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Drying characteristics and antioxidant properties of Java plum seed and skin waste

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Java plum seeds and skin wastes recovered after passing fruits through a pulper were separated manually and dried in tray/fluidised bed drier at 50, 70 and 90˚C or in freeze drier at -55°C at 4.4 torr. Drying behaviour of java plum seeds and skin followed falling rate period and described adequately by Page's model. Drying rate constant was higher for fluidized bed drier varying from 0.00163 to 0.255406 h^{-1} for seeds and 0.002042 to 0.004258 h^{-1} for skin followed by tray and freeze drier. Anthocyanin content of freeze dried java plum skin was 1944 mg/100 g dry basis but high drying temperature resulted in lower anthocyanin retention in tray and fluidized bed driers. 'L' and 'b' value of java plum seeds increased but 'a' value decreased. Free radical scavenging activities of fresh java plum seeds and skin were 92.41 and 93.42%, respectively which decreased after drying.

Key words: Java plum waste, drying, free radical scavenging activity, anthocyanin content, Page's model.

INTRODUCTION

Syzygium cumini also known as jambolao, black plum, jambolan, java plum or jamun is a member of Myrtaceace family (Veigas et al., 2007). Ripe Jamun fruit is about 2 to 3 cm long, oval shaped, purple-red to black peel and white to pink pulp with astringent taste (Benherlal and Arumughan, 2007). Fruit constitutes about 75% pulp and 25% seeds and skin. Fruit and seeds are used for treatment of various diseases such as antiscorbutic, diuretic, antidiabetic, and antidiarrohea (Achrekar et al., 1991; Chaturvedi et al., 2009). Java plum seeds and skin are the by-products of juice production containing high moisture level that limits their storage life and utilization. Drying is a simple preservation technique to extend storage life. In this investigation Java plum seed and skin waste was dehydrated using three techniques and its effect was analysed on pigment and antioxidant properties.

MATERIALS AND METHODS

Plant materials

Fresh java plum fruits were procured from local orchard located at Attari, Amritsar, India. Fruits were rinsed thoroughly with water and passed through pulper (Kalsi Industries, Ludhiana, India). The peel and seeds were separated manually. The seeds were cut in longitudinal and cross section direction using stainless steel knife.

Drying

Whole, longitudinal and cross section cut seeds and skin of java plum fruits were dried in tray drier (Narang Scientific Works, New

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Delhi, India) and fluidized bed drier (Endecotts, London, UK) at 50,70 and 90°C whereas in freeze drier (Heto Power Dry, Allerod, Denmark) at -55°C at 4.4 torr pressure. Moisture content was observed at every 15 min interval to study drying characteristics. Page's model was used to describe drying behaviour of Java plum seeds and skin.

$$M.R = \frac{m - \mathrm{me}}{\mathrm{mo} - \mathrm{me}} = \exp(-\mathrm{kt}^{\mathrm{n}})$$

Where, M.R = moisture ratio
m = % moisture content at any given instant time t (% db)
me = equilibrium moisture content (% db)
mo = initial moisture content (% db)
k= drying rate constant (1/h)
n= dimensionless coefficient

Composition of java plum seeds and skin

Moisture, ash, crude fat, protein and fibre contents were measured following standard method of analysis (AOAC, 1990). Carbohydrate content was determined by difference.

Determination of anthocyanin content

Java plum skin was extracted with ethanolic HCl (85% of ethanol-95% and 15% of 0.1N HCl) and absorbance of extract was measured at 535 nm (Ranganna, 1986).

$$\text{Anthocyanin Content} = \frac{\text{OD at 535 nm} * \text{volume made} * \text{dilution factor}}{\text{weight of sample} * 98.2} * 100$$

Extinction factor = 98.2

Colour measurements

Ultra Scan VIS Hunter Lab (Hunter Associates Laboratory Inc., Reston, USA) was standardized using standard tiles, and *L, a* and *b* values were measured.

Free radical scavenging activity

Seeds/ Peel (100mg) was extracted with 1 ml of methanol for 2 h in shaker (LabTech, Namyangju, Korea), centrifuged at 10,000 xg for 8 min. 1 ml of supernatant was added to 3.9 ml of 0.1 mMol DPPH solution in brown glass vial. The reaction mixture was shaken and incubated in dark for 30 min. The absorbance was taken at 515 nm (Genesys 10S UV-VIS, Thermo Scientific, Massachusetts, USA) against a blank. The percentage of scavenging was determined by the formula:

$$\%\ \text{Inhibition} = \frac{\text{absorbance control} - \text{absorbance sample}}{\text{absorbance control}} * 100$$

Statistical analysis

One way analysis of variance (ANOVA) was applied on the data of proximate composition, anthocyanin content, free radical scavenging activity, coefficients of Page's model and hunter colour parameters. Least significant difference values were calculated to find significant difference at $p \leq 0.05$. Mean values, standard deviation and ANOVA were computed using Mini Tab (Version 17) (Minitab Inc., State College, Pennsylvania, USA).

RESULTS AND DISCUSSION

Composition of java plum seeds and skin

Fresh java plum seeds contained 53% moisture, 6.4% protein, 1.5% ash, 4.53% fat, 16.4% fibre and 21.9% total carbohydrates (Table 1). Java plum skin contained 79% moisture, 0.91% ash, 0.80% fat, 0.12% protein and 15.35% total carbohydrates. Statistical analysis revealed that there was significant ($p \leq 0.05$) difference in moisture, fat, protein and total carbohydrates of java plum skin and seeds. Previous studies have reported 40.86 to 57.33% moisture, 2.42 to 5.05%, protein, 1.47 to 6.21% ash, 1.55 to 8.00% fat and 1.28 to 10.95% crude fibre in java plum seeds (Kochar et al., 2006; Swami et al., 2012). Present results of seed composition were close to previously reported values except for protein and fibre content which were higher. These differences might arise from the variation in variety, agricultural practices and climatic conditions. The composition of java plum skin could not be traced in the literature. Red grape skin had the moisture, fat and protein contents in the range of 74.6 to 73.2%, 3.35 to 6.33% and 11.26 to 12.12% respectively (Deng et al., 2011; Torres et al., 2010). Composition of java plum was quite different from red grape skin which contained low moisture but high protein and fat contents.

Drying curves

The initial moisture contents of whole, longitudinal cut and cross section cut java plum seeds were 113, 122 and 127% (dry basis - db) respectively (Figure 1). Tray and fluidized bed dried seeds had final moisture content of about 10% (db) and freeze dried seed had about 15% (db). The drying of java plum seeds took different time intervals in tray, fluidized bed and freeze drier operated at different temperatures.

The experimental data showed higher rate of moisture removal in the beginning of drying and later it slowed down with decrease in moisture content just like other biological materials. However, a considerable variation was observed in drying curves of whole, longitudinal cut and cross section cut java plum seeds. Drying rate increased significantly ($p \leq 0.05$) with increase in surface area due to size reduction. Similar results were reported for tomato seeds that drying rate decreased continuously indicating that drying of tomato seeds took place in falling rate period (Sogi et al., 2003).

The drying of the java plum skin took about 375, 105 and 75 min in tray drier while 75, 35 and 30 min in fluidized bed drier at 50, 70 and 90°C respectively (Figure 1) whereas it took about 300 min in a freeze drier. Drying rate was higher in the beginning but it became slow at the later stage in all the drying curves. Drying was rapid in fluidized bed dryer as compared to tray and freeze dryer.

The drying of java plum seeds and skin took place in falling rate period under experimental condition just like

Table 1. Proximate composition for fresh Java plum seeds and skin (n=3).

Parameter	Fresh java plum seeds	Fresh java plum skin
Moisture content (% wb)	53±1.21[b]	79.09±1.98[a]
Ash content (% wb)	1.5±0.23	0.91±0.01
Fat content (% wb)	4.53±0.68[a]	0.8 ± 0.15[b]
Protein content (% wb)	6.4±0.62[a]	0.12±0.01[b]
Crude fibre content (%wb)	16.4±0.36	ND
Total carbohydrates (by difference)	21.9±0.94 [a]	15.35±1.8[b]

Superscripts with different letters indicate significant difference p≤0.05 among treatments.

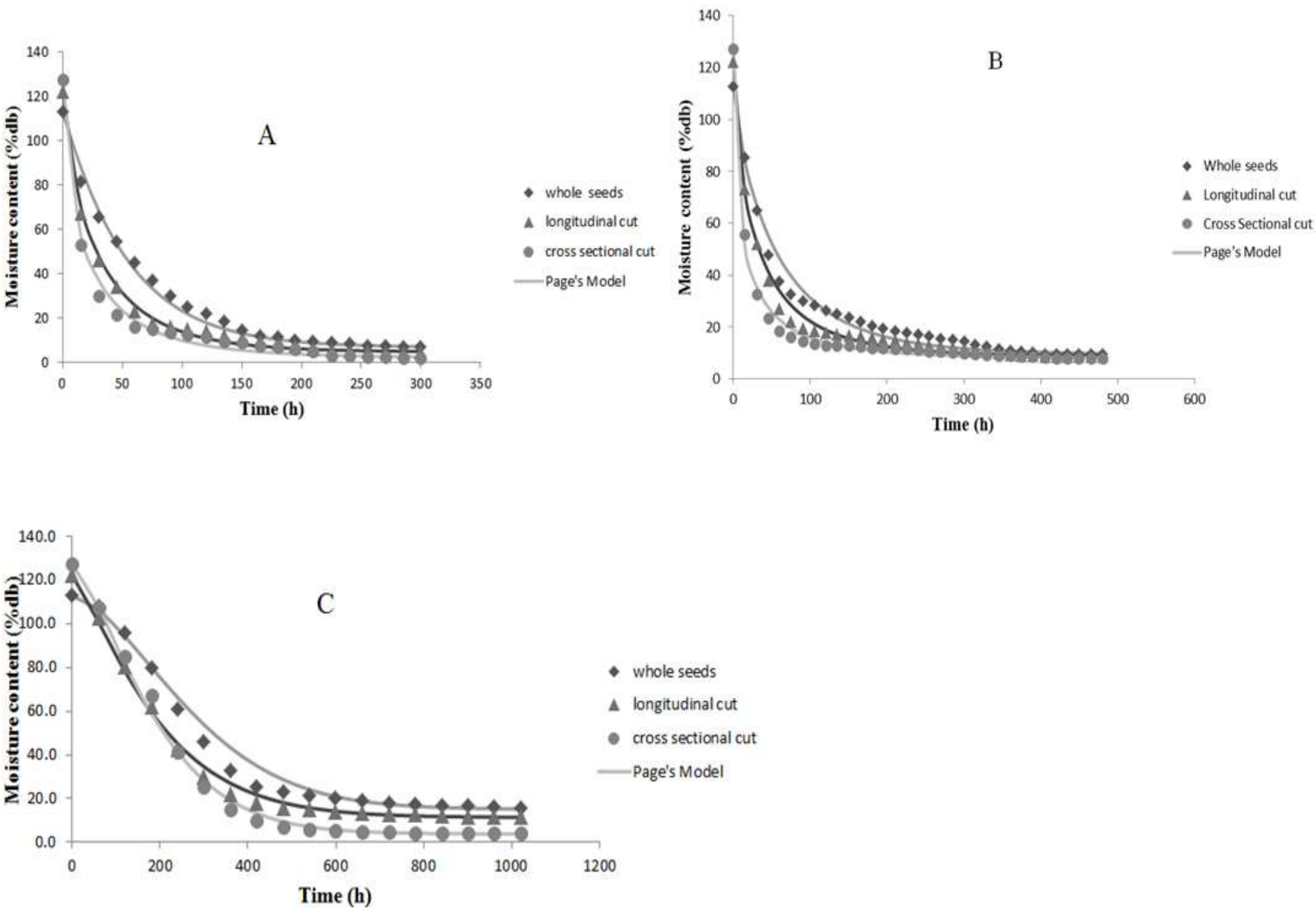

Figure 1. Drying curves of java plum seeds in cabinet drier at 70˚C (A), fluidised bed drier at 70˚C (B) and freeze drier (C) at -55˚C at 4.4 torr.

other biological materials. Drying of tomato skin took place in falling rate period as drying rate decreased during drying period. In fluidized bed drier, tomato skin dried in 108 min whereas in cabinet drier drying occurred in 1080 min (Kaur et al., 2006). Present results find support from previous studies on rate of drying of java plum seeds in different dryers.

Drying model

Drying data was analysed by using Page's model and its coefficients were computed. The drying rate constant (k) for seeds varied from 0.000374 to 0.004221 h^{-1} for tray dryer (Table 2). The drying rate constant was the highest for cross sectioned cut java plum seeds due to more

Table 2. Coefficients of Page's model for Java plum seeds (n=3).

Drier	Temperature (°C)	Java plum seed type	Drying rate constant K (1/h)	Dimensionless number (n)	R^2
		Whole seeds	0.000263±0.0001[b]	0.9163±0.0003[p]	0.982
	50	Longitudinal cut	0.001342±0.0002[f]	0.7088±0.0001[i]	0.9661
		Cross section cut	0.002241±0.0001[l]	0.4984±0.0002[a]	0.8287
		Whole seeds	0.000374±0.00001[c]	1.0358±0.0002[q]	0.974
Tray	70	Longitudinal cut	0.001131±0.0003[e]	0.7873±0.0002[k]	0.9509
		Cross section cut	0.002313±0.0002[j]	0.6503±0.0002[f]	0.8635
		Whole seeds	0.000620±0.00001[d]	0.8794±0.0003[o]	0.9196
	90	Longitudinal cut	0.001731±0.0001[i]	0.7224±0.0002[j]	0.8945
		Cross section cut	0.002733±0.0001[k]	0.6607±0.0002[g]	0.9553
		Whole seeds	0.001663±0.0002[h]	1.1595±0.0003[r]	0.9722
	50	Longitudinal cut	0.01371±0.0001[m]	0.8441±0.00001[n]	0.9451
		Cross section cut	0.103519±0.002[q]	0.5025±0.0005[b]	0.9385
		Whole seeds	0.03538±0.0001[n]	0.8221±0.0004[l]	0.9262
Fluidized bed	70	Longitudinal cut	0.093621±0.0003[p]	0.6776±0.00001[h]	0.9175
		Cross section cut	0.255406±0.0001[t]	0.5111±0.0001[c]	0.8803
		Whole seeds	0.057908±0.0002[o]	0.8301±0.0003[m]	0.9773
	90	Longitudinal cut	0.160365±0.0001[r]	0.6402±0.00001[e]	0.891
		Cross section cut	0.251553±0.0004[s]	0.5615±0.0003[d]	0.8562
		Whole seeds	0.0000926±0.000001[a]	1.376±0.0003[u]	0.9914
Freeze	-50	Longitudinal cut	0.000632±0.00001[d]	1.2339±0.0002[t]	0.9858
		Cross section cut	0.001373±0.0001[g]	1.6115±0.0002[s]	0.9769

Superscripts with different letters indicate significant difference p≤0.05 among treatments.

surface area. The drying rate constant (k) for java plum seeds in fluidized bed drier varied from 0.00163 to 0.255406 h^{-1}. In fluidized bed drier the drying rate constant (k) for cross section cut was maximum 0.255406 h^{-1}.

In freeze drying, the drying rate constant (k) varied from 0.0000926 to 0.001373 h^{-1}. The dimensionless constant (n) varied from 0.4984 to 1.0358 in tray drier. Seeds dried in fluidized bed drier had dimensionless constant in the range of 0.5025 to 1.1595. The adequacy of fitness of any model can be judged by coefficient of determination (R^2). Its values decreased with increase in surface area of seeds during drying. Therefore, R^2 was the highest for whole seeds and the lowest for cross sectioned cut seeds in all three types of driers at all temperatures. The study showed that drying was rapid in fluidized bed drier followed by tray and freeze driers. Predicted values of moisture content during drying of java plum seeds in tray, fluidized bed & freeze drier has been shown in Figure 1.

Page's model was also used to study the drying behaviour of java plum skin (Table 3). The drying rate constant, k (h^{-1}) varied from 0.001867 to 0.003933 in tray dryer. The maximum value of drying rate constant in tray dryer was found to be 0.003933 h^{-1} at 90°C for java plum skin. In fluidized bed dryer, the drying rate constant varies from 0.002042 to 0.004258 h^{-1} and maximum value was observed during drying at 90°C. Drying rate constant of freeze drier was 0.000572 h^{-1}.

No systematic relation was observed for dimensionless number (n) during drying of java plum skin. The dimensionless number (n), varied from 0.555 to 0.814 for tray drier, 0.927 to 1.036 for fluidized bed drier, and 1.449 for freeze drier. The value of R^2 increased with increase in temperature in driers. The peak value of R^2 for tray and fluidized bed dryer was 0.8874 and 0.9964 respectively at 90°C. The R^2 value for freeze dryer was found to be 0.9954. The coefficients of Page's model for tray, fluidized bed and freeze dryer are shown in Table 3. Drying rate constant (k) of tomato skin dried in cabinet and fluidized bed drier ranged between 0.074-0.528 and 0.937-2.482 respectively (Kaur et al., 2006). Page's model was applied for calculating the coefficients for watermelon pomace drying (Oberoi and Sogi, 2015).

Table 3. Coefficients of Page's model for Java plum skin (n=3).

Drier	Temperature (°C)	Drying rate constant K (1/m)	Dimensionless number (n)	R^2
Tray	50	0.001867±0.001[b]	0.555±0.001[a]	0.8777
	70	0.003624±0.001[d]	0.814±0.001[c]	0.878
	90	0.003933±0.001[e]	0.698±0.001[b]	0.8874
Fluidised bed	50	0.002042±0.001[c]	0.987±0.001[e]	0.964
	70	0.004074±0.001[f]	1.036±0.001[f]	0.9755
	90	0.004258±0.001[g]	0.927±0.001[d]	0.9964
Freeze	-50	0.000572±0.001[a]	1.449±0.001[g]	0.9954

Superscripts with different letters indicate significant difference p≤0.05 among treatments.

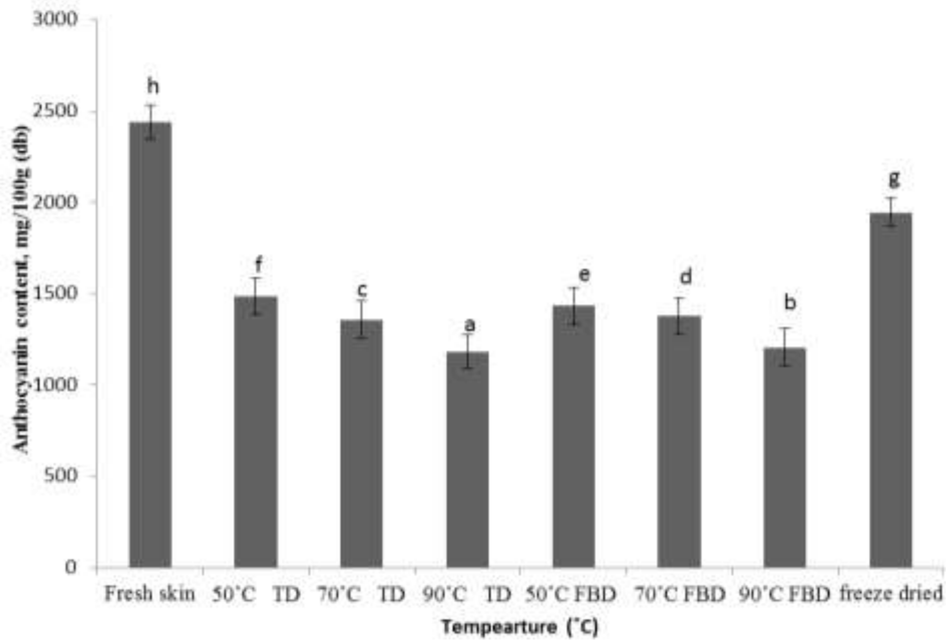

Figure 2. Anthocyanin content of fresh & dehydrated java plum skin. TD-Tray Drier; FBD – Fluidized Bed Dryer.

Although tomato and Java plum had thin peel or skin but the rate of drying was much higher for Tomato skin which might be due to the difference in soluble solids.

Anthocyanin content

The anthocyanin content of the fresh and dried java plum skin has been shown in Figure 2. Anthocyanin content of fresh java plum skin was 2438.10 mg/100g db. After dehydration, the java plum skin became moisture free due to which the anthocyanin content of the dried sample increased but at high temperature, degradation of anthocyanin occurred. The minimum value of anthocyanin content was 1180.97 mg/100g db when dried in a tray drier at 90°C while the maximum value was 1944.14 mg/100g db for freeze dried java plum skin. In fluidised bed drier, anthocyanin content of java plum skin varied from 1205.18 to 1432.60 mg/100g db. Sublimation effectively preserves the valuable food compounds than traditional methods of drying (Uddin et al., 2002). In previous studies, 731 mg/100g (wb) anthocyanin content in ripened java plum skin was reported (Sari et al., 2009). Bilberries contain 300 to 530mg/100g anthocyanin content (Prior et al., 1998). Anthocyanins colour and stability was affected by temperature, light and oxygen. Anthocyanin degradation was positively affected by air temperature and got reduced by 60 to 70% after drying

Table 4. Colour of fresh and dehydrated Java plum seeds and skin (n=3).

Drier	Temperature (°C)	Java plum seeds			Java plum skin		
		L	a	b	L	a	b
Fresh	-	38.93±0.34^{a}	7.58 ±0.13^{f}	8.38 ±0.23^{b}	26.56±0.05^{f}	2.97±0.09^{d}	-1.03±0.05^{f}
Tray	50	49.28±0.07^{d}	6.34 ±0.08^{c}	10.48 ±0.15^{f}	26.60±0.13^{g}	3.29±0.02^{f}	-0.52±0.03^{a}
	70	48.31 ±0.8^{c}	6.04 ±0.005^{b}	9.79 ±0.2^{d}	25.90±0.04^{d}	2.85±0.01^{c}	-0.77±0.05^{d}
	90	47.38 ±1.3^{b}	6.4 ±0.2^{c}	9.38 ±0.6^{c}	23.51±0.25^{a}	2.59±0.01^{b}	-1.25±0.03^{h}
Fluidized bed	50	53.63 ±0.2^{e}	6.94 ±0.04^{e}	12.86 ±0.02^{h}	26.52±0.43^{e}	3.42±0.71^{g}	-1.07±0.02^{g}
	70	53.97±0.1^{e}	6.36 ±0.01^{c}	10.9 ±0.03^{g}	25.42±0.39^{c}	3.05±0.17^{e}	-0.66±0.05^{c}
	90	48.91 ±0.3^{c}	6.6 ±0.04^{d}	10.17 ±0.09^{e}	24.21±0.16^{b}	2.3±0.22^{a}	-0.62±0.04^{b}
Freeze	-50	61.89 ±0.3^{f}	5.69 ±0.03^{a}	8.06 ±0.05^{a}	26.64±0.09^{h}	3.02±0.05^{d}	-0.89±0.04^{e}

Superscripts with different letters indicate significant difference $p \leq 0.05$ among treatments.

(Mussi et al., 2015). Freeze dried products retained the properties of raw material as compared to the air dried products (Michalczyk et al., 2009). It indicated that low temperature and vacuum helps in retaining the anthocyanin during drying operation.

Visual colour values

Fresh java plum seeds had ‘L’ value of 38.93 and dehydrated seeds had 47.38 to 61.89 (Table 4). Increase in ‘L’ value of java plum seeds on drying might be due to effect of thermal treatment as evident from the data which was found negatively correlated. In case of java plum skin the ‘L’ value was not affected by freeze drying as well as in tray and fluidized bed drying at 50°C, however, it decreased at 70 and 90°C.

The ‘a’ values of fresh java plum seed and skin were 7.58 and 2.97 respectively. Java plum seeds had higher ‘a’ value as compared to java plum skin due to pink pulp adhering on the surface. The ‘a’ value decreased due to the exposure of heat in fluidised bed and tray driers but in freeze dryer it might be due to prolong drying process. Java plum skin dried in freeze dryer, tray drier or fluidised bed drier at 70˚C had close ‘a’ values as in case of fresh peel but increased at 50˚C and decreased at 90°C in tray and fluidized bed dryer. It might be due to browning at 50°C and pigment degradation at 90°C.

The ‘b’ value of fresh java plum seed and skin was 8.38 and -1.03 respectively. The 'b' value of java plum seeds increased on drying but showed low values at higher temperatures in tray and fluidised bed driers. The ‘b’ value of freeze dried seeds was close to the fresh seeds. Negative values of 'b' showed blueness in the java plum skin. The trend of ‘b’ values of skin was opposite in fluidised bed dryer and tray dryer where it decreased and increase respectively. The ‘b’ value of freeze dried skin was slightly lower than the fresh skin. Statistical analysis showed a significant ($p \leq 0.05$) change in colour values on drying in three dryers. Blanching and heating decreased brightness (L), redness (a) and yellowness (b) (Bao and Chang, 1994). 'L', 'a' and 'b' values of black currants varied between 22.01-23.63, -0.08-0.90 and -0.03-1.53 respectively (Ochmian et al., 2014). Thus previous results support the present findings on change in colour values due to heat involved during drying.

Free radical scavenging activity

The antioxidant activity of fresh and dried java plum seeds was measured from decolourizing of DPPH (2,2-diphenyl-1-picrylhydrazyl) solution in term of neutralizing free radical ability (Naik et al., 2003). The study showed that the free radical scavenging activity of java plum seeds reduced after drying. Free radical scavenging activity of fresh java plum seeds was 92.41% and it got decreased to 91.66, 90.99 and 88.65 at 50, 70 and 90°C in the tray drier respectively, while freeze dried seeds had maximum (91.98%) activity after drying (Table 5).

The free radical scavenging activity of fluidised bed dried seeds varied from 90.64 to 91.92%. Statistical analysis depicted the significant difference ($p \leq 0.05$) in the free radical scavenging activity of java plum seeds after drying. Java plum seeds dried at 90°C in the tray drier had lowest scavenging activity whereas freeze dried java plum seeds showed the highest free radical scavenging activity. The analysis showed that Java plum seeds are rich source of antioxidants but antioxidants got partially destroyed with the application of heat.

Java plum skin had high content of anthocyanins and contributed to high antioxidant properties. Fresh java plum skin had 93.42% free radical scavenging activity and it reduced to 92.97, 90.66 and 90.01% at 50, 70 and 90° C in tray drier respectively whereas in fluidised bed drier free radical scavenging activity decreased from

Table 5. Free radical scavenging activity of java plum seeds and skin (n=3).

Drier	Temperature (°C)	Java plum seeds	Java plum skin
Fresh sample	-	92.41±0.73^{g}	93.42±0.49^{h}
	50	91.66±1.07^{e}	92.97±1.20^{g}
Tray	70	90.99±0.71^{c}	90.66±1.46^{c}
	90	88.65±1.05^{a}	90.01±1.23^{a}
	50	91.92±0.85^{f}	92.54±0.77^{f}
Fluidised bed	70	91.48±1.39^{d}	91.43±1.42^{d}
	90	90.64±0.88^{b}	90.17±1.37^{b}
Freeze	-50	91.98 ±2.11^{e}	92.46 ± 0.51^{e}

Superscripts with different letters indicate significant difference p≤0.05 among treatments.

92.54 to 90.17%. Statistical analysis revealed significant (p<0.05) change in the free radical scavenging activity of java plum skin. During drying, heat damage occurred at high temperature which resulted in lowering the antioxidant activities.

Syzygium cumini fruits have high antioxidant activity (Afify et al., 2011). The antioxidant activity of fresh java plum seed and skin was 93.90 and 94.55% respectively (Shrikanta et al., 2015). Jamun seeds dried in sun, shade and freeze drier had 92.57, 93.48 and 96.27% antioxidant activity respectively (Shahnawaz et al., 2010). More losses of antioxidant and anthocyanins were found in the air dried serviceberries than freeze dried (Kwok et al., 2004). Previous findings are in accordance with the present results which reaffirm that java plum waste seeds and skin had excellent antioxidant activities.

Conclusion

Drying behaviour of java plum seeds and skin waste followed falling rate period pattern and was well described by Page's model. Anthocyanin retention of skin was higher in the freeze dryer but least in tray and fluidized bed drier at 90˚C. Drying rate was affected by size of java plum seeds, and higher drying rate was obtained in cross section cut seeds. Fluidized bed drier was efficient for the drying of java plum seeds and skin.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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