thousand hectares with a production of 2266 thousand tonnes during the year 2009-10. The onion varieties grown in Karnataka are *Arka Pragati, Baswant 780, Nasik red, Arka bindu, Arka kalyan, Pusa white round, Udaipur 101, 102, 103, N-53, N-2-4-1, Pusa Red, Bijapur white, Ghataprabha white, etc.* Though, there is great potential for the state of Karnataka in the cultivation of onion crop, farmers often incur losses due to low prices during the glut, lack of sufficient market outlets and other infrastructure facility in the marketing system. The storage losses of onion in India ranges from 30 to 60% due to various factors such as physiological weight loss (25-30%), rotting due to fungal diseases (10-15%) and sprouting of bulbs (10-15%). The *Arka kalyan, Bijapur white* and *Arka pragati* onions were selected for the present study, since these varieties having more total soluble solids but less shelf-life, hence with this technology can enhance the shelf-life and quality of these onions.

The common preservation techniques followed for onion worldwide are mostly sun or solar drying [3] and hot air drying [4]. However, these methods demand longer drying time, higher processing temperature, affected by daily fluctuation of weather and thereby making it difficult to maintain the product moisture content and quality properly because of air borne dirt and dust [5]. New and innovative techniques that increase the drying rate and enhance the product quality have achieved considerable attention in the recent past. Dehumidified air drying is one of them, which is gaining popularity because of its inherent advantages over conventional heating such as reducing the drying time of biological material without quality loss. Dehydrated onions available in the market are not of very good quality in respect of pungency, storage life and appearance [6]. Very little information is available on the effect of pre-treatments on the quality characteristics of dehydrated onion slices. So in the present study, treating onion slices with 0.2% potassium metabisulphite (KMS) for 15 minutes [7] was selected as a pretreatment to enhance the quality of dehydrated onion. Dehydrated onion can be used in many processed or ready to eat foods in place of raw onion. This has several advantages such as convenience of transportation, storage, preparation and use [8]. Dehydrated onion is also used as a flavouring additive in several products in food industries such as meat products, sauces, soups, salad dressings, pickles and other snack items [9].

The objective of the work was aimed to study the drying behaviour of selected onion varieties under sun drying, solar tunnel drying and dehumidified air drying. An attempt was made to establish suitable drying models to describe the drying behaviours.

2. Materials and Methods

2.1. Sample preparation

Three varieties of fresh onions *viz.*, *Arka kalyan*, *Bijapur white* and *Arka pragati* were procured from two different production catchments namely, Bijapur and Chikkaballapur in Karnataka. Care was taken to select good quality onions by considering the factors like size, shape and freedom from physical damage. The onion bulbs were then thoroughly cleaned to remove any dirt or dust particles attached to the surface. The cleaned onions were peeled and the roots were cut with a sharp stainless steel knife and peeled onion bulbs were washed with 1% sodium hypochloride solution to avoid infestation. Onions were sliced using a power operated onion slicer into slices of 2 to 5 mm thickness.

The onion slices were weighed and pre-treated with 0.2% potassium metabisulphite (KMS) for 15 minutes at room temperature. After pre-treatment, onion slices were drained for 5 minutes to remove surface moisture. Then the treated onion slices of 5 kg weight was spread in tray and dried in open yard sun drying (OYSD), solar tunnel drying (STD) and dehumidified air drying (DAD) at 50±1 °C and 15±1% RH from an initial moisture content of 614.29% (w.b.) to a final moisture content of 5% (d.b.).

2.2. Solar tunnel drying (STD)

The solar tunnel dryer of one tonne capacity designed and developed in the Department of Processing and Food Engineering, College of Agricultural Engineering, University of Agricultural Sciences, Raichur was used for drying of onions. The solar tunnel dryer was positioned in East-West direction, which had length, breadth and height of 9.0, 3.0 and 3.2 m, respectively. The dryer was of tunnel shape made of semi cylindrical metallic (galvanized pipe) structure covered with UV-stabilized transparent thermic polyethylene sheet of 200 micron. The drying tunnel had a sliding door of 1.5 m width and 2.0 m height for easy loading and unloading of onions. An exhaust pipe (PVC) of 110 mm diameter with two outlets (chimney) on either side of the drying chamber was provided at the top of the tunnel.

2.3. Dehumidified air drying (DAD)

The dehumidified air dryer (Make: Bry Air Asia; model: FSD-600) of 600 kg capacity installed in the Department of Processing and Food Engineering, College of Agricultural Engineering, University of Agricultural Sciences, Raichur was used for dehydration of onions. In this method of drying, the ambient air was passed through a desiccated medium or source of silica gel. The desiccators absorbed moisture from the air, as a result, the relative humidity of air was reduced and at the same time there was an increase in its temperature. The drying took place when such air came into contact with wet products. In the present investigation, dehumidified air dryer was used for drying of onions. Drying temperature of 50±1 °C and relative humidity of 15±1% were adopted during the present investigation [10].

2.4. Experimental procedure

The treated onion slices of 5 kg were spread in each tray in single layers. Initial weights of tray and the samples were noted. Trays were used in all drying methods. Initially the onion sample trays were taken out for weighing at 30 min intervals up to 120 min and thereafter at every 1 h interval till a constant weight were achieved. Each experiment was replicated thrice and average values were used for analysis.

2.5. Mathematical modeling

The mathematical models *viz.*, Page, Midilli-Kucuk and Logarithmic models were selected for fitting the experimental data and these selected models were best models to describe the drying curve equations of onion slices during drying [11]. These are explained here under.

Page model: $MR = \exp(-k^*\theta^n)$ …(1) Midilli-Kucuk model:

$$MR = a^*\exp(-k^*\theta^n)+b\theta \quad \text{… (2)}$$

Logarithmicmodel:

$$MR = a^*\exp(-k^*\theta^n)+c \quad \text{…(3)}$$

where,

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

M_e=equilibrium moisture content, % (d.b.)

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

M_o=initial moisture content, % (d.b.)

K=drying rate constant

θ = drying time (min)

n=dimensionless empirical coefficient; a, b, c=empirical constants in drying models.

The constants of the selected models were estimated by non-linear regression [12]. 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.

2.6. Statistical analysis

The experiment was carried out in three factorial Complete Randomised block Design (CRD) with three replications. After proper analysis, data were accommodated in the tables as per the needs of objective for interpretation of results. The Microsoft office excels (2007) was used for analysis and interpretation. The statistical procedures for agricultural research given by [13] were referred. The goodness of fit of different models under different drying methods was evaluated based on values of coefficient of determination (R^2). A model is characterized by root mean square error (RMSE), coefficient of determination (R^2) and sum of square error (SSE) [14]. These parameters can be calculated as follows.

$$\mathrm{RMSE} = \sqrt{\frac{\sum_{i=0}^{N} \left(\mathrm{MR_o} - \mathrm{MR_p}\right)^2}{\mathrm{df}}} \quad \ldots (4)$$

$$R^2 = \frac{\text{SSTotal-SSError}}{\text{SSTotal}} \quad \ldots (5)$$

$$\mathrm{SSE} = \frac{1}{N}\sum_{i=1}^{N}(\mathrm{MR_o} - \mathrm{MR_p})^2 \quad \ldots (6)$$

where,

MR_o = observed moisture ratio
MR_P = predicted moisture ratio
df = degrees of freedom
N = No. of data points
z = No. of constants
SSToatl = Sum of squares total
SSError = Sum of squares error

3. Results and Discussion

3.1. Drying characteristics

The moisture content of onions were got reduced exponentially. The *Arka kalyan, Bijapur white* and *Arka pragati* onions pre-treated with 0.2% KMS were dried under open yard sun drying, solar tunnel dryer and dehumidified air dryer. In open yard sun drying the *Arka kalyan, Bijapur white* and *Arka pragati* onions required 17 h to dry from initial moisture content in the ranging of 774.13-891.08% (d.b.) to a final moisture content ranging of 4.56-4.97% (d.b.), respectively. This variation might be due to less ambient air temperature and more relative humidity fluctuations in the atmosphere. Open yard sun drying is widely practiced in tropical countries, but the method is extremely time-consuming, weather dependent and has the problem of contamination, infestation and microbial attack [15]. The present results are in good agreement with [16] who reported that the pre-treated onion slices required 19 sunshine hours in green house/solar dryer. Similar results were also reported by [11] who concluded that the reduction of moisture content from 89.8 g.100^{-1} g^{-1} to 48.86 g.100^{-1} g^{-1} (w.b.) for sun drying method was 17 h for onion slices.

In case of solar tunnel drying, the *Arka kalyan, Bijapur white* and *Arka pragati* onions required 15 h to dry from initial moisture content range of 774.13-784.96% (d.b.) to final moisture content range of 4.77-4.95% (d.b), respectively. The present results are in good agreement with [18] who reported that the onion slices required 15 sunshine hours for drying in solar dehydration unit. It was also observed that all the drying curves showed a clear exponential tendency and as expected the drying time decreased when the temperature increased until all the samples reached similar equilibrium moisture content [19].

In dehumidified air dryer the *Arka kalyan, Bijapur white* and *Arka pragati* onions took 12 h dry from initial moisture content range of 778.73-890.10% (d.b.) to final moisture content in the range of 4.34-5.10% (d.b.), respectively at different drying air temperatures and relative humidities. The results were in good agreement with the findings of [18] using dehumidified air drying at optimum temperature of 64 °C and 18% RH and at air velocity of 0.8 $m.s^{-1}$ for dehydration of Aloe vera gel. Similar results were also reported by [14] who reported that, almost 99% of initial moisture was removed within 60 min for 1.0 mm, 180 min for 3.0 mm and 300 min for 5.0 mm thick slices using laboratory scale vacuum dryer. Similar results were also reported by earlier researchers for onion [17].

The drying rate was calculated as quantity of moisture removed per unit time per unit dry matter. It can be seen that drying process mainly consisted of three drying periods i.e., heating up, constant rate and falling rate periods. The drying rate of *Arka kalyan, Bijapur white* and *Arka pragati* onions dried under OYSD was varied from 208.00 to 0.60% (d.b.).h^{-1}, from 197.90 to 0.45% (d.b.).h^{-1} and from 169.71 to 0.53% (d.b.).h^{-1}, respectively for samples pre-treated with 0.2% KMS. In case of STD the drying rate was varied from 169.25 to 1.23% (d.b.).h^{-1}, from 186.92 to 0.35% (d.b.).h^{-1} and from 202.64 to 0.52% (d.b.).h^{-1}, respectively and in DAD the drying rate was varied from 320.28 to 2.58% (d.b.).h^{-1}, from 266.62 to 0.76% (d.b.).h^{-1} and from 385.09 to 2.32% (d.b.).h^{-1}, respectively for samples pre-treated with 0.2% KMS. The drying rate was higher in the beginning of the drying process and gradually reduced through the end of the drying process. This was due to more energy was absorbed by the water at the product surface initially, resulting in faster drying and with the product surface drying out subsequently, heat penetration through the dried layer decreased thus retarding the drying rates [17]. The same behaviour of drying was reported by earlier researchers for onion [18].

3.2. Fitting curves of drying of onion slices with different drying methods

The moisture ratio versus time data were fitted to the selected thin layer drying models namely Page, Midilli-Kucuk and Logarithmic model. The model coefficients for all the three models were estimated by nonlinear regression technique using MATLAB 7 version software.

Current Trends in Technology and Science
ISSN: 2279-0535. Volume: 3, Issue: 3 (Apr-May. 2014)

The estimated values of statistical parameters obtained under different drying methods and varieties for these models are presented in Table 1-3.

Table (1) Estimated values of statistical parameters of Page model used for different drying methods and different varieties

Method	Variety	K	n	*SSE*	R^2	*RMSE*
D_1	V_1	0.195	1.011	2.713×10^{-2}	0.9817	0.0411
	V_2	0.198	1.273	1.241×10^{-2}	0.9922	0.0278
	V_3	0.164	1.128	1.177×10^{-2}	0.9926	0.0271
D_2	V_1	0.190	1.283	8.007×10^{-3}	0.9947	0.0239
	V_2	0.218	1.148	6.889×10^{-3}	0.9952	0.0221
	V_3	0.265	1.052	3.799×10^{-3}	0.9972	0.0164
D_3	V_1	0.468	0.956	1.199×10^{-3}	0.9989	0.0104
	V_2	0.472	1.027	5.807×10^{-3}	0.9948	0.0229
	V_3	0.643	0.781	3.604×10^{-3}	0.9963	0.0181

D_1- Open yard sun drying; D_2- Solar tunnel dryer; D_3- Dehumidified air dryer
V_1- Arka kalyan (Red) onion; V_2- Bijapur white onion; V_3- Arka pragati (Pink) onion

Table (2) Estimated values of statistical parameters of Midilli and Kucuk model used for different drying methods and different varieties

Method	Variety	K	b	A	N	*SSE*	R^2	*RMSE*
D_1	V_1	0.230	-8.21×10^{-3}	0.992	0.80	1.099×10^{-2}	0.9926	0.0280
	V_2	0.172	-6.54×10^{-5}	0.965	1.34	1.119×10^{-2}	0.9930	0.0282
	V_3	0.168	-2.97×10^{-3}	0.980	1.05	6.609×10^{-3}	0.9959	0.0217
D_2	V_1	0.175	5.29×10^{-4}	0.979	1.34	7.441×10^{-3}	0.9951	0.0249
	V_2	0.212	-8.41×10^{-4}	0.984	1.14	6.136×10^{-3}	0.9957	0.0226
	V_3	0.263	-4.22×10^{-4}	0.992	1.04	3.632×10^{-3}	0.9973	0.0174
D_3	V_1	0.466	6.49×10^{-4}	1.002	0.97	1.055×10^{-3}	0.9990	0.0108
	V_2	0.473	7.78×10^{-4}	1.006	1.04	5.515×10^{-3}	0.9950	0.0247
	V_3	0.645	-4.10×10^{-5}	0.999	0.77	3.562×10^{-3}	0.9963	0.1989

D_1- Open yard sun drying; D_2- Solar tunnel dryer; D_3- Dehumidified air dryer
V_1- Arka kalyan (Red) onion; V_2- Bijapur white onion; V_3- Arka pragati (Pink) onion

Table (3) Estimated values of statistical parameters of Logarithmic model used for different drying methods and different varieties

Method	Variety	a	c	K	*SSE*	R^2	*RMSE*
D_1	V_1	1.040	-9.121×10^{-2}	0.1535	1.500×10^{-3}	0.9898	0.0131
	V_2	1.057	-3.217×10^{-2}	0.2780	2.142×10^{-2}	0.9866	0.0377
	V_3	1.064	-7.654×10^{-2}	0.1719	6.244×10^{-3}	0.9961	0.0204
D_2	V_1	1.068	-3.417×10^{-2}	0.2749	1.786×10^{-2}	0.9882	0.0370
	V_2	1.047	-3.496×10^{-2}	0.2503	7.644×10^{-3}	0.9947	0.0242
	V_3	1.015	-1.495×10^{-2}	0.2758	3.788×10^{-3}	0.9972	0.0170
D_3	V_1	0.989	1.126×10^{-2}	0.4638	1.001×10^{-3}	0.9991	0.0100
	V_2	1.006	4.683×10^{-3}	0.4963	5.718×10^{-3}	0.9948	0.0239
	V_3	0.952	2.649×10^{-2}	0.5625	8.337×10^{-3}	0.9915	0.0288

D_1- Open yard sun drying; D_2- Solar tunnel dryer; D_3- Dehumidified air dryer
V_1- Arka kalyan (Red) onion; V_2- Bijapur white onion; V_3- Arka pragati (Pink) onion

The Logarithmic model successfully described the relationship between moisture ratio and drying time but Page and Midilli-Kucuk models did not describe well. The experimental and predicted drying curves of dehydrated onion slices pre-treated with 0.2% KMS at different drying methods and varieties for Logarithmic model are shown in Fig 1-3.

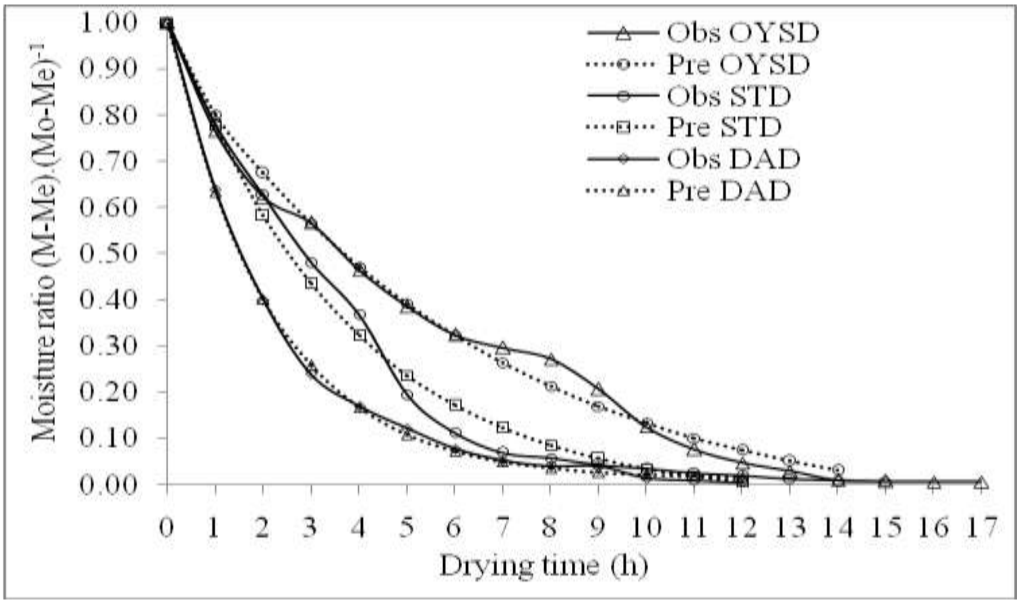

FIG. 1. COMPARISON OF EXPERIMENTAL AND PREDICTED MOISTURE RATIOS FOR LOGARITHMIC MODEL FOR DIFFERENT DRYING METHODS PRE-TREATED WITH 0.2% KMS FOR *ARKA KALYAN* (RED) ONIONS (OBS- OBSERVED; PRE- PREDICTED; OYSD - OPEN YARD SUN DRYING; STD - SOLAR TUNNEL DRYER; DAD - DEHUMIDIFIED AIR DRYER)

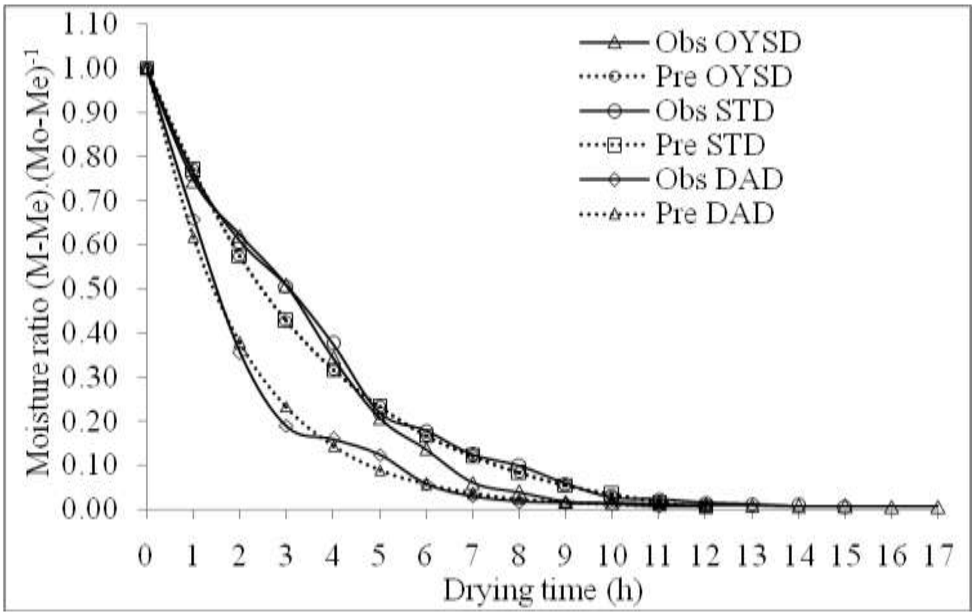

FIG. 2. COMPARISON OF EXPERIMENTAL AND PREDICTED MOISTURE RATIOS FOR LOGARITHMIC MODEL FOR DIFFERENT DRYING METHODS PRE-TREATED WITH 0.2% KMS FOR *BIJAPUR WHITE* (WHITE) ONIONS (OBS- OBSERVED; PRE- PREDICTED; OYSD - OPEN YARD SUN DRYING; STD - SOLAR TUNNEL DRYER; DAD - DEHUMIDIFIED AIR DRYER)

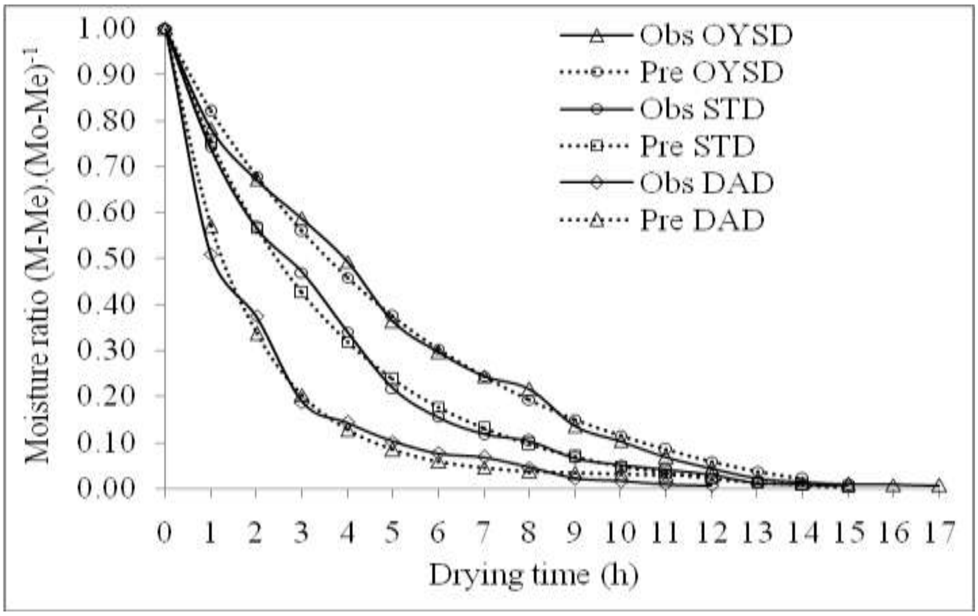

FIG. 3. COMPARISON OF EXPERIMENTAL AND PREDICTED MOISTURE RATIOS FOR LOGARITHMIC MODEL FOR DIFFERENT DRYING METHODS PRE-TREATED WITH 0.2% KMS FOR *ARKA PRAGATI* (PINK) ONIONS (OBS- OBSERVED; PRE- PREDICTED; OYSD - OPEN YARD SUN DRYING; STD - SOLAR TUNNEL DRYER; DAD - DEHUMIDIFIED AIR DRYER)

The Logarithmic model gave the best fit to the experimental data with higher R^2 value of 0.9991 and lowest root mean square error (RMSE) and sum of square error (SSE) values of 0.0100 and 1.001×10^{-3}, respectively. The Midilli-Kucuk model described a poor fit to the experimental data with lowest R^2 value of 0.9990, higher root mean square error (RMSE) and sum of square error (SSE) values of 0.0108 and 1.055×10^{-3}, respectively and the Page model described a very poor fit to the experimental data with lowest R^2 value of 0.9989, higher root mean square error (RMSE) and sum of square error (SSE) values of 0.0104 and 1.199×10^{-3}, respectively. These results were in good agreement with [11] who reported that the Page, Modified Page and Midilli-Kucuk Models exhibited high coefficient of determination (R^2) values for all the drying methods used in the assay, ranging between 0.9992 and 0.9999. [7] reported the coefficient of determination (R^2) values ranging from 0.9713 to 0.9997 for untreated onion samples and 0.9840 to 0.9999 for treated onion samples whereas the RMSE values of onion slices ranged from 0.0052 to 0.0495 for untreated samples and 0.0024 to 0.0448 for treated samples, Page model showed the highest R^2 and lowest RMSE in case of both treated and untreated samples.

4. Conclusions

The reduction of moisture content of *Arka kalyan, Bijapur white* and *Arka pragati* onion took less drying time of 12 h in dehumidified air drying to dry the samples from an initial content in range of 774.13-891.08% (d.b.).h^{-1} to final moisture content range of 4.34-5.10% (d.b.).h^{-1}, respectively as compared to open yard sun drying and solar tunnel drying methods. The drying rate was higher in the beginning of the drying processes and gradually reduced through the end of the drying process. Thin layer drying models such as Page, Midilli-Kucuk and Logarthmic models, which were commonly used to describe the drying behaviour of food materials, were tested for different drying methods and varieties. Logarithmic model gave better fit to the experimental data with higher R^2 value of 0.9991 and lower root mean square error (RMSE) and sum of square error (SSE) values of 0.0100 and 1.001×10^{-3}, respectively over the other two models.

References

[1] Augusti KT. “Therapeutic values of onion (Allium cepa L.) and garlic (Allium sativum L.)”, Indian Journal Exp bill, vol.34, issue.7, 634 - 40, 1996.

[2] Nuutila AM. Puupponen-Pimia R. Aarni M. Oksman-Caldentey KM. “Comparison of antioxidant activity of onion and garlic extracts by inhibition of lipid peroxidation and radical scavenging activity”, Food Chemistry, vol.81, vol.4, 485 - 493, 2003.

[3] Stavric B. “Chemopreventive agents in foods. In: Johns T, Romeo J.T. (eds) Functionality of food phytochemicals”, Plenum, New York, pp 53-87, 1997.

[4] Sarsavadia, PN. “Development of a solar-assisted dryer and evaluation of energy requirement for the drying of onion”. Renewable Energy, vol.32, issue.15, 2529 - 2547, 2007.

[5] Sharma P.K. & Nath N. “Dehydration characteristics of ten onion cultivars”, Journal of Food Science and Technology, vol.28, issue.6, 348 - 351, 1991.

[6] El-Beltagy A. Gamea GR. & Amer-Essa AH. “Solar drying characteristics of strawberry”.

Current Trends in Technology and Science
ISSN: 2279-0535. Volume: 3, Issue: 3 (Apr-May. 2014)

Journal of Food Engineering, vol.78, issue.2, 456 - 464, 2007.
[7] Raj D. Subanna VC. Ahlawat OP. Pardeep Gupta. & Huddar AG. "Effect of pre-treatments on the quality characteristics of dehydrated onion rings during storage", International Journal of Food Agricultural and Environment, vol.4, issue.1, 30 - 33, 2005.
[8] Mitra J. Shrivastava SL. & Srinivasa Rao P. "Vacuum dehydration kinetics of onion slices", Food and Bioproducts Processing, vol.89, issue.1, 1 - 9, 2011.
[9] Lewicki PP. Witrowa-Rajchert D. Pomaranska-Lazuka W. & Nowak D. "Rehydration properties of dried onion". International Journal of Food Properties vol.1, issue.3, 275 - 290, 1998.
[10] Adam E. Muhlbauer W. Esper A. Wolf W. & Spiess W. "Quality changes of onion (Allium cepa L.) as affected by the drying process", Die Nahrung, vol.44, issue.1, 32 - 37, 2000.
[11] Ramachandra CT. & Rao PS. "Modelling and optimization of drying variables of Aloe vera (Aloe barbadensis Miller) gel", Paper presented at ASABE Annual Meet held at Reno, Nevada, USA during June 21 - 24, paper No. 096498, 2009a.
[12] Derya A. & Mehmet MO. "Study the effect of sun, oven and microwave drying on quality of onion slices", Journal of Food Science and Technology, vol.43, issue.7, 1121 - 1127, 2010.
[13] Ramachandra CT. & Srinivasa Rao P. "Equilibrium sorption isotherms of Aloe vera gel powder", Transactions of ASABE, vol.52, issue.3, 901 - 906, 2009.
[14] Gomez KA. & Gomez AA. "Statistical procedures for agricultural research", Wiley Int Sci Pub New York, 1976.
[15] Mota CL. Luciano C. Dias A. Barroca MJ. & Guine RPF. "Convective drying of onion: Kinetics and nutritional evaluation", Food and Byproducts Processing vol.8, issue.8, 115 - 123, 2010.
[16] Ratti C. & Mujumdar AS. "Solar drying of foods; modelling and numerical simulation". Solar Energy, vol.60, 151-157, 1997.
[17] Kadam DM. Nangare DD. Rajbir singh. & Kumar S. "*Low-cost greenhouse technology for drying onion (Allium cepa L.) slices", Journal of Food Process Engineering vol.34, issue.*1, 67 - 82, 2008.
[18] Sharma GP. Verma RC. & Pankaj Pathare. "Mathematical modeling of infrared radiation thin layer drying of onion slices", Journal of Food Engineering, vol.71, 282-286, 2005.
[19] Edukondalu L. & Samuel DVK. "Effect of pre-treatment on solar dehydration of selected varieties of onion", Journal of Food Engineering, vol.46, issue.2, 18-21, 2009.
[20] Akpinar EK. "Determination of suitable thin layer drying curve model fors some vegetables and fruits", Journal of Food Engineering, vol.73, issue.1, 75-84, 2006.

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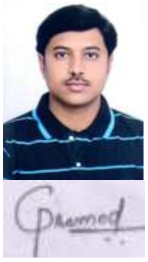

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