Application of response surface methodology (RSM) to osmotic dehydration and drying of green bell peppers

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Summary

A study to investigate the effect of osmotic solution concentrations of common salt (5%(w/w), 10%(w/w), 15%(w/w), 20%(w/w) and 25%(w/w)) and osmotic process durations (60 min, 90 min, 120 min, 150 min and 180 min) at average room temperature of 31 °C on the drying rate and nutritional qualities (vitamin C, crude protein, crude fibre, fat and ash content) of green bell peppers was conducted. Response Surface Methodology (RSM) under central composite design in Design Expert 8.0.3 computer software package was used to design the experiment, analyze data, and present all results with 3-dimensional plots. The temperature of 50 °C was used to dry all the pre-treated samples to the moisture content of about 7% (wb) in a fabricated cabinet dryer. The results showed that an increase in osmotic solution concentration and osmotic process duration caused the drying rate to drop to about 18g/h, then later increase to more than 21g/h; vitamin C did not reduce below 50mg/100g; crude protein increased but later reduced, however the range of about 18-20.5% was obtained; crude fibre increased to about 4.8% but later reduced to about 4.6%; also, fat decreased but later increased to a maximum value of about 16.5%. The increase in osmotic solution concentration kept the ash content at a steady value of about 4.01%, but the increase in osmotic process duration led to a very sharp increase in ash content from 4.01% to 4.25%. All drying rate (15.53g/h) and nutrients values obtained were better than the control value, that is, an untreated dried sample (vitamin C (46.02 mg/100g), crude protein (17.40%), crude fibre (4.16%), fat (11.42%), ash content (4.01%). This further confirmed that osmotic dehydration is a quality improving pre-treatment method.

Keywords: Response Surface Methodology (RSM), osmotic dehydration, green bell pepper, drying, nutritional qualities

Introduction

Green bell pepper is a perishable vegetable crop that belongs to the family *Solanaceae* and genus *Capsicum*. It contains vitamin C, vitamin A, vitamins Bs, vitamin K, vitamin E, magnesium, manganese, potassium, fibre, low calories, folate, protein, and carbohydrate (GMF, 2008). Green bell pepper can cure cataracts, rheumatism, fever, cold, diabetes, sores and bruises, arthritis, and cancer. It also has the potency to keep the body cholesterol level under control, and promotes stimulation of stomach secretion, thereby leading to the improvement of food digestion (www.fruitsinfo.com and GMF, 2008).
For the crop to grow well and to produce a yield of up to 15 ton/ha, the soil must be moist, but not water logged, and the temperature should be in the range of 21-29 °C; rainfall condition should be in the range of 600 to 1250 mm, intercrop and inter-row spacing should be from 45.72 cm to about 86.40 cm, respectively (GardenersGarden.com and FAO, 2013).

Green bell pepper, just like other green plants, uses photosynthesis to manufacture its food and this is most efficient when attached to the parent plant. However, after harvesting, it may not be able to continue this process because it would have used up its stored food meant for maintaining physiological constancy. Hence, decay and deterioration sets in, this situation would lead to serious post-harvest losses if not checked early. Some of the ways of reducing post-harvest losses are drying, effective pre-treatment before further processing, and storage. However, it was reported that green bell pepper would not be able to maintain its maximum natural nutritional contents beyond 10 days in refrigerated storage (Moody, 1985).
Subjecting fruits and vegetables to pre-treatment before drying is a method of enhancing the drying operation and improving qualities. One of the promising pre-treatment methods is osmotic dehydration. Osmotic dehydration is the partial removal of water from cellular materials when placed in a hypertonic solution (Singh et al., 2006) of salt, sugar, or their combinations. This

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method of pre-treatment is a mass transfer process and its phenomenon was explained by Tiwari (2005) and Karthiayani (2004). Some of the advantages of osmotic dehydration include the improvement of texture and the rehydration properties of food, retention of colour, flavour, and organoleptic properties of food, amongst others (Chavan and Amarowicz, 2012). Odewole and Olaniyan (2016) reported that osmotic solution concentration, osmotic process duration, osmotic solution temperature, and the type of osmotic solution were some of the factors influencing the osmotic dehydration process. Chavan and Amarowicz (2012), Odewole and Olaniyan (2016), Odewole et al. (2014), Tiwari (2004), Karthiayani (2004), Fasogbon et al. (2013), Porhartar and Prasad (1998), Phisut et al. (2013) are some of the researchers that had worked on osmotic dehydration and their results confirmed the advantages of osmotic dehydration. Azoubel and Murr (2004) effectively achieved osmotic dehydration of a cherry tomato at room temperature of 25 °C.

Drying is one of the oldest methods of reducing post-harvest losses. It is a simultaneous heat and mass transfer process leading to the removal of enough, or a pre-determined amount, of moisture from food and crops, with the aim of preventing decay and spoilage. It also leads to saving storage space and reducing transportation and storage costs, as a result of the reduction in the volume of the product. It is a means of ensuring all year round availability of nutrients found in fruits and vegetables for human consumption Kiremire (2010). Drying usually leads to the concentration of essential nutrients in food and crops after removal of moisture, therefore a safe temperature, that would reasonably retain the nutritional qualities of products, must be used for drying. Idah et al. (2012), Mu’azu et al. (2012), Awogbemi and Ogunleye (2009), and Phisut et al. (2012) suggested that the best temperature range for drying fruit and vegetables should be between 35 °C and 75 °C.

In the fields of Science, Engineering, and Technology, experiments are not conducted haphazardly, but are rather designed and analyzed in systematic ways that would lead to getting reliable data and results that could be used for making sound decisions. Some conventional experimental designs include the Randomized Complete Block Design, Completely Randomized Design (CRD), Latin Square Design, Split Plot Designs, and so on. The principles governing their use are explained in Oyejola (2003). One of the recent, or probably an emerging method of designing experiments is the use of a specialized statistical computer software package like Design Expert. This package has various categories; some of those are Response Surface Methodology (RSM), Taguchi Orthogonal Design, Box-Behnken, and many others. The suitability of the type of design to be selected is usually based on the study objective. Singh et al. (2006) and Dehkordi (2010) used RSM in the study of osmotic dehydration and drying of carrots and edible button mushrooms, respectively.

Olaniyan and Omoleyomi (2013), Odewole et al. (2014), Odewole and Olaniyan (2016), Alabi et al. (2016), and many other authors have worked on osmotic dehydration and drying of food materials, with the aim of studying the effects of process conditions on outputs, up to the stage of modelling and optimizing the process for industrial applications. The conventional/traditional experimental design and analysis techniques were used. This technique is time consuming, it usually involves the use of more experimental materials which could lead to wastage (post-harvest loss) of materials; it could also be expensive because of the many experimental runs that need to be analyzed before and after processing. In addition, in locations where energy for processing is not readily available, and is more expensive when available, the results of the economic analysis of the processes may not be desirable. The use of a better approach, that would offset the aforementioned problems in designing the experiment for carrying out the processing operation of green bell peppers in terms of osmotic dehydration and drying, is a good and viable alternative. Therefore, the objective of this study was to use Response Surface Methodology (RSM) to investigate the effect of osmotic process duration and osmotic solution concentration on the drying rate and some nutritional qualities (vitamin C, crude protein, crude fibre, fat, and ash content) of osmo-pre-treated dried green bell peppers.

Materials and methods

Experimental equipment and materials

The equipment used for the study was: a laboratory oven, a fabricated cabinet dryer, an electronic weighing balance, a stop watch, a desiccator, containers for osmotic dehydration pre-treatment, stainless steel tray and knife, foil paper, a spatula, hand gloves. Common salt, distilled water, fresh green bell pepper.

Experimental design

Design Expert 8.03 version computer software was used to design the experiment. Response Surface Methodology under Central Composite Design was used. Five levels of osmotic solution concentrations of common salt (5%(w/w), 10%(w/w), 15%(w/w), 20%(w/w), and 25%(w/w)) and five levels of osmotic process duration (60 min, 90 min, 120 min, 150 min, and 180 min) were substituted into the experimental design interface of the software. In order to get the real values of all the levels of process conditions as whole numbers, the alpha value of 0.5 was selected against the default value of 1.4142. The result of the design provided 13 interactions that captured all the levels of process conditions, and replications were put into consideration. (Note that if the conventional/ traditional experimental design techniques were used, the result would not be less than 75 runs).

Experimental procedure

Fresh green bell peppers were procured from a commodity market in Ilorin, Kwara state, Nigeria early in the morning. They were graded in order to get better quality for the experiment. Other procedures are in Odewole and Olaniyan (2016). 100 g of sliced green bell peppers was introduced into the osmotic solution for each pre-treatment combination at average ambient temperature of 26 °C. At the end of the pre-treatment, a non-uniform mass of between 76-82 g was achieved. For the drying operation, 75 g of pre-treated product was introduced into the dryer for each pre-treatment combination. The temperature of 50 °C was maintained throughout the period of drying using a temperature regulator on the dryer. The hourly loss of mass for each sample was measured with the use of the electronic weighing balance; this was done until the end of drying, which lasted for about 4 hours. After drying to average moisture content of about 7%(wb), all the dried samples were arranged inside the desiccator and were later taken for nutritional analysis. The experiment was performed at the Processing and Storage Laboratory of the Department of Agricultural and Biosystems Engineering, University of Ilorin, Ilorin, Nigeria, in June 2016. The average room temperature was around 31 °C and relative humidity was about 65% throughout the period of the experiment.

Output parameters

Drying rates were estimated using the equation in Odewole and Olaniyan (2016). Nutritional qualities, in terms of vitamin C, crude protein, crude fibre, fat, and ash content, were determined using the AOAC (2002) standard.

Data analysis

All the output data obtained was introduced back into the experimental table designed earlier with the Design Expert computer software package. The data was analyzed following the stipulated procedures of the software for RSM, in order to get the 3-dimensional (3-D) plots that relate the two process conditions with each of the output parameters.

Results and discussion

The effect of osmotic solution concentration (%w/w) and osmotic process duration (min) on the drying rate (g/h.) of osmo-pre-treated dried green bell peppers

The effect of the process conditions on the drying rate (g/h) of osmo-pre-treated dried green bell peppers is shown in Fig. 1. The 3-dimensional plot presents a kite-like pattern. From the figure, it means that the increase in osmotic solution concentration from 5% (w/w) to 25% (w/w) caused the drying rate to drop progressively from 22g/h to slightly above 18 g/h. For osmotic process duration, the increase in pre-treatment time caused the drying rate to be around 21 g/h. The reason for this observation could be due to one the advantages of osmotic dehydration, which is the partial removal of water from cellular materials (Singh et al., 2006). This would lead to the presence of less moisture in the pre-treated products, and hence, a gradual reduction in the drying rate as the osmotic dehydration process continues. This observation is also in agreement with the results obtained from osmotic dehydration and drying of red bell peppers, okra, and onions, respectively (Odewole and Olaniyan, 2016; Olaniyan and Omoleyomi, 2013; and Alabi et al., 2016).

The effect of osmotic solution concentration (%w/w) and osmotic process duration (min) on the vitamin C (mg/100g) content of osmo-pre-treated dried green bell peppers

Fig. 2 shows the effect of the process conditions on the vitamin C content of the dried product. The 3-dimensional plot presents a pattern that looks like a slightly sloppy channel. The inference from this is that the increase in osmotic solution concentration caused the vitamin C content to maintain a value that is not less than 51.8 mg/100g. However, increasing the values of osmotic process duration first caused the vitamin C content to drop from 51.9 mg/100g to less than 51.5mg/100g, but a short rise in value to slightly above 51.6 mg/100g was later achieved. The cause of the slight drop in vitamin C content could be the side effect of the heat on vitamin C during drying at 50 °C, since vitamin C is a heat sensitive nutrient, and another cause may be the possible leaching of nutrients into the solution during osmotic dehydration (Tiwari, 2005 and Karthiayani, 2004). In addition, the retention of vitamin C content with values close to the fresh sample (56.81 mg/100g) was obtained for the control sample, but a reduction in value (46.02 mg/100g) was also recorded. This is a confirmation that osmotic dehydration pre-treatment is a quality improving pre-treatment method for food before drying (Chavan and Amarowicz, 2012 and Pokharkar and Prasad, 1998). Famurewa et al. (2006) and Odewole and Olaniyan (2016) got vitamin C values in the range of 120 mg/100g – 125 mg/100g for red bell peppers after osmotic dehydration and drying.

The effect of osmotic solution concentration (%w/w) and osmotic process duration (min) on the crude protein content (%) of osmo-pre-treated dried green bell peppers

Fig. 3 illustrates the effect of the process conditions on the crude protein content of osmo-pre-treated dried green bell peppers. The increase in process conditions caused the crude protein to form an undulating pattern on the 3-dimensional plot. This implies that crude protein increased at some points and later decreased at other points. The lowest value is below 18.5% and the highest value is greater than 20.5%, but not as high as 21%. This observation could be due to the level of maturity, physiological variations, and other inherent characteristics of fresh green bell peppers during and after processing, which will most likely affect the initial and final nutrient levels (Chavan and Amarowicz, 2012 and Odewole and Olaniyan, 2016).

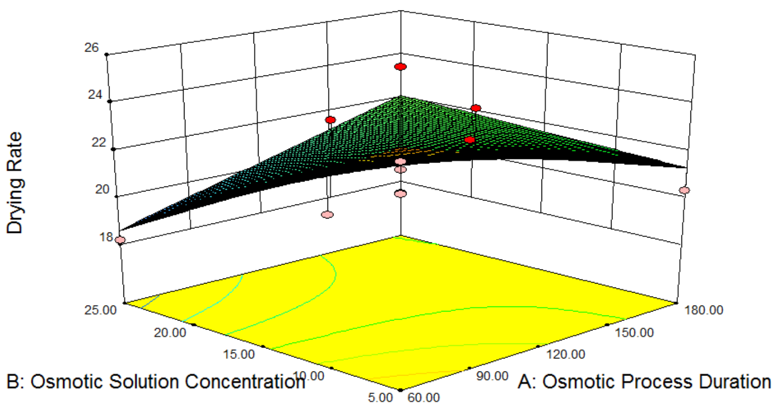

Fig. 1. The effect of the process conditions on the drying rate of osmo-pre-treated dried green bell peppers

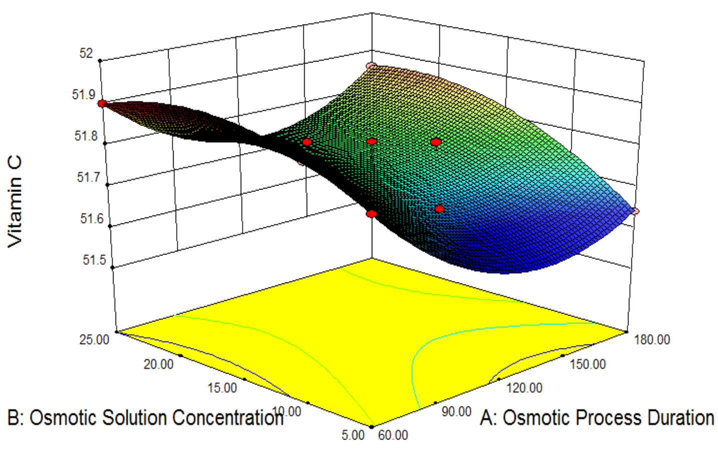

Fig. 2. The effect of the process conditions on the vitamin C content of osmo-pre-treated dried green bell peppers

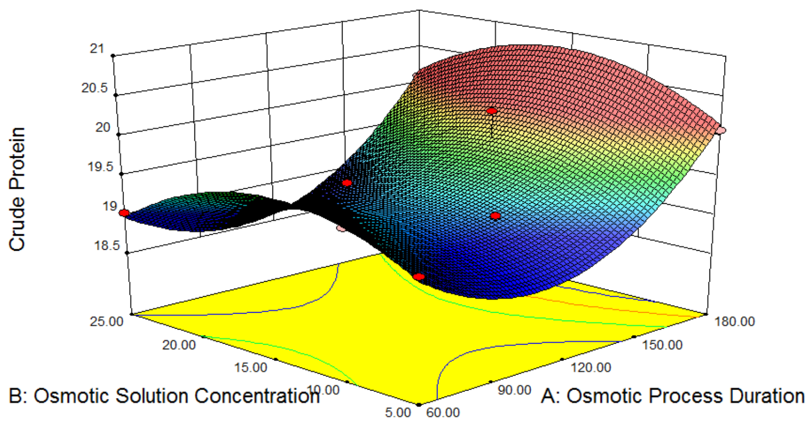

Fig. 3. The effect of the process conditions on the crude protein content of osmo-pre-treated dried green bell peppers

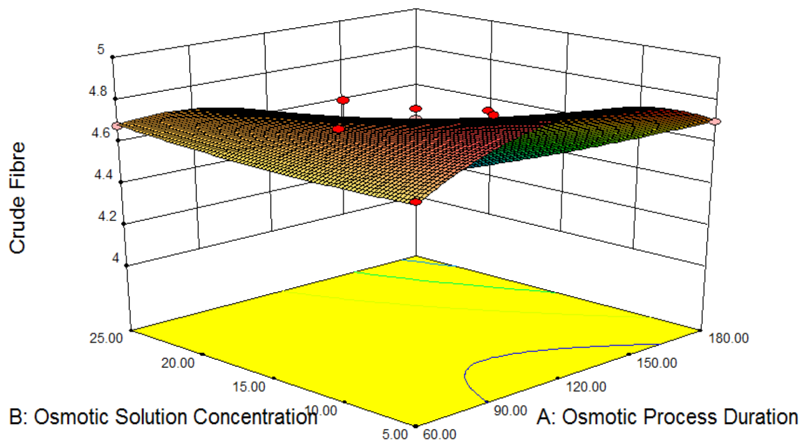

Fig. 4. The effect of the process conditions on the crude fibre content of osmo-pre-treated dried green bell peppers

The effect of osmotic solution concentration (%w/w) and osmotic process duration (min) on the crude fibre content (%) of osmo-pre-treated dried green bell peppers

The effect of the process conditions on the crude fibre content of processed products is shown in Fig. 4. The 3-dimensional plot shows an upside down parabola with gentle slopes at both sides. The implication of this is that the increase in process conditions caused the crude fibre content to increase to a maximum value (close to 4.8%) at a particular point (around 120 min), but to later reduce steadily to slightly above 4.6% at the end of the pre-treatment time of 180 min. This observation could be due to the fact that fibre can either be soluble or insoluble in water. This means that the crude fibre in the green pepper used might be more the insoluble type, which made the end result close to the value of crude fibre content in fresh samples. Taheri-Garavand et al. (2011) reported 1.70 g per 100 g of total dietary fibre for green bell peppers.

The effect of osmotic solution concentration (%w/w) and osmotic process duration (min) on the fat content (%) of osmo-pre-treated dried green bell peppers

Fig. 5 presents the effect of the process conditions on the fat content of processed products. The 3-dimensional plot shows an upside down parabolic pattern with sharp slopes at both sides and compressed in the middle. The interpretation is that the increase in osmotic solution concentration reduced the fat content to a point (15 % (w/w)) and later increased it steadily up to the last concentration (25 % (w/w)) of about 12.5%. On the other hand, the increase in osmotic process duration caused the fat content to increase to a point and later drop down to the highest value of the 180 min pre-treatment. The lowest and highest values of the fat content are about 9% and 16.5%, respectively. Fat is not naturally soluble in water, so it is expected that the leaching effect during osmotic dehydration reported by Tiwari (2005) and Karthiayani (2004) is not likely to cause the negative effect on the fat content, but it could be the factor responsible for the increment at some points due to the outward movement of water and other water soluble nutrients, thus leading to the availability of more water insoluble nutrients like fat. However, heat treatment during drying after osmotic dehydration could likely be the cause of the drop in value of fat content.

The effect of osmotic solution concentration (%w/w) and osmotic process duration (min) on the ash content (%) of osmo-pre-treated dried green bell peppers

The effect of the process conditions on the ash content of processed products is presented in Fig. 6. The 3-dimensional plot displays an inclined plane pattern. This means the ash content maintained a constant value of about 4.01% with the increase in osmotic solution concentration from 5% (w/w) to 25% (w/w). However, the increase in osmotic process duration led to a sharp increase in ash content from 4.01% to about 4.25%. The increase in osmotic solution concentration did not have a significant effect on the ash content, but the increase in osmotic process duration caused a sharp rise in ash content. Furthermore, it could be said that the increase in osmotic process duration led to the liberation of more ash content during processing, since some parts of the ash content of food are soluble in water. The highest value of ash content obtained in this study is below more than 8% obtained by Odewole and Olaniyan (2016) for the osmotic dehydration and drying of red bell peppers.

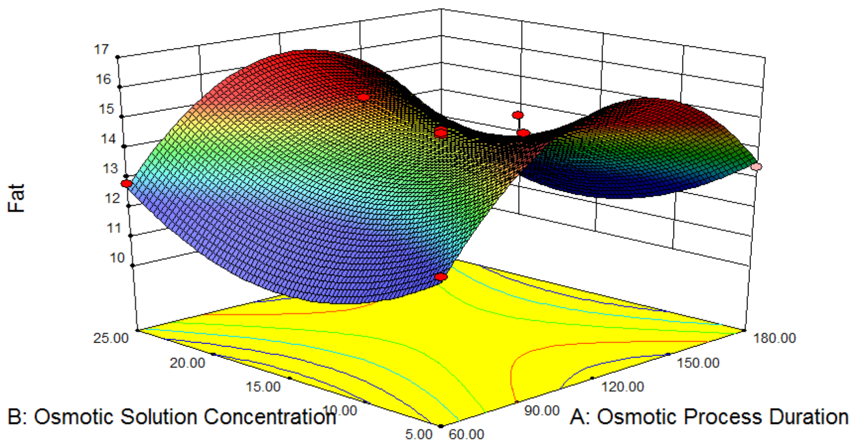

Fig. 5. The effect of the process conditions on the fat content of osmo-pre-treated dried green bell peppers

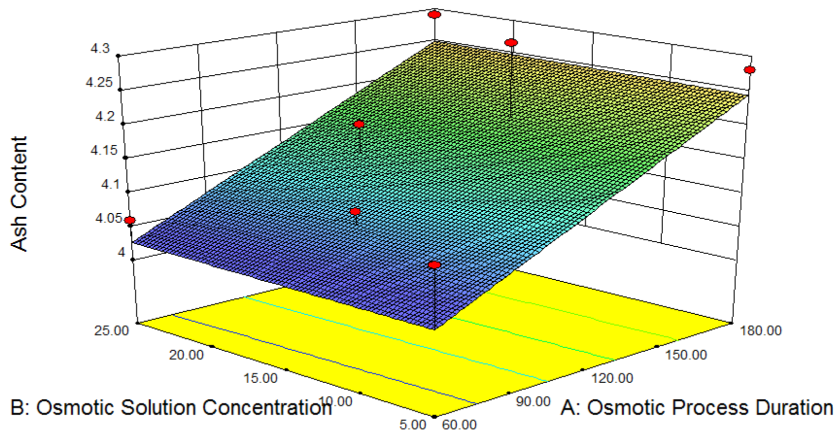

Fig. 6. The effect of the process conditions on the crude protein content of osmo-pre-treated dried green bell peppers

Conclusions

The 3-dimensuonal plots from RSM clearly showed, in terms of the highly illustrative patterns displayed, that osmotic solution concentration and osmotic process duration, coupled with drying, imposed different effects on the drying rate, vitamin C, crude protein, crude fibre, fat, and ash content of osmo-pre-treated dried green bell peppers. The increase in osmotic solution concentration and osmotic process duration caused the drying rate to drop to about 18 g/h, then later increase to more than 21 g/h; the vitamin C content did not reduce below 50 mg/100 g; the crude protein content increased but later reduced, however, about the 18-20.5% range was obtained; the crude fibre content increased to about 4.8% but later reduced to about 4.6%; also, the fat content decreased but later increased to a maximum value of about 16.5%. The increase in osmotic solution concentration kept the ash content steady at 4.01%, but the increase in osmotic process duration led to a very sharp increase in ash content from 4.01% to 4.25%. All values of the drying rate (15.53 g/h) and the nutrients obtained were better than the control value, that is, the untreated dried sample (vitamin C (46.02 mg/100 g), crude protein (17.40%), crude fibre (4.16%), fat (11.42%), and ash content (4.01%)). This further confirmed that osmotic dehydration is a quality improving pre-treatment method. Further study should be done on modelling and optimising the process.

References

Alabi, K. P., Olaniyan, A. M., Odewole, M. M. (2016): Characteristics of Onion under different Process Pretreatments and Drying Conditions. *J. Food Process. Technol.* 7 (2), 1000555. https://doi.org/10.4172/2157-7110.1000555.

AOAC, (2002): Official Methods of Analysis. Association of Official Analytical Chemists, Washington D.C.

Awogbemi, O., Ogunleye, I. O. (2009): Effects of Drying on the Qualities of some Selected Vegetables. *Int. J. Eng. Technol*. 1 (5), 409-414.

Azoubel, P. M. Murr, F. E. X. (2004): Mass Transfer Kinetics of Osmotic Dehydration of Cherry Tomato. *J.Food Eng.* 61 (1), 291-295. https://doi.org/10.1016/S0260-8774(03)00132-8.

Chavan, U. D., Amarowicz, R. (2012): Osmotic Dehydration Process for Preservation of Fruits and Vegetables. *J. Food Researc.* 1 (2), 202-209. https://doi.org/10.5539/jfr.v1n2p202.

Dehkordi, B. M. (2010): Optimization of the Process of Osmo-Convective Drying of Edible Button Mushrooms using Response Surface Methodology (RSM). *World Acad. Sci. Eng. Technol.* 37, 1014-1018.

Famurewa, J. A. V., Oluwamukomi, M. O., Adenuga, A. L. (2006): Dehydration of Osmosised Red Bell Pepper (*Capsicum annum*). *J. Biol. Sci*. 1 (1), 36-39.

FAO (2013). Faostat Database. Available from faostat.fao.org. Date accessed: April, 2013.

Fasogbon, B. M., Gbadamosi, S. O., Taiwo, K. A. (2013): Studies on the Osmotic Dehydration and Rehydration Characteristics of Pineapple Slices. *J. Food Proc. Technol*. 4 (220), 1-8. https://doi.org/10.4172/2157-7110.1000220.

GardenersGardening.com. Accessed on 10th January 2013.

GMF (George Metaljan Foundation) (2008). Bell Peppers - World Healthiest Foods. . Accessed on 4th March, 2013.

Idah, P. A., Musa, J. J., Olaleye, S. T. (2011): Effect of Temperature and Drying Time on some Nutritional Quality Parameters of Dried Tomatoes. *AUJT*. 14 (1), 25-32.

Karthiayani, A. (2004): Osmotic Dehydration of Fruits and Vegetables with Special Reference to Vacuum Treatment. *Food and Pack.* 39, 82-84.

Kiremire, B. T., Musinguzi, E., Kikafunda, J. K., Lukwago, F. B. (2010): Effects of Vegetable Drying Techniques on Nutrient Content: A Case Study of South Western Uganda. *AJFAND.* 10 (5), 2587-2600.

Moody, B. (1985). Drying Vegetable Part 1. www,dryit.com/drying. Accessed on 3rd April 2013.

Mu'azu, K., Bugaje, I. M., Mohammed, I. A. (2012): Performance Evaluation of Forced Air Convection Vegetable Drying System. *JBASR*. 2 (3), 2562-2568.

Odewole, M. M., Olaniyan, A. M. (2016): Effect of Osmotic Dehydration Pretreatments on Drying Rate and Post-Drying Quality Attributes of Red Bell Pepper(Capsicum annuum). *Agric. Eng. Int. CIGR.* 18 (1), 226-235.

Odewole, M. M., Olaniyan, A. M., Olalekan, L. A. (2014): Effect of Osmotic Dehydration Pretreatments and Drying Temperatures on Drying Rate and Quality of Mango Chips. *JAET*. 22 (3), 21-34.

Olaniyan, A. M., Omoleyomi, B. D. (2013): Characteristics of Okra under Different Process Pretreatments and Different Drying Conditions. *J. Food Proc. Technol*. 4 (6), 1-6. https://doi.org/10.4172/2157-7110.1000237.

Oyejola, B. A. (2003). Design and Analysis of Experiments for Biology and Agriculture Students. Olad Publishers, Ilorin, Nigeria, pp 1-139.

Phisut, N. (2012): Factors Affecting Mass Transfer during Osmotic Dehydration of Fruits. *Int. Food Res. J.* 19 (1), 7-18.

Pokharkar S. M., Prasad, S. (1998): Mass Transfer during Osmotic Dehydration of Banana Slices. *Journal Food Sci. Technol*. 35 (4), 336-338.

Singh, B., Panesar, P. S., Nanda, V., Gupta, A. K., Kennedy, J. F. (2006): Application of Response Surface Methodology for the Osmotic Dehydration of Carrots. *J. Food Process. Eng.* 29, 592-614.

Taheri-Garavand, A., Rafiee, S., Keyhani, A. (2011): Study on Effective Moisture Diffusivity, Activation Energy and Mathematical Modelling of Thin Layer Drying Kinetics of Bell Pepper. *AJCS.* 5 (2), 128-131.

Tiwari R. B. (2005): Application of Osmo Air Dehydration for Processing of Tropical Fruits in Rural Areas. *Indian J. Food Ind.* 24 (6**)**, 62-69.

www.fruitsinfo.com. Accessed on 4th April, 2013.

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