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Characteristics of Onion under Different Process Pretreatments and Different Drying Conditions

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Abstract

Introduction: Onion (*Allium cepa*) is an important spice crop often grown outdoors in temperate climates as an annual crop because of its adaptability to varying weather conditions. It is an underground vegetable which varies in size colour, firmness and strength of flavour. Onion is often called "poor man's orange" because it is a good source of vitamins, particularly Vitamin A and C. It is also a rich source of minerals such as iron, thiamine, niacin and manganese contents. Onion is said to be very useful against heart diseases and many bacterial species including bacillus subtilis, salmoneva, and *E. coli*. This vegetable crop is highly perishable in its natural state after harvest resulting in huge postharvest losses during storage, transportation and marketing in the production season and extreme scarcity in the off-season which can be checked by drying.

Material and methods: The main materials used were 192 samples of pre-treatment and 10 samples of untreated (control) fresh onion. Others equipments used were temperature controlled dryer, sensitive weighing balance, water baths (Shell Lab Model and HH-W420, XMTD-204 Model), thermo-hygrometer, desiccators, desiccants, stop watch, onion slicer, stainless tray, foil wrap, conical flask, measuring cylinder, NaCl and distil water. Agarry and AOAC methods were used for quantitative analysis and nutritional analysis respectively. Statistical analysis of all data obtained was done.

Results: Results showed that drying rate, water loss, solid gain, vitamin C, manganese and iron contents varied with different levels of OSC, OPD and OST at $p \le 0.05$. However, drying rate, water loss, solid gain and all the quality parameters were influenced by all the process parameters.

Where;

OSC = Osmotic solution concentration

OST = Osmotic solution temperature

OPD = Osmotic process duration

Conclusion: Osmotic dehydration pretreatments had significant effect on process outputs (drying rate, water loss, solid gain, vitamin C, manganese and iron contents of onion.

Keywords: Onion (*Allium cepa*); Osmotic dehydration; Process pretreatments; Quality parameters

Introduction

Onion is an important underground vegetable compared with the other root and tuber crops (cassava, yam and potatoes) that has many nutritional and medicinal values that are beneficial to human beings.

Productivity of onion shows variable trends as the crop is susceptible to various weather variations. The optimum temperature required for its cultivation is 15 to 27°C and it can withstand drought fairly and do well in heavy rainfall areas [1]. Onion is among the most important vegetable grown in the tropic and a good source of calorie (50 gcal/100g). The growing and handling has received considerable attention in agricultural and food research and development and can be found in almost every fresh market in Africa.

Drying process is a thermo-physical and physio-chemical operation by which moisture is being removed from food materials. It involves the movement of water from the interior of the drying material to the surface from where it evaporates. Drying makes food materials suitable for safe storage and protects them against attack of insects, molds and other micro-organisms during storage [2]. In addition to preservation, dehydration helps to decrease the weight and bulk of material by significant amounts and improves the efficiency of product transportation and storage. Alam *et al.* [3] studied the effect of process parameters on the effectiveness of osmotic dehydration of summer onion. In the studied onion was treated in three sucrose (40, 50 and 60%), five salt (5, 10, 15, 20 and 25%) and five sucrose-salt (combine) solution (40:15, 45:15, 45:20, 50:15 and 55:15%) under different osmo-drying systems and osmotic solution temperature of 5, 25, and 40°C at the same time. The result obtained showed that among different solution concentration and temperature for 6 hours contact time 50:15° brix at 40°C gave water loss (50.05%), solid gain (16.25%) and normalized solid content (2.34). The result also showed that the 60° brix sucrose solution gave 35.60%, 9.32%, 1.81 and 25° brix salt solution gave 33.50%, 12.21%, 2.25 water loss, solid gain and normalized solid content respectively (Figure 1).

Asiru *et al.* [4] studied the effects of drying temperature and drying duration on colour changes in cashew kernels during hot air drying. Cashew nuts were steamed in an autoclave at 121°C for 30 min at a pressure of 7.93×10^5 N/m^3 and allowed to cool at 30°C ± 2°C for 24 hours. Result showed that both air temperature and drying time had significant effect on L-, a- and b- values of cashew kernel colour during over the temperature range studied.

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Figure 1: Whole Onion Samples.

Afolabi and Adeniyi [5] mathematically modeled mass transfer during osmotic dehydration of Red Paprika. The drying kinetics was experimental determined using an explicit finite difference (EFD). Experimental condition such as osmotic solution concentration, osmotic process duration at constant osmotic solution temperature were investigated while measured parameters included predicted moisture content, solid contents, the rate of water loss and solid gain. The results showed that the difference equations from EFD predict moisture, solid contents, the rate of water loss and solid gain which were found to be pronounced at the first two hours of the process. Results also confirmed that EFD at the usage of 7 × 90 nodal points and $\frac{\Delta x}{\Delta x^2} \leq 0.5$ for all cases of osmotic conditions was efficient at predicting the process parameter in terms of water loss and solute impregnated.

Kalse *et al.* [6] studied microwave drying of onion slices. The effect of various power levels (0.25, 1.00, 1.50 and 2.25 kW) on mass reduction, water loss and diffusivity were studied. The results showed that the mass reduction and water loss increased with increase in power level. The results also showed that the moisture diffusivity varied in the range of 6.491×10^{-9} to 6.491×10^{-8} m^2/s.

Rzepecka *et al.* [7] studied foam-mat dehydration of tomato paste using microwave energy. A comparative study of foam-mat dehydration of tomato paste by a conventional hot-air method and a microwave energy method were demonstrated. In the investigation, the thickness of the foam 3.17 mm (1/8 inch), 6.35 mm (1/4 inch) and 12.7 mm (1/2 inch) were tested. The drying tests were performed for five forward power setting between 150W and 350W with a 50W increment operated at a frequency of 2,450 MHz. The measured parameter includes drying rate and colour. The results showed that the moisture removal rate was faster at any of the examined levels of microwave power for each of the thickness, than for the hot air dehydration, especially for the samples of thickness 6.35 mm and 12.7 mm the difference was significant. The result also indicated that no lightness-darkness effects for samples dehydrated by microwave power where as maximum power setting at the maximum foam thickness gave slightly lower lightness-darkness effects with the hot air drying.

The demand for onion by the growing population has not been met despite the increase in the production of onion. This is as a result of wastes that come from biological and biochemical activities taking place in this fresh product. Their (coating) protection mechanisms are not well sealed making them more vulnerable to deterioration due to rapid metabolic activities that take place within their cells. These activities causes sprout growth which reduces their quality when not kept under the best storage condition after harvest thereby lower their market value. Onion (moisture content 82% wb) is highly perishable after harvest and cannot be keep more up to 30 days.

Onion is available during the production season but very scarce and expensive during the off-season. This crop contains many nutritional and medical values that are beneficial to human beings to the extent that it should be made available for both industrial and domestic uses all the year round at it nutritional qualities. Drying is the most effective and reliable unit operations of postharvest preservation of onion and other highly perishable fruits and vegetables. Therefore, the main objective of this research work was to investigate the effects of some processing parameters on the drying rate, water loss, solid gain and post-drying quality attributes of onion. The specific objectives are: (i) to investigate the effects of osmotic solution concentration (OSC) as a pre-treatment factor on drying rate, water loss, solid gain and post- drying quality attributes of onion; (ii) to investigate the effects of osmotic solution temperature (OST) as a pre-treatment factor on drying rate, water loss, solid gain and post- drying quality attributes of onion and; (iii) to investigate the effects of osmotic process duration (OPD) as a pre-treatment factor on drying rate, water loss, solid gain and post- drying quality attributes of onion.

Materials and Methods

Experimental equipment

The major equipment used for this study is an experimental dryer which was designed and built prior to this study. Other and materials included matured and firm onions, sensitive weighing balance, water baths (Shell Lab Model and HH-W420, XMTD-204 Model), thermo-hygrometer, desiccators, desiccants, stop watch with alarm, onion slicer, stainless tray, foil wrap, conical flask, measuring cylinder, NaCl and distil water.

As shown in Figures 2 and 3, the dryer consists of heating chamber having three electrical heating coils of 1.8 kW each, connected directly to a centrifugal fan 0.5 hp and drying chamber. The heating coils are connected in series and the whole unit connected to the temperature regulator (0-400°C) which controls the temperature of the heaters. The drying cabinet measures 50 cm long, 50 cm wide and 80 cm high (with external dimension of 56 cm × 56 cm × 86 cm) consisting of three set of trays separated by 15 cm clearance. The drying chamber is double walled insulated with fibre glass with a thickness of 3 cm. The drying trays having an area of 50 cm × 50 cm are made from one inch square pipe with expanded metal having an aperture wide enough to allow free flow of heated air.

The heating chamber is trapezoidal in shape with the length of the side touching the drying chamber 60 cm while the opposite side touching the fan is 20 cm. The length of the chamber is 50 cm in order to accommodate the heating elements. To ensure that the hot air touches all the products simultaneously the heating chamber opened directly into the drying chamber. To avoid moisture condensation at the top of the dryer vents are provided with the aid of two galvanized pipes of four inch diameter. This was achieved by drilling holes of about 5 mm diameter for discharge of moisture laden air and for the placement of the thermo-hygrometer probe.

Experimental design

In order to investigate the effects of the processing parameters on

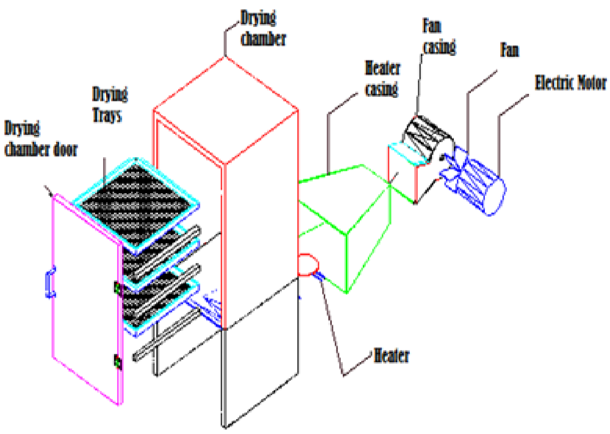

Figure 2: Exploded view of the dryer showing the component parts.

Figure 3: Pictorial view of the dryer showing the temperature regulator.

the drying rate, water loss, solid gain and post-drying quality attributes of onion, a 4 × 4 × 4 factorial experiment under randomized complete block design (RCBD) was used for the study. The design included four levels of osmotic solution concentration (5, 10, 15 and 20 g), four levels of osmotic solution temperature (35, 40, 45 and 50°C) and four levels of osmotic process duration (30, 60, 90 and 120 minutes). All tests were carried out in triplicates making a total of 192 experimental runs that were individually tested and measured.

Experimental procedure

Sample pretreatment: Fresh, mature onions that were healthy and free from mechanical injuries were purchased from Ipata market in Ilorin metropolis and kept in the Agricultural and Bio-systems Engineering Laboratory University of Ilorin to attain room temperature. Samples were weighed using a sensitive weighing balance with an accuracy of 1 g and range 0-5000 g (Figure 4).

Onions were rinsed in clean water at room temperature and cut with onion slicer to a thickness of 3 mm. 50 g of the sample were weighed and immersed in a hypertonic (NaCl) solution of four different concentrations (0.05, 0.10, 0.15 and 0.20 % w/w- mass ratio of fruit to solution was 1:2) for two simultaneous counter-current flows- an exist of water from the product to the solution and a migration of natural solids into the product. The samples were then immersed in a water bath continuously stirred to maintain a uniform temperature not higher than ± 1°C for the four temperature levels (35, 40, 45 and 50°C). Samples were removed from the osmotic solution after 30, 60, 90 and 120 minutes of immersion. All samples were drained, weighed and checked for sample weight, moisture content, and dry solids mass after osmotic dehydration pretreatment.

Drying procedure: The dryer was pre-heated to a temperature of 60°C by the means of temperature regulator while the samples were being prepared to ensure stability of the condition of the drying chamber. After arranging the trays in the dryer, the fan was switched on and set to a velocity of 0.5 m/s using the fan regulator with the speed measured with anemometer. The initial condition of the environment and the drying chamber was recorded immediately after loading. Reduction of masses of samples was noticed (less than 50 g that was introduced for osmotic dehydration). As a result of this, a uniform sample mass of 40 g was used for each sample combination, and properly re-arranged on the drying trays for drying with each experiment carried out in triplicates. The temperature of the exhaust air from the dryer was also measured and recorded. The drying samples were weighed at intervals of 1 h and drying continued until the desirable moisture contentment of 8% (db) was reached.

Output parameters

Drying rate: Drying rate is the quantity of moisture removed from products per unit time during the drying operation. In this study, drying rate was estimated by using equation 1 below:

$$d = \frac{d_m}{d_t} = \frac{m_i - m_f}{t} \qquad (1)$$

Where; d is the drying rate in g/h; d_m is change in mass of onion in g; d_t is change in time in h; t is the total time of drying in h; m_i and m_f are the initial and final mass of onion samples respectively in g.

Mass transfer: Two mass transfer parameters of onion were

Figure 4: Sample of sliced onion before dehydration.

determined during the osmotic dehydration process for each sample using Agarry *et al.* [8] method. The mass transfer parameters determined were water loss and solid gain.

$$WL = \frac{(M_O - m_O) - (M_t - m_t)}{M_0} \quad (2)$$

$$SG = \frac{m_t - m_O}{M_O} \quad (3)$$

Where; WL is the water loss in g/g; SG is the solid gain in g/g; M_0 is the initial weight of fresh onion in g; m_0 is the dry mass of fresh onion in g; M_t is the mass of onion after time t of osmotic treatment in g and m_t is the dry mass of onion after time t of osmotic dehydration pre-treatment in g.

Post-drying qualities: The post-drying qualities of onion were determined at Chemistry Laboratory of the University of Ilorin using the AOAC [9] standards. The post-drying qualities determined included: Vitamin C, Manganese and Iron.

Statistical analysis: The data obtained from the experiments for drying rate, water loss, solid gain and post-drying qualities were subjected to the statistical Analysis of Variance (ANOVA) at 95% confidence level ($p \leq 0.05$) using the SPSS computer software package. Further analysis by Duncan New Multiple Range Test (DNMRT) was used to compare the means among different levels of each experiment factors.

Results and Discussion

ANOVA of process variables on drying rate, water loss, solid gain and post-drying qualities

The result of the statistical analysis of variance (ANOVA) of the data obtained from the experiment is presented in table 1. From the analysis table, it is clear that all the process parameters examined had significant effect drying rate, solid gain and all the post-drying quality parameters except water loss and vitamin C. Osmotic solution concentration was significant on drying rate, solid gain and post drying quality except vitamin C and percent water loss; Osmotic solution temperature was significant on drying rate, solid gain and manganese content; osmotic process duration was not significant on drying rate, water loss but was significant on solid gain and post drying quality except vitamin C and iron; interaction of the process variables were significant on all of the output parameters except vitamin C on which all the process variables and their interactions were not significant, all at $p \leq 0.05$. This implies that osmotic solution concentration, osmotic solution temperature and osmotic process duration had appreciable effects on the drying rate, water loss, solid gain and post drying attributes of onion. Therefore, while drying onion, these factors must be carefully controlled.

Effect of Osmotic solution concentration on drying rate, water loss, solid gain and post-drying qualities

The effect of osmotic solution concentration on drying rate is shown in Figure 5. The figure showed that, osmotic solution concentration had no appreciable effect on drying rate. However, the interaction between the first level of osmotic solution concentration (5% w/w) and second level of osmotic solution temperature (40°C) gave significantly higher mean drying rate. As shown in Figure 6, increase in osmotic solution concentration increased the water loss at first and second levels of osmotic solution temperature and decreased slightly with increasing osmotic solution temperature from 45 to 50°C. Soli gain slightly decreased with increasing osmotic solution temperature form 35 to 50°C (Figure 7) at all levels of osmotic solution concentration.

As indicated by Figure 8, osmotic solution concentration had no appreciable effect on vitamin C. However, the interactive effect between the third level of osmotic solution concentration (15% w/w), and second level of osmotic solution temperature (40°C) gave significantly higher mean vitamin C.

Manganese content increased with increasing osmotic solution concentration for all osmotic solution temperature (Figure 9). As seen from Figure 10, iron content at 20% w/w was higher when compared with that of 5% w/w. However, it is obvious that increase in osmotic solution concentration from 5% w/w to 20% w/w led to increase in iron content.

Effect of osmotic solution temperature on drying rate, water loss, solid gain and post-drying qualities

From table 2, it can be seen that drying rate increased as the osmotic solution temperature increased from 35°C to 40°C. This is in agreement with the finding of past researchers such as Alam *et al.* [3]. Duncan's new multiple range tests (Table 2) showed that all levels of osmotic solution temperature had effect on drying rate (at $p \leq 0.05$). This implies that increase in osmotic solution temperature from 35°C to 40°C showed a progressive increase in drying rate. Water loss increased progressively (though not statistically significant) as the osmotic solution temperature increased from 35°C to 45°C at all level of osmotic solution concentration and osmotic process duration. However, all levels of osmotic solution temperature had effect on water loss ($p \leq 0.05$). This implies that increase in osmotic solution temperature from 35 to 45°C resulted in progressive increase in water loss.

Solid gain decreased with increasing osmotic temperature for all level of osmotic solution concentration and osmotic process duration. Further analysis showed that solid gain between 45°C and 50°C were not significantly different. From the data, the highest solid gain was recorded at 35°C.

	Inputs			Interactions			
Outputs	**A**	**B**	**C**	**A × B**	**A × C**	**B × C**	**A × B × C**
Drying Rate (g/hr)	0.001*	0.001*	0.063	0.001*	0.028*	0.245	0.001*
Water Loss (g/g)	0.548	0.142	0.294	0.001*	0.017*	0.001*	0.001*
Solid Gain (g/g)	0.001*	0.001*	0.038*	0.001*	0.058	0.101	0.006*
Vitamin C (mg/100 g)	0.548	0.142	0.294	0.001*	0.000*	0.001*	0.000*
Manganese (mg/1000 g)	0.027*	0.000*	0.029*	0.005*	0.001*	0.000*	0.000*
Iron (mg/1000 g)	0.002*	0.987	0.057	0.050*	0.024*	0.021*	0.051*

*Significantly different at $p \leq 0.05$

Table 1: Analysis of variance (ANOVA) of the effect of process variables on quantity and post-drying quality of onion: A-osmotic solution concentration; B-osmotic solution temperature; C-Osmotic process duration

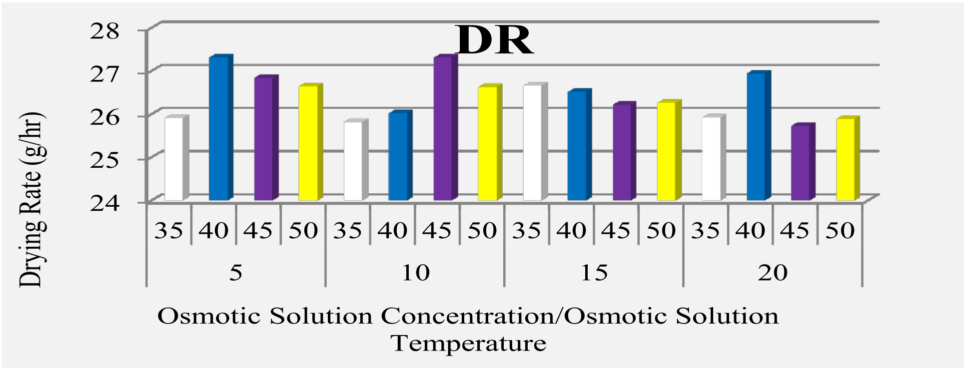

Figure 5: Effect of osmotic solution concentration on drying rate at different osmotic solution temperature.

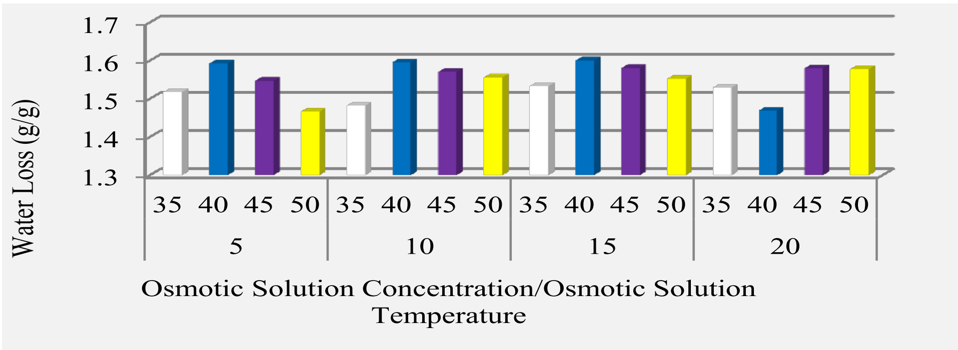

Figure 6: Effect of osmotic solution concentration on water loss at different osmotic solution temperature.

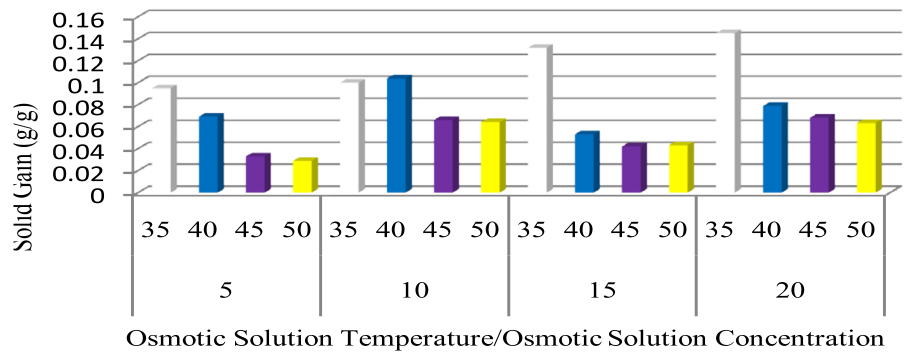

Figure 7: Effect of osmotic solution concentration on solid gain at different osmotic solution temperature.

Vitamin C between 35 and 50°C were not significantly different from each other but values at 50°C level of osmotic solution temperature was found to be the highest. Manganese increased with increasing osmotic solution temperature from 35 to 50°C but values from 40 to 50°C were not significantly different from each other. Iron content was almost the same for all osmotic solution temperature. Values of iron from 35 to 50°C were not significantly different.

Effect of Osmotic process duration on drying rate, water loss, solid gain and post drying qualities

Table 2 showed all the effect of osmotic process duration on drying rate, water loss, solid gain and post-drying qualities of onion. Drying rate increased as osmotic process duration increased from 30 to 60 minutes at different osmotic solution temperature and for all osmotic solution concentration.

Water losses were almost the same for all the process duration and were not significantly different. Values of solid gain were also almost the same for all process duration at different osmotic solution temperature for all osmotic solution concentration. Vitamin C content increased as osmotic process duration increasing from 30 to 90 minutes at different osmotic solution temperature and for all osmotic solution concentration but were not significant different. Manganese and iron

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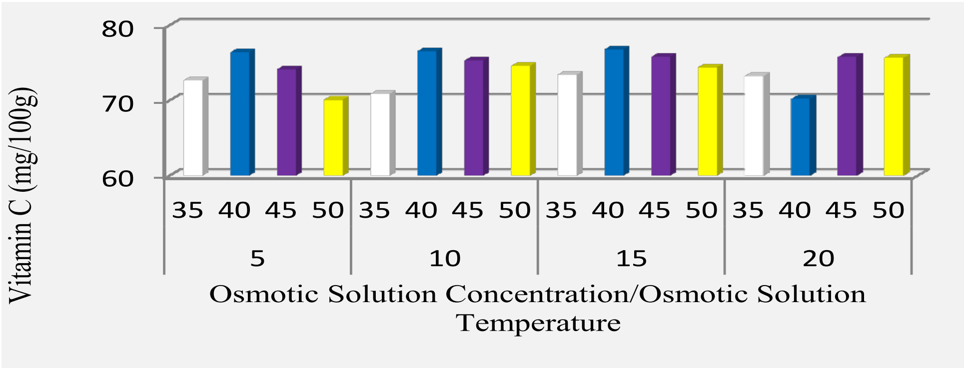

Figure 8: Effect of osmotic solution concentration on vitamin C at different osmotic solution temperature .

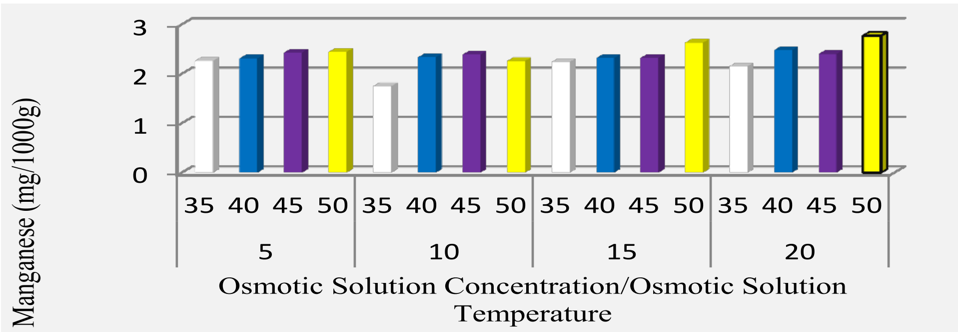

Figure 9: Effect of osmotic solution concentration on manganese at different osmotic solution temperature.

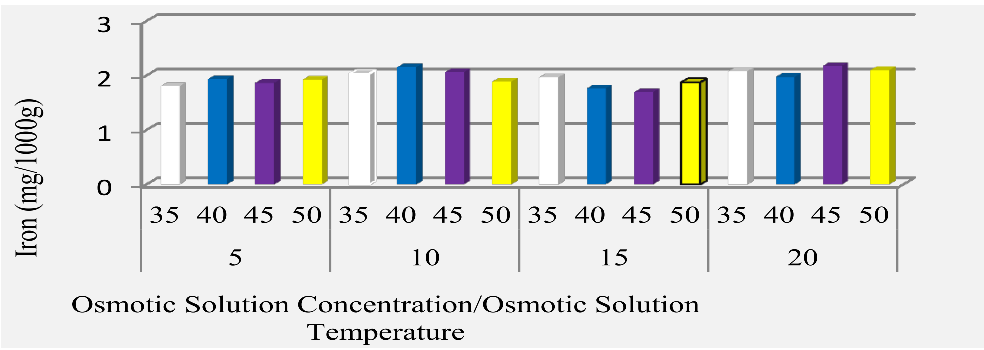

Figure 10: Effect of osmotic solution concentration on iron at different osmotic solution temperature.

content increased with increased in osmotic process duration from 30 to 60 minutes at different osmotic solution temperature and for all osmotic solution concentration.

Conclusion

Osmotic dehydration pretreatments had significant effect on process outputs (drying rate, water loss, solid gain, vitamin C, manganese and iron contents of onion.

Onion dried faster when treated 5% w/w at 50°C osmotic solution temperature for 30 minutes process duration. Vitamin C content can best be preserved in onion by drying at a temperature of 60°C, osmotic solution concentration of 5% w/w, osmotic solution temperature of 40°C and osmotic process duration of 30 minutes. Based on the result of this study, solid gain and iron content in dried onion can be maximized by drying at 60°C after pretreatment with osmotic solution concentration of 20% w/w and osmotic solution temperature of 50°C for 120 minutes process duration. Manganese was higher at drying temperature of 60°C, osmotic solution concentration of 20% w/w and osmotic solution temperature of 50°C for 30 minutes process duration. Further analysis should be carried out on shrinkage, microbial load and rehydration properties of dried onion as related to storage and preservation.

Osmotic Solution Concentration (g/g)	**5**	**10**	**15**	**20**
Drying Rate (g/h)	26.68 ^{a}	26.45 ^{b}	26.41 ^{b}	26.12 ^{c}
Water Loss (g/g)	1.53 ^{a}	1.55 ^{a}	1.57 ^{a}	1.54 ^{a}
Solid Gain (g/g)	0.06 ^{a}	0.08 ^{b}	0.07 ^{a}	0.09 ^{b}
Vitamin C (mg/100 g)	73.33 ^{a}	74.35 ^{a}	75.13 ^{a}	73.75 ^{a}
Manganese (mg/1000 g)	2.36 ^{a}	2.18 ^{b}	2.38 ^{a}	2.45 ^{a}
Iron (mg/1000 g)	1.88 ^{a}	2.03 ^{b}	1.83 ^{a}	2.08 ^{b}
Osmotic Solution Temperature (^{0}C)	**35**	**40**	**45**	**50**
Drying Rate (g/h)	26.08^{a}	26.70^{b}	26.53^{c}	26.36^{c}
Water Loss (g/g)	1.52^{a}	1.56^{a}	1.57^{a}	1.54^{a}
Solid Gain (g/g)	0.12^{a}	0.08^{b}	0.05^{c}	0.05^{c}
Vitamin C (mg/100 g)	72.56^{a}	75.02^{a}	75.28^{a}	73.70^{a}
Manganese (mg/1000 g)	2.10^{a}	2.36^{b}	2.39^{b}	2.53^{b}
Iron (mg/1000 g)	1.97^{a}	1.96^{a}	1.95^{a}	1.95^{a}
Osmotic Process Duration (min)	**30**	**60**	**90**	**120**
Drying Rate (g/h)	26.58^{a}	26.31^{b}	26.46^{a}	26.31^{b}
Water Loss (g/g)	1.54^{a}	1.53^{a}	1.57^{a}	1.55^{a}
Solid Gain (g/g)	0.07^{a}	0.08^{b}	0.07^{a}	0.07^{a}
Vitamin C (mg/100 g)	73.61^{a}	73.06^{a}	75.43^{a}	74.46^{a}
Manganese (mg/1000 g)	2.22^{a}	2.36^{a}	2.32^{a}	2.49^{b}
Iron (mg/1000 g)	1.98^{a}	2.02^{a}	1.83^{b}	1.99^{a}

*Means with the same letter are not significantly different but means with different letters are significantly different (at $p \leq 0.05$).

Table 2: Duncan's Multiple Range Test (DNMRT) for the effect of process conditions on drying rate, water loss, solid gain and post drying qualities of onion.

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