Instant vegetable from osmo-air drying of jimikand (*A. campanulatus*) in NaCl solution: nutritional, functional, micro-structural and other quality aspects

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Revised: 3 August 2016 / Accepted: 25 August 2016 / Published online: 9 September 2016
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Abstract The aim of this work was to study the effect of osmotic dehydration on the quality of jimikand which can be used as an instant vegetable to get its nutritional and functional benefits. Osmotic dehydration was applied as pre-treatment to hot-air drying for increasing palatability, mass transfer improvement and minimizing nutritional losses. To see the effect of osmotic dehydration on various quality parameters, conditions of osmotic dehydration selected were osmotic solution concentrations (5, 10 and 15 % w/w) and temperatures (40, 50 and 60 °C) for constant process time (80 min) on the basis of mass transfer analysis. The observed values of hardness, oxalate content and water activity of osmo-dried samples varied from 66.04 ± 14.5 to 79.12 ± 14.8 N, 60.0 ± 0.40 to 69.1 ± 0.65 mg/100 g, 0.911 ± 0.001 to 0.826 ± 0.001 , respectively, and found less as compared to fresh sample, i.e. 131.12 ± 9.5 N, 110.5 ± 0.78 mg/100 g and 0.990 ± 0.00 respectively. Rehydration ratio of fresh sample was 3.52 ± 0.03 and varied from 2.82 ± 0.06 to 3.57 ± 0.10 for osmo-dried samples being higher at lower concentrations and temperatures. The best conditions of osmotic dehydration found were 10 % NaCl, 50 °C temperature and 80 min duration on the basis of appreciable mass transfer, lowest oxalate content, water activity, better rehydration, textural and sensory quality. The selected osmo-dried sample was better due to low anti-nutritional content, less micro-structural damage and appreciably

comparable to fresh hot-air dried in terms of total phenol, antioxidant activity, and other quality parameters.

Keywords Rehydration ratio · Sodium chloride · Total phenol · Antioxidant activity · Oxalate content

Introduction

Jimikand or Elephant foot yam (*Amorphophallus campanulatus*), is one of the most popular underground stem tuber among tuberous crops. It is extensively used as a favorite vegetable by millions of people in various regions of India and is popular as a food security and as a remunerative cash crop. Sometimes these tubers are referred as famine crop, to be used when other staple crops are in short supply (Sankaran and Palaniswami 2008). They are usually consumed as a cooked vegetable, pickles, and are used in many indigenous medicinal preparations. This tuber is referred as ‘King of Tuber crops’ because of its culinary properties, therapeutic values, medicinal utility and higher yield potential. A wide range of phytochemicals viz. Phenols, flavonoids, alkaloids, glycosides, steroids and tannins are present in jimikand. It has antioxidant, hepatoprotective and uterus stimulating effect, and is also known as *ar-soghna* in Sanskrit, because of its piles curing properties (Dey 1896). Like pharmacological industry, jimikand has a great scope in the food industry for commercial exploitation. This is because of its functional properties and nutritional components like carbohydrates, fiber, protein, high minerals (Ca, K, Mg, P, Zn, Mn) and vitamins (Chattopadhyay et al. 2009). It can be converted into various value added products after proper processing, enhancing effectively the consumption of this tuber and utilizing its functional benefits. As jimikand contains high

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moisture content, hence drying is necessary for preserving it for a long time or converting into value added products. Drying has several advantages related to storage economies and final product distribution. So, the question is, what kind of drying methods should be used to achieve good quality finished product. Among the commonly used methods, hot-air drying is the ancient method based on lowering the moisture content in the products, but degrades the final product quality and freeze drying is a costly process.

Osmotic dehydration (OD) is a good alternative, in which foods are partially dehydrated by immersion in an aqueous hypertonic solution (Thippanna and Tiwari 2015; Yadav and Singh 2014; Yadav et al. 2012). This reduces the time of exposure to high temperature, minimizes nutritional losses and increases acceptability, without causing too much increase in process costs. OD reduces the water activity (a_w) of the food, which extends the shelf life of food products by minimizing the potential growth of microorganisms (Abraao et al. 2013). Commonly used osmotic agent is sucrose; however, an alternative, for example, sodium chloride (NaCl) can be used as salty taste is desirable for vegetables and also for some value-added products like pasta, noodles, pickles, soup, etc. Salt solution leads to a strong driving force for the OD because of low a_w (Mayor et al. 2006). OD can be used as a pre-treatment prior to convective drying to get improved quality final product.

The OD of jimikand in NaCl solution and its impact on quality parameters has not been studied. Therefore, the objective of the present work was to study the impact of OD at different concentrations of NaCl and temperatures on different quality parameters of jimikand.

Materials and methods

Osmotic dehydration (OD)

A commercial variety of jimikand (*Amorphophallus* spp.) free from any type of defect was purchased from the local market of Sangrur (Punjab), stored at room temperature and used within 12–24 h. The initial moisture content of the jimikand determined by hot-air oven method (Ranganna 1986) was 79.94 ± 0.68 % (wet basis). Washed and peeled tubers were cut into uniform size cubes (1 cm^3) and blanched ($95^\circ\text{C}/5 \text{ min}$) to inactivate enzymes and reduce browning, followed by immediate dipping in ice-cold water for 30 min. The soluble oxalate content and acidity reduced greatly by blanching and soaking process (Noonan and Savage 1999). Blanched samples exhibit higher water loss as compared to

untreated and frozen samples (Kowalska et al. 2008). The blanched samples were subjected to OD using osmotic solutions of NaCl having different concentrations (5, 10 and 15 % w/w) and temperatures (40, 50 and 60°C) for constant period of time (80 min). The cubes were taken out from the salt solution at predetermined time interval and blotted with absorbent paper to remove adhered osmotic agent. On the basis of mass transfer analysis results as explained in detail in our previous study (Sangeeta and Hathan 2015), the optimum time (80 min) for OD was selected for quality analysis of osmo-dried samples. The osmo-dried samples were dried in a cabinet dryer at 60°C temperature (10.43 ± 0.07 % moisture content) for the analysis of different quality parameters. These results were further used for the selection of optimum OD conditions to get the best osmo-dried jimikand product. All the analysis was done in triplicates.

Analysis of quality parameters

Texture (N), a_w and oxalate content (mg/100 g)

Effect of OD conditions on texture in term of hardness was measured by using a texture analyzer (ta-xt2i, stable microsystems, UK) in compression mode using 75 mm cylindrical probe (Sangeeta and Hathan 2016). Texture analysis for more than 15 cubes of fresh (no-treatment), each osmo-dried (OD only), selected osmo-air dried (jimikand subjected to OD followed by hot-air drying) and fresh hot-air dried (hot-air drying only) was done. Texture analysis of hot-air dried samples was done after rehydration.

Water activity (a_w) was measured by using a_w measurement device (Hygrolab, Cole Parmer) with an accuracy of ± 0.001 at 25°C .

The total oxalate content of jimikand samples was calculated by the titrimetric method as described by Day and Underwood (1986).

Rehydration parameters

Five grams of dehydrated sample and 55 ml of cold water in a small container covered with a watch glass were boiled gently for 20 min. After this, the excess water was removed and then the weight of rehydrated sample was recorded. The rehydration ratio was calculated by using the formula given below (Srivastava and Kumar 1993).

$$\text{Rehydration ratio} = B/A \quad (1)$$

The rehydration capacity (% weight gain) was calculated from the difference in sample weight before and after the rehydration as given below:

$$\text{Weight gain (\%)} = \frac{B - A}{A} \times 100 \quad (2)$$

where B and A are the weights (g) of rehydrated and dried samples, respectively.

The cooked solutions were evaporated and dried at $105 \pm 2^\circ\text{C}$ in a hot-air oven to constant weight to determine solids loss during rehydration.

Sensory evaluation

The sensory quality of the rehydrated osmo-dried samples was evaluated by using nine point hedonic scale (Ranganna 1986). An expert panel was selected on the basis of training as described by Sangeeta and Hathan (2016) with little modifications. Twenty-six trained panelists with consistent results (selected from 30 members) assessed the products for color and appearance, irritability, taste and mouth feel, texture and hardness, and overall acceptability (OA) by using a nine-point hedonic scale (9-like extremely, 8-like very much, 7-like moderately, 6-like slightly, 5-Neither like nor dislike, 4-dislike slightly, 3-dislike moderately, 2-dislike very much, 1-extremely dislike). Before analysis of other sensory parameters the panel members were asked to judge the acidity after applying the jimikand paste from each batch presented in separate dishes on the soft part (inside) of the forearm (3–4 min) for feeling the itchy sensation if any, and asked to give a score on the basis of sensation. Samples which scored 5 or below 5 were considered as extremely acrid and were not served for further sensory analysis.

Proximate analysis

Moisture content and dry matter was determined by hot-air oven method. Analysis of crude protein, crude fiber, crude fat, and ash was done using standard procedures (AOAC 1980).

Color

The color properties in terms of L, a, and b values were measured using a Hunter Lab Mini Scan XE Plus colorimeter (Reston, VA) and color difference (ΔE) was calculated using Eq. 3 as given below.

$$\Delta E = \sqrt{(L - L^*)^2 + (a - a^*)^2 + (b - b^*)^2} \quad (3)$$

ΔE indicates the degree of overall color change of a sample in comparison to the color values of an ideal (Fresh) sample having color values of L^* , a^* , b^* .

Non-enzymatic browning (NEB)

Five grams of sample was soaked in 100 ml of 60 % alcohol for 12 h and filtered. The absorbance of the filtrate was recorded at 440 nm using 60 % alcohol as blank and expressed in terms of optical density (Ranganna 1986). The increase in the absorbance of the sample extract was taken as a measurement of NEB.

Functional properties

The extracts preparation and calculations of functional properties in term of total polyphenol content, Flavonoids (mg/g dry extract) and DPPH Radical Scavenging Activity (g/100 g) were done by methods as described in a previous study (Sangeeta and Hathan 2016).

Scanning electron microscopy (SEM) analyses

The jimikand Samples, previously fixed with glutaraldehyde and critically dried (20–100 mL/100 mL aqueous ethanol) for SEM analysis were obtained by cutting the slabs along the thickness and images of transversal surfaces were captured using a scanning electron microscope (JEOL, Tokyo, Japan, Model No., JSM-6610-LV). The samples were coated prior analysis with a thin layer of gold, palladium in a sputter coater (JEOL-JFC-1600).

Statistical analysis

Data were subjected to ANOVA and Duncan's multiple range test (Duncan's 1955) using statistical 7 (statistical _soft, TULSA, USA). Values were expressed as means $\pm$ standard deviations. Differences were considered significant at $p < 0.05$.

Results and discussion

Osmotic dehydration (OD)

On the basis of mass transfer (WL and SG) behavior during OD of jimikand cubes in salt solution under different processing conditions, it was observed that most of the mass transfer takes place initially (up to 80–90 min) and become almost negligible in later stages (after 150 min) as described previously (Sangeeta and Hathan 2015). It was observed that no significant mass transfer occurred after 80 min for all the combinations of concentration (5, 10, and 15 %) and temperature (40, 50, 60 $^\circ\text{C}$) used. Thus, optimum time of OD selected for analysis of all the quality parameters was 80 min.

Effect of OD on a_w , hardness and oxalate content of jimikand cubes

The hardness, a_w , and oxalate content of jimikand cubes as affected by OD are given in Table 1. As compared to fresh sample (0.990 ± 0.001), a significant decrease of a_w in osmo-dried samples ($0.90\text{--}0.826 \pm 0.001$) was observed. The decreased a_w of osmo-dried samples may be due to the incorporation of solute (NaCl— a_w depressant) and reduction of free water during OD. The increase in temperature at lower concentration (5 %), and increase in concentration at a lower temperature (40 °C) resulted in a significant decrease of a_w in osmo-dried samples. In contrast, non-significant difference in a_w was observed at higher concentrations (10 and 15 %) and temperatures (50–60 °C). This may be due to less difference in mass transfer at higher concentration and temperature. The reduced a_w of osmo-dried jimikand samples ensures their microbial safety and shelf stability. In addition, lower a_w can help to reduce the rate of adverse reactions to food such as browning, protein denaturation, fat oxidation and vitamin degradation (Fernandez 2011).

As compared to fresh sample, the hardness of osmo-dried jimikand samples decreased significantly. This might be due to solubilization of the lamella media because of blanching and OD, which reduces the pressure exerted by water (Aboubakar et al. 2009). The effect of temperature on the hardness of osmo-dried samples was more as compared to concentration, but the difference was non-significant.

Like hardness and a_w , oxalate content also decreased significantly in osmo-dried samples ($60.0 \pm 0.40\text{--}69.1 \pm 0.65$ mg/100 g) as compared to fresh jimikand (110.5 ± 0.78 mg/100 g). The oxalate content of osmo-

dried jimikand decreased with increase in concentration and temperature of the osmotic solution being lower for higher concentration (15 %) and temperature (60 °C). This reduction in oxalate content may be due to leaching of soluble oxalate during blanching, soaking, and OD. Savage and Dubois (2006) also observed 36 % reduction in soluble oxalate after 2 min blanching. The oxalic acid and its salts (mainly soluble) can have deleterious effects on human nutrition and health, mainly by decreasing calcium absorption and aiding in the formation of kidney stones (Noonan and Savage 1999). Heat treatment (blanching, OD) effectively reduces the soluble oxalate content, makes the product nutritionally better and safe for human consumption (Savage 2002). The reduction in oxalate content makes osmo-dried jimikand nutritionally superior due to increase in bioavailability of minerals and other nutrients.

Effect of OD on rehydration quality of jimikand cubes

Rehydration is one of the important quality parameters of dried food materials and can be considered as a measure of the injury caused by drying or treatment preceding drying. The rehydration ratio (RR) and rehydration capacity (RC) of samples osmo-air dried at lower concentrations (5 and 10 %) and temperatures (40 and 50 °C) were non-significantly higher than fresh hot-air dried samples (Table 2). This slight increase in rehydration quality may be due to the structural and mechanical strength provided by solute infused during OD. Thus, osmo-dried cells can withstand the shock during hot-air drying and prevent cell rupture due to less shrinkage, which improves water uptake during rehydration (Jayaraman et al. 1990). Torringa et al. (2001) also reported

Table 1 Effect of osmotic dehydration on a_w , hardness and total oxalate content of jimikand cubes

Conc.(%) ¹	Temp (°C)	a_w^{BCD}	Hardness ^{BCD} (N)	Total oxalate ^{ACD} (mg/100 g)
Fresh ²	–	0.990 ± 0.001^a	131.12 ± 9.5^a	110.5 ± 0.78^a
5	40	0.911 ± 0.001^b	79.10 ± 14.4^b	69.1 ± 0.65^b
10	40	0.872 ± 0.001^c	78.09 ± 15.4^b	68.3 ± 0.59^b
15	40	0.841 ± 0.001^f	79.12 ± 14.8^b	66.9 ± 0.61^b
5	50	0.906 ± 0.001^c	67.21 ± 14.7^b	62.3 ± 0.45^c
10	50	0.827 ± 0.001^g	65.23 ± 11.9^b	61.2 ± 0.31^{de}
15	50	0.826 ± 0.001^g	66.09 ± 15.6^b	61.5 ± 0.46^{cd}
5	60	0.903 ± 0.001^d	66.04 ± 14.5^b	60.9 ± 0.37^{df}
10	60	0.827 ± 0.001^g	66.12 ± 12.8^b	60.5 ± 0.48^{ef}
15	60	0.826 ± 0.001^g	67.22 ± 10.9^b	60.0 ± 0.40^f

Mean values in the same column with different letter are significantly different ($p < 0.05$), Mean $\pm$ standard deviation ($n = 3$)

¹ Conc. concentration; Temp temperature; a_w water activity; BCD before hot-air drying; ACD after hot-air drying

² Fresh-sample without any treatment

Table 2 Rehydration quality fresh hot-air dried and osmo-air dried jimikand cubes

Conc. (%) ¹	Temp (°C)	RR	RC (% weight gain)	% Solid loss
Fresh ²	–	3.52 ± 0.03 ^a	251.67 ± 3.15 ^a	1.45 ± 0.01 ^{cd}
5	40	3.53 ± 0.04 ^a	253.04 ± 4.00 ^a	1.46 ± 0.04 ^{cd}
10	40	3.48 ± 0.04 ^{ab}	248.08 ± 3.61 ^a	1.47 ± 0.02 ^c
15	40	3.29 ± 0.10 ^c	229.67 ± 10.61 ^{bc}	1.51 ± 0.01 ^b
5	50	3.56 ± 0.05 ^a	255.67 ± 5.13 ^a	1.42 ± 0.02 ^d
10	50	3.57 ± 0.10 ^a	256.61 ± 10.10 ^a	1.44 ± 0.03 ^c
15	50	3.27 ± 0.13 ^c	224.33 ± 4.51 ^c	1.53 ± 0.01 ^{ab}
5	60	3.37 ± 0.10 ^{bc}	236.73 ± 1.16 ^b	1.51 ± 0.02 ^b
10	60	3.10 ± 0.06 ^d	210.33 ± 5.51 ^d	1.53 ± 0.02 ^{ab}
15	60	2.82 ± 0.06 ^c	182.33 ± 5.77 ^e	1.56 ± 0.01 ^a

Mean values in the same column with different letter are significantly different ($p < 0.05$), Mean $\pm$ standard deviation ($n = 3$)

¹ Conc. concentration; Temp temperature; RR rehydration ratio; RC rehydration capacity

² Fresh-sample without any treatment

improved rehydration properties of osmo-dried mushrooms due to reduced shrinkage and increased porosity. The rehydration quality decreased significantly with increase in concentration and temperature being lowest for highest concentration (15 %) and temperature (60 °C) used. This may be due to cell permeabilization by high osmotic stress (Lewicki 1998) and blockage of pores due to higher solute gain. The porous microstructure and porosity play an important role in the rehydration mechanism (Marabi and Saguy 2004).

After rehydration of fresh hot-air dried and osmo-air dried jimikand samples % solutes lost in solution left after rehydrated was observed. The values of % solute loss were significantly higher for osmo-dried jimikand at higher concentration (15 %) and temperature (60 °C) of the osmotic solution. This may be due to structural changes induced by osmotic pre-treatment at high concentration and temperature, and interaction of the osmo-active substances with the cell components (Lewicki 1998). In contrast to higher concentration and temperature, significantly lower values of % solute loss were observed for samples osmo-dried in osmotic solutions of lower concentrations (5 and 10 %) and temperatures (40–50 °C). This may be due to the protective effect of OD at lower concentrations and temperature as discussed above. The values of % solute loss of rehydrated samples osmo-dried at lower concentrations and temperatures were significantly similar to the values of rehydrated fresh hot-air dried samples. The loss of dry matter was thought to be less in osmo-air dried samples in comparison to fresh hot-air dried samples. Lewicki et al. (1998) also reported that osmotic dewatering of onion before drying improved the retention of the constitutive dry matter.

Effect of OD on sensory quality of jimikand cubes

Consumer acceptability of dehydrated products is highly dependent on their sensory attributes. In addition to visual appearance the attributes like taste, color, and texture are critical in determining their degree of acceptance (Kumar and Sagar 2014).

The sensory quality of osmo-air dried samples was found better than fresh hot-air dried sample after rehydration as shown in Table 3. This may be due to less shrinkage (Torrington et al. 2001) and better retention of color due to blanching and OD. The jimikand samples osmo-dried in osmotic solutions having concentrations 5 and 10 %, and temperatures of 40 and 50 °C scored significantly higher values in terms of color and appearance.

Irritability of jimikand decreased significantly with increase in osmotic solution temperature up to 50 °C however, with further increase in temperature (60 °C) the reduction was not significant. The effect of concentrations (5, 10 and 15 %) at constant temperature was non-significant on the irritability of osmo-dried jimikand. The fresh hot-air dried jimikand was not analyzed further for sensory quality because of high irritability (score <5.0) and low color and appearance score. In contrast, the low irritability of osmo-dried samples may be due to a reduction in oxalate content because of blanching, soaking, and osmotic temperature.

The osmo-dried jimikand up to certain concentration, i.e. 5–10 % have a significantly higher scores for taste and mouth feel in comparison to those osmo-dried at higher concentration (15 %) and temperature (60 °C). Like taste and mouth-feel, hardness and texture had similar results on the basis of sensory score. The increase in OA was observed for the increase in concentration (5–10 %) and

Table 3 Sensory evaluation of fresh hot-air dried and osmo-air dried Jimikand cubes after rehydration

Conc.(%) ¹	Temp (°C)	Color and appearance	Irritability	Taste and mouthfeel	Hardness and texture	Overall acceptability
Fresh ²	–	5.55 ± 0.04 ^d	4.0 ± 0.92 ^c	Nd	Nd	Nd
5	40	8.21 ± 0.05 ^a	6.5 ± 0.57 ^b	7.50 ± 0.25 ^{ab}	7.41 ± 0.14 ^{ab}	7.01 ± 0.16 ^{cf}
10	40	8.25 ± 0.04 ^a	6.8 ± 0.82 ^b	7.70 ± 0.15 ^{ab}	7.60 ± 0.05 ^a	7.49 ± 0.11 ^{bc}
15	40	8.15 ± 0.02 ^b	6.8 ± 0.51 ^b	6.51 ± 0.41 ^c	6.40 ± 0.31 ^c	7.02 ± 0.14 ^{ce}
5	50	8.25 ± 0.01 ^a	8.0 ± 0.25 ^a	7.89 ± 0.31 ^a	7.81 ± 0.20 ^a	7.20 ± 0.09 ^{cd}
10	50	8.23 ± 0.04 ^a	8.4 ± 0.41 ^a	8.01 ± 0.15 ^a	7.91 ± 0.04 ^a	8.21 ± 0.08 ^a
15	50	8.15 ± 0.05 ^b	8.6 ± 0.19 ^a	6.19 ± 0.21 ^c	6.11 ± 0.10 ^c	6.70 ± 0.11 ^{ef}
5	60	8.10 ± 0.03 ^b	8.5 ± 0.28 ^a	6.89 ± 0.9 ^{bc}	6.79 ± 0.81 ^{bc}	7.90 ± 0.03 ^{ab}
10	60	8.12 ± 0.02 ^b	8.4 ± 0.31 ^a	6.90 ± 0.25 ^{bc}	6.81 ± 0.14 ^{bc}	7.15 ± 0.02 ^{ce}
15	60	8.11 ± 0.04 ^b	8.4 ± 0.11 ^a	5.40 ± 0.15 ^d	5.32 ± 0.03 ^d	6.42 ± 0.03 ^f

Mean values in the same column with different letter are significantly different ($p < 0.05$), Mean ± standard deviation ($n = 3$)

¹ Conc. concentration; Temp temperature; nd not determined

² Fresh-sample without any treatment

temperature (40–50 °C) being maximum for 10 % concentration at 50 °C temperature. Thus, OD in combination with hot-air drying contributes to the development of characteristic sensory qualities in the products, which influences their utilization as food. Prajapati et al. (2011) also observed that NaCl enhances color and the sensory quality of the anola product.

Although, the increase in temperature increase diffusivity and reduced oxalate content, but concentration and temperature above 10 % and 50 °C, respectively, reduced the overall quality of the final product. Thus, it can be concluded that osmo-dried jimikand in osmotic solution having 10 % NaCl and 50 °C temperature for 80 min immersion time was found better in terms of all the quality parameters studied.

The jimikand samples osmo-dried at these process conditions (i.e. 10 % concentration, 50 °C temperature and 80 min immersion time) were selected as the best osmo-dried jimikand product and used for further quality evaluation.

Quality attributes of fresh and selected osmo-dried jimikand samples

The physicochemical and functional properties of fresh and selected osmo-dried jimikand before and after hot-air drying are summarized in Table 4.

Proximate composition, water activity (a_w), hardness (N), and color parameters

The reduction in moisture content was 32.79 % in selected osmo-dried jimikand sample, which was in agreement with the results of mass transfer (WL) analysis during OD as described previously. As compared to fresh sample, a_w of osmo-dried jimikand samples reduce significantly due to the

reduction of free water. After hot-air drying, a_w of both the samples i.e. 0.693 ± 0.001 for fresh and 0.695 ± 0.00 for osmo-dried sample decreased to a greater extent, which ensures the microbial safety of the final product (Fernandez 2011). The crude protein was slightly lower in the osmo-dried sample as compared to fresh hot-air dried sample. However, in comparison to fresh sample (2.74 ± 0.14 %) high increase in protein content was observed in both osmo-dried (6.33 ± 0.1 %) and osmo-air dried (9.16 ± 0.12 %) samples. Like crude protein slight decrease in crude fat and ash content was observed in osmo-air dried sample (Table 4). In contrast, the crude fiber of osmo-dried and osmo-air-dried sample was high as compared to fresh and fresh hot-air dried samples, respectively. This may be due to the formation of the protein-fiber complex during thermal treatments viz. boiling and cooking (Caprez et al. 1986).

The texture in terms of hardness, reduced greatly for selected osmo-dried samples (65.23 ± 11.90 N) in comparison to fresh (131.12 ± 9.52 N) samples, discussed previously in detail. Decrease in hardness of rehydrated samples (Table 4) may be due to softening of tissues and loss in firmness as a result of substantial dissolution, depolymerization and apparent destruction of cell wall pectin. Although rehydration quality and hardness were significantly similar in fresh hot-air dried and osmo-air dried jimikand samples but slightly firm texture of rehydrated osmo-air dried sample might be due to the protection of cells by OD at lower concentration (Lewicki 1998).

Color was the most characteristic feature to differentiate between the samples as the color of jimikand sample was significantly affected by process treatments i.e. OD and hot-air drying. The L-value of osmo-dried and osmo-air dried jimikand samples were significantly higher than fresh sample with and without hot-air drying. This might be due to inhibition of browning by enzyme inactivation during

Table 4 Quality attributes of fresh and selected osmo-dried jimikand samples

Parameters	J ^F	J ^{FCD}	J ^O	J ^{OCD}
<i>Physico-chemical properties</i> ¹				
Moisture (%)	79.94 ± 0.68 ^a	9.49 ± 1.01 ^c	53.73 ± 0.15 ^b	10.43 ± 0.07 ^c
Dry matter (%)	20.06 ± 0.08 ^c	90.51 ± 1.01 ^a	46.27 ± 0.15 ^b	89.57 ± 0.07 ^a
Crude protein (%)	2.74 ± 0.14 ^d	10.05 ± 0.09 ^a	6.33 ± 0.1 ^c	9.16 ± 0.12 ^b
Crude fiber (%)	1.27 ± 0.12 ^d	6.74 ± 0.20 ^b	2.49 ± 0.14 ^c	7.52 ± 0.11 ^a
Crude fat (%)	0.85 ± 0.05 ^d	2.95 ± 0.13 ^a	1.12 ± 0.07 ^c	2.78 ± 0.09 ^b
Ash (%)	Nd	5.26 ± 0.08 ^a	Nd	5.19±0.10 ^a
Water activity	0.990 ± 0.001 ^a	0.695 ± 0.001 ^c	0.827 ± 0.001 ^b	0.693 ± 0.001 ^d
Texture (N)	131.12 ± 9.52 ^a	47.98 ± 3.51 ^c	65.23 ± 11.90 ^b	49.87 ± 2.11 ^c
Oxalate (mg/100 g)	Nd	110.50 ± 0.78 ^a	Nd	61.21 ± 0.31 ^b
L-value	60.12 ± 0.04 ^c	51.34 ± 0.07 ^d	60.45 ± 0.05 ^b	60.98 ± 0.02 ^a
a-value	05.24 ± 0.03 ^c	11.37 ± 0.05 ^a	05.13 ± 0.02 ^d	07.94 ± 0.04 ^b
b-value	16.54 ± 0.03 ^c	13.16 ± 0.04 ^d	17.04 ± 0.06 ^a	16.78 ± 0.05 ^b
ΔE	Nd	11.23 ± 0.02 ^a	0.61 ± 0.03 ^c	2.84 ± 0.01 ^b
NEB	0.10 ± 0.02 ^c	0.25 ± 0.04 ^a	0.12 ± 0.03 ^{bc}	0.17 ± 0.02 ^b
Parameters	J ^{FCD}		J ^{OCD}	
<i>Functional properties</i>				
Extract yield ^M	1.94 ± 0.16 ^a		1.92 ± 0.25 ^a	
TPC (mg GAE/gm extract)	47.03 ± 0.91 ^a		42.84 ± 0.47 ^b	
TFC (mg CE/gm extract)	31.42 ± 1.03 ^a		29.14 ± 0.74 ^b	
AOA (DPPH ^R) (g/100 g)	83.14 ± 0.62 ^a		74.09 ± 1.03 ^b	

Mean values in the same column with different letter are significantly different ($p < 0.05$). Mean ± standard deviation ($n = 3$)

¹ J^F fresh sample; J^{FCD} fresh hot-air dried; J^O osmo-dried; J^{OCD} osmo-air dried; J Jimikand; a_w water activity; NEB non-enzymatic browning; ^M Methanol extract; TPC total phenol content; GAE gallic acid equivalents; TFC total flavonoids content; CE catechin equivalents; AOA antioxidant activity; ^R radical scavenging activity; nd not determined

blanching, and also due effect of OD in NaCl solution. Significantly higher a-value was observed for fresh hot-air dried sample, which may be due to a higher impact of temperature (colored products of Maillard reaction) and enzymatic browning. The higher b-value was observed for osmo-dried samples as compared to fresh jimikand samples before and after hot-air drying. The difference in color (ΔE) was high for fresh hot-air dried (11.23 ± 0.02) as compared to osmo-dried (0.61 ± 0.03) and osmo-air dried (2.84 ± 0.01) jimikand samples. Like ΔE, non-enzymatic browning was higher for fresh hot-air dried sample as compared to osmo-air-dried samples. The lower values of non-enzymatic browning for osmo-air dried samples may be due to low a_w of osmo-dried samples (before hot-air drying) as reduced a_w limit the non-enzymatic browning (Hoskin and Dimick 1995).

Functional properties: total phenols (TPC), flavonoids (TFC), and antioxidant activity (AOA)

Phenols are the important micronutrients of diet capable of preventing the degenerative diseases such as cancer and

cardiovascular diseases. The yield of phenols in methanol extract was significantly similar for both fresh hot-air dried (1.94 ± 0.16) and osmo-air dried (1.92 ± 0.25) jimikand samples. The slight reduction in TPC, TFC and AOA was observed in osmo-dried samples, may be due to leaching and destruction of the functional components by soaking, blanching and osmotic process used (Lindley 1998). This decrease was not so much as osmo-air dried sample still contain appreciable amounts of functional components and can be proved beneficial, if used regularly in the diet.

Microstructure analysis

The typical SEM images of jimikand i.e. Fresh (Sangeeta and Hathan 2016), osmo-dried in salt solution (Fig. 1a), both after hot-air drying (Fig. 1b, c) and hot-air dried after rehydration (Fig. 1d, e) were compared for microstructure analysis. Micrograph of fresh jimikand, i.e. without any treatment as given in Fig. 7a of previous study (Sangeeta and Hathan 2016) clearly shows the cellular network with embedded starch of different shape and size ranging from 9–12 μm. After OD, the cells were not affected so much, but

Fig. 1 Micrographs of jimikand: Osmo-dried (a), Osmo-air dried (b), Fresh hot-air dried (c), Rehydrated-Fresh hot-air dried (d) and, Rehydrated-osmo-air dried (e)

the granular structure of starch disappeared, this may be due to the disintegration of starch by the blanching temperature and OD. Due to OD, incorporation of salt within cells, binding of salt, protein and starch can be observed at some places. The microstructure of fresh jimikand was affected strongly by hot-air drying, but cell damage was less when OD was used as a pre-treatment prior to hot-air drying. This may be due to reduction in length of exposure to hot-air

drying, which reduced the structural damage associated with hot-air drying (Puig et al. 2012). More dense and shrunken cell structure was observed for jimikand samples dried without OD as compared to osmo-air-dried samples. After rehydration, maceration of some cells and disintegration/gelatinization of starch granules was observed in both fresh hot-air and osmo-air dried samples due to cooking temperature. However, the gain of the original structure of some

cells in rehydrated osmo-air-dried samples was clearly seen. This may be due to less cellular damage in osmo-air dried samples because of reduced hot-air drying time and higher cell strength provided by OD. This may be the reason of better textural and rehydration quality of rehydrated osmo-air dried samples as compared to rehydrated fresh hot-air dried sample. In fresh hot-air dried sample more swelling, thickening and abrupt opening of cells was observed. The observed swelling of the cell walls, accompanied by a loss of electron density, surely indicates a loosening of the cellulose fibril network (Grote and Fromme 1984). Lastly, we can conclude that microstructure properties of selected osmo-air dried jimikand were better as compared to fresh hot-air dried jimikand sample.

Conclusion

OD of jimikand cubes using NaCl as osmotic agent was done at different concentrations (5–15 % (w/w)), temperatures (40–60 °C) and constant immersion time (80 min). However, the increase in mass transfer and reduction in oxalate content was higher at higher concentrations and temperature, but concentration above 10 % and temperature above 50 °C reduced the overall quality of osmo-air dried jimikand. It can be concluded that sample osmo-dried at 10 % concentration and 50 °C temperature for 80 min was found better in terms of reduced a_w , oxalate content, better rehydration, color, textural and higher sensory quality. The selected osmo-air-dried sample was found superior than fresh hot-air dried due to low anti-nutritional content, less micro-structural damage, and appreciably comparable to fresh hot-air dried sample in terms of functional properties (TPC, TFC, and AOA) and other quality parameters. The osmo-air dried jimikand cubes (NaCl) may be used as an instant vegetable after rehydration and in value added extruded products like pasta, noodles, etc., where salty taste is preferred thus making it possible to use this medicinal and nutrition crop in regular diet.

Acknowledgments The first author is grateful to the Ministry of Human Resource Development and Sant Longowal Institute of Engineering and Technology, Sangrur, Punjab for providing financial assistance in the form of institutional Fellowship.

Compliance with ethical standards

Conflict of interest None.

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