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Application of Dehumidification as supplementary treatment for Osmotic Dehydrated Fruits and Vegetables.

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ABSTRACT:
The phenomenon of osmotic dehydration of fruits and vegetables had been popular and accepted for its numerous advantages which include retained organoleptic properties but products are not shelf-stable. Further dehydration at low-temperature dehumidification were conducted in a fabricated equipment using sliced pawpaw (Carica papaya L) as fruit sample. The samples were dimensioned into 2cm in width by 20 cm in length and were treated at optimal conditions of 50°C temperature, 60 °Brix sucrose concentration for 3 hours of immersion in a pilot-scale plant. The osmotically treated samples were further treated conventionally in a fabricated equipment with and without a de-humidification Chamber application. The equipment was operated at 60 °C until consistent weights of samples were achieved. The effect of dehumidification revealed appearances of samples without dehumidifier were golden browns in colour and the textures crispy while the dehumidified sample retained golden yellow and was leathery to touch. The Physico-chemical analysis of the processed samples revealed retention of nutritional properties. Dehumidification reduced the water content in the samples at a faster rate to attain constant weight at about 400 hrs when compared with 550 hrs of treatment without dehumidification to attain relatively constant weights that is suitable for storage and packaging of treated samples.

Keywords: Dehydrator, dehumidifier, organoleptic, physicochemical. Shelf-stable.

I. INTRODUCTION:

Fruits and vegetables are sources of nutrients such as vitamins and minerals with potential health benefits capable of preventing several chronic diseases in humans and animals. Fruits are highly perishable due to enzymatic and non-enzymatic reactions taking place during the maturation period by senescence and further storage. They are important sources of digestible and indigestible minerals, carbohydrates and certain vitamins, particularly vitamins A and C (Moazzam. 2012). Fruits and vegetables generally have high water content in the range of 75 to 95% water and pH ranging from 2.5 to 4.5 (Torres et al., 2006). Hence, fruits are prone to putrefaction and attacks by microbial activities which thus affect their respective nutritional, sensorial and physicochemical properties with reduced shelf life. The fruit processing industry in Nigeria is utilizing less than 20% of the produce annually and about 35-40% of fruits and vegetables are lost due to improper post-harvest handling (FMA, 2013). These result in losses of about 45% of gross production and some of the farm produce becomes invariably wasted with attendant environmental menace.

Fruit processing is very important for minimising post-harvest losses and improving the symbiotic linkages between industries and agricultural produce. Some of these agricultural products especially fruits and vegetables are processed into purée, fruit juices, kinds of ketchup and others as intermediate raw materials for the industries. However, as soon as the season is over, supply outage sets in and this no doubt affect adversely industrial production outfits. Although processing is considered an important tool to limit degradative reactions, some vitamins and minerals may however be lost in the due course. Several processing methods have been explored for modified high-quality products with extended shelf life. Dried un-cooked samples of fruits especially pawpaw was found to have the highest mineral content compared with the raw and dried cooked samples (Okon et al., 2017)

Osmotic dehydration (OD) refers to the partial removal of water through the mechanism of osmosis in which the water content of fruits and vegetables is immersed in a hypertonic solution of soluble solutes like sugars or salts in cases of vegetables have partial dehydration and solute uptake occur simultaneously. Movement of solutes from solution into food material and outflow of water from the material into solution depends on the osmotic pressure imposed by the solution concentration across the food material, leaching of water-soluble components from fruits such as minerals, vitamins and organic acids may be extensive (Chandra and Kumari, 2015; Yadav and Singh, 2014). The efficacy of the phenomenon is influenced by many factors but of utmost importance are solution concentration, period or time of immersion and the processing temperature (Duduyemi et al, 2018). This process received considerable attention over the years and its application to fruits and vegetables on bench-scale product analysis is enormous. The benefits of the OD process are reported to retain the organoleptic properties and extended the shelf life of the products. The product requires further drying to be shelf-stable, pre-treatment with OD decreased the overall energy required to dehydrate it to about 10 to 15 % when it would be shelf-stable or storable. However, restriction from high-temperature treatment was reported, to prevent the denaturation of the vital contents and help improve the sensorial, nutritional and organoleptic properties of foods (Khan, 2012)

Sun drying is a natural method commonly used for drying and reducing the water level of agro-produce to extend the shelf life and reduce postharvest losses. However, high temperatures or long drying times negatively affect the quality of the dried products, particularly in terms of flavour, colour, texture, nutrients and rehydration capacity (Drouzas et al., 1999). Vitamin C and carotenoids are the most sensitive compounds that when exposed to heat during the drying processes may be affected (Arun and Sachin, 2011; Kong and Singh, 2013.Rekha et al. [6]). There are various drying techniques to improve the quality of dried products, they include; Conventional dryers ,Heat pump dryers Superheated steam Impinging stream dryers. Use of renewable energies (Solar and Wind).Since all renewable energy sources are intermittent it is necessary to provide backup heat or heat storage using possibly phase change material (PCM) heat store exchangers. Multi-stage drying is a highly accepted way of enhancing drying performance

Although, a large number of studies on osmotic dehydration have been published considering osmotic dehydration and convective drying (Kaushal and Sharma , 2016; El-Ishaq and Obirinakem, S. 2015). Few studies have focused on changes that betide the physical and organoleptic properties of samples as a result of the processing techniques. . This drying system incorporates a dehumidified cycle, where condensation of water allows the removal of water from the closed system of drying air circulation. The effect of de-humification on the organoleptic properties of optimally Osmo-dehydrated papaya fruits in a fabricated pilot plant was investigated using the hybrid model of dehydration.

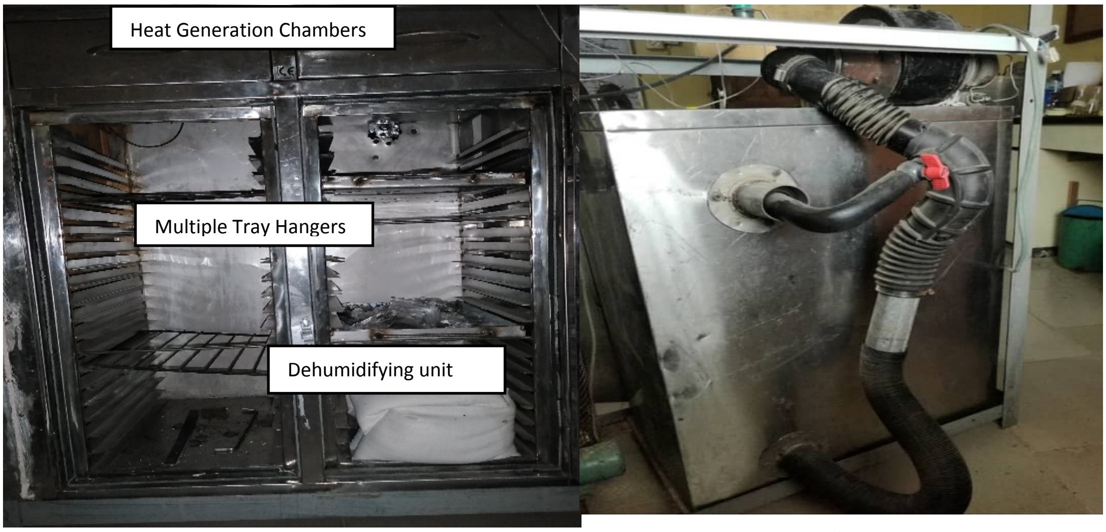
II. MATERIALS AND METHODS

Freshly harvested Pawpaw (Carica papaya L.) fruits were obtained from a local farmer in the Epe Local government area of Lagos State, Nigeria. Laboratory grade Granulated Sugar was purchased from a local store. Hypertonic sucrose solutions were prepared with distilled water to obtain the required concentration of 60 °Brix. The sucrose concentrations were measured with a Refractometer, Conventional Oven (Genlab LTD, Model MINO/50), Spectrophotometer for product analysis and a customized versatile pilot-scale plant (Hybrid Osmodehydration/dehumidifying dryer).

2.1 Description of Hybrid Osmotic Dehydrator

The hybrid dehydrator consisted of osmotic dehydration compartments and a cabinet dehydratorchamber,both are constructed of stainless steel. The OD section is equipped with a pump for agitation and re-circulation of spent liquor, An A-C power source was connected to powerthe electric motor for the blower, Heaters, the pump and voltage regulator to control the air velocity. Other materials of construction for the pilot plant include three plastic or galvanised tanks, a mixer, piping, supporting framework, electrical accessories and a control panel for monitoring processing conditions.The pilot plant was designed to operate at a regulated temperature, air velocity, liquid flow rate, and re-concentration mechanism with PID controllers.

The Cabinet Dehydrator section was constructed to provide means of experimentally evaluating the effect of varying temperature and air velocity concerning the time of operation. The equipment has a heating plate with a blower attached at the top to conventionally transfer the heat flux from the heating device onto the trays where the samples were positioned. Dehumidifying Hot-Air Compartment had discrete bags of Silica piled in the chamber to absorb water from humidified air conventionally blown from the sample. The trays are well perforated to allow free flow of air across the trays. The pictorial view of the equipment is shown in Figure 1.



(1a) (1b)

Fig: 1. Anterior (a) and posterior (b) view of the customized Dehumidifier

2.3 Sample and Osmotic Agent Preparation

The Pawpaw (Carica Papaya) obtained were firm and adequately ripe. The fruit was washed, peeled, deseeded, cut into uniform slices 2cm by 20 cm dimension using a sharp clean knife, weighed and kept in a desiccator to equilibrate and prevent contamination. Granulated sugar was purchased from a local shop in the Epe suburb of Lagos state. The 4200 g of sugar granules were dissolved in 2800 ml of distilled water at room temperature and allowed for 24 hours for complete dissolution and adjusted to obtain sugar syrup of 60 °Brix measured with a Refractometer at 27 deg Celcius ambient temperature.

2.4 Procedure

The Processing conditions adopted were based on optimized experimental conditions of 50 °C temperature, 60 °Brix sugar solution concentration and 3 hours immersion time (Duduyemi et al, 2016). The PID temperature controller used to monitor and maintain the temperature within the contactor was set at 50 °C. The liquid flow rate for regular agitation was set at 6 m^3 per minute in circulation. For effective dehydration, a liquor ratio of 1:10 was used and the samples were dehydrated in the contactor. The mass of samples was determined at 30 minutes intervals until a constant weight is attained at about 3 hours. Dehydrated slices were drawn from sugar solution and rinsed quickly under running tap water to remove surface sugar and thereafter, mopped with a clean soft tissue to remove surface moisture. The quantitative analysis was performed to determine the percentage of water loss in the samples by dehydration. Samples were immediately transferred to the dehumidified hot-air cabinet dryer and Convectional Oven (without dehumidification) both set at 60 °C drying temperature to remove residual moisture in the osmotically dehydrated samples at this low temperature till constant weight is achieved. Measurements were recorded for the sample weights at intervals and the process was repeated to validate the data recorded.

Finally, Physicochemical analysis of samples is carried out for both samples dried by the conventional oven and customized dehumidified hot-air dryer and values were compared. The proximate analysis of the samples was conducted (AICHE 2016).

2.5 Gravimetric Analysis of Sample Content:

The analyses of the samples were conducted using equations 1 to 7 to evaluate the relevant parameters according to Suhasini L. (2014);

Moisture Loss (%)= …(1)

Water Loss (%) = …(2)

Solid Gain (%) = …(3)

Dehydration Yield (Ψ) percent
(%) = ...(4)

Dehydration Ratio =
…(5)
(Where subscripts; o, and t represent initial and final time respectively)

Drying chamber efficiency: It can be defined as the ratio of a difference between the drying chamber inlet and drying chamber outlet temperature to the difference between the drying chamber inlet and ambient temperature was also estimated using equation 6..

Drying Efficiency ($\dot{\eta}_d$) …(6)
Where T_1 and T_2 are inlet and outlet Temperature; T_a is the ambient Temperature

Effectiveness factor: It can be defined as the ratio of drying rate in the biomass dryer to the drying rate in the open sun drying.

… (7)

III. RESULTS AND DISCUSSION

The features of food materials often influence the acceptability, the fresh pawpaw samples had a golden yellow colour while treated samples had golden-brown characteristics. A pictorial view of the treated samples and the fresh sample is shown in Figure 2:

Fig 2: (a) Fresh Sample of diced Pawpaw fruit (b) Dehydrated samples at optimized conditions

The water content of the fresh sample of Carica papaya was estimated to be 87±0.5 percent on average, which compared relatively with 88.83 obtained from the USDA data analysis. The use of the pilot-scale equipment for osmotic dehydration investigation and subsequent evaluation showed that the water loss from the samples was in the range of 30.77 to 38.2 % with a solute gain of 7.44±0.5 percent. Hence, the water content of the ripe pawpaw fruit (Carica papaya)" achieved approximately 36 percent reduction on a wet basis from the initially estimated water content. The progressive water loss as the time of immersion progressed for three hours is presented in figure 3.

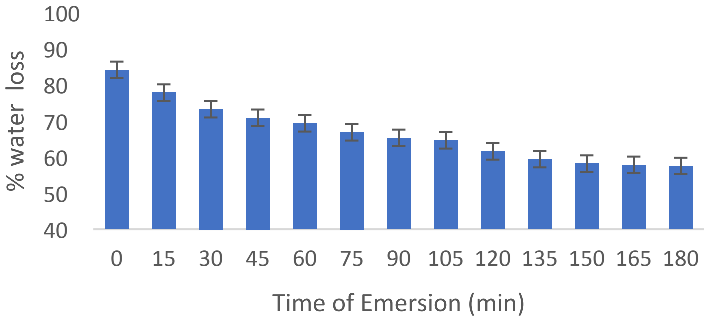


Figure 3: The rate of water losses in the customized osmotic dehydration equipment

The trends of dehydration in the pilot plant revealed initial drastic dehydration which reduced gradually to a relatively similar value, this may be partially attributed to the progressive solute impregnation leading to blockages of the dehydration pores and surface area reduction.

Drying is characterized by the complete removal of water activity in any substance (organic or inorganic). Before drying, Osmotic Dehydration is carried out for the partial reduction of water content to about 30-50% in fruits and vegetables and thereby limiting the microbial activity if not completely stopped by water activity reduction in the samples and reducing drying time. The importance of dehydration is to prevent loss of mineral contents while mild temperature treatment between 50 °C to 60 °C ensures the contents are not denatured by heat. Effects of the further dehydration treatment should therefore at low temperature to maintain the organoleptic properties of the samples after treatment in the respective equipment. At low temperatures operation of 60 ±5°C automatically regulated in the air dehumidifier and the oven drier, Analysis of the results from samples further treated using Origin Pro70 App showed that the samples in the dehumidifier dehydrated faster to attain a stabilized moisture content, thus indicating a reduced process time. This is presented in Figure 4:

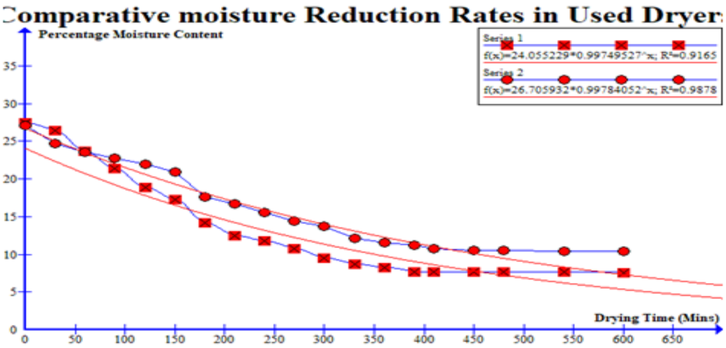


Fig 4: Comparison of the dehydration with and without dehumidification

Both curves deduced from the results revealed drawn that drying using the conventional Oven took about 10 hours to achieve consistency in weight of samples whereas in the customized dehumidifier, at approximately 8 hours the samples had attained shelf stables status. The method of forced convection had a higher thermal dissipation rate (Joules per sec) and thermal conductivity compared to the conventional oven. Statistical analysis of the results showed gave squared Regressions of (R^2) of 0.9165 showing lower moisture percent for samples further dehydrated in dehumidified air dryer against 0.9878 obtained from samples treated in the oven for the period. The drying rate was correlated by equations 6 and 7 respectively.

$$f(x)=24.06*0.99749527^x \qquad ...8$$

$$f(x)=26.7*0.99784052^x \qquad …9$$

Physico-chemical analysis of the samples revealed that the final products exhibited similar contents retention. Proximate analysis of samples further dehydrated carried out in the customized dehumidifier and the conventional oven was evaluated in comparison with existing USDA data as presented in Table 1. However, retention of vitamin C and vitamin A (β-carotene) were observed to differ significantly (at $p \leq 0.05$).

Table 1: Physico-chemical Analysis of Dehydrated Pawpaw Samples

Test Performed/Method	Fresh Samples	Conventional Oven	Fabricated Dehumidifier
General Appearance	Fair Orange moist fruit	Golden brown dried fruit	Golden brown dried fruit
Moisture content, %	26.1	19.0	19.2
Water	88.83	87±0.5	87±0.5
Total Ash (Minerals), %	3.5	2.4	2.3
Fat Content, %	0.26	0.82	0.85
Protein (TKN x 6.25) %	0.47	ND	ND
Total Carbohydrates, %	10.82	77.7	77.6
Energy Value, KJ/100g	179	299	299
Titrable Acidity (as Malic acid), %	-	1.3	1.1
Vit. C, mg/100g	60.9	8.0	6.7
Vit. A, mg/100g	0.27	0.66	0.65

Source for Fresh Pawpaw Nutrient Value/100g: USDA National database 2018. ND- Not Determined.

The general appearance of both dehumified and non= dehumidified samples was golden brown. The samples in the dehumidified dehydrator retained their relative organoleptic properties which include: total ash, Fat content, Carbohydrate, Energy Value, Malic acid and Vitamin A. The pretreatment with osmotic had a great impact on the retentions of heat-sensitive compounds like ascorbic acid. However, Vitamin C retention without dehumidification is higher in value as compared to the dehumidified samples with 8.0mg/100g and 6.7 mg/100g on dry weight respectively.

The papaya samples treated in the dehumidifier attained stable temperature earlier as the mechanism of dehumidification reduced the water content in the samples at a faster rate to attain constant weight at about 400 hrs compared with 550 hrs treatment without dehumidification to attain relatively different moisture content. Moreover, the samples' tenderness made the dehumidified samples preferred as they appeared better than products dehydrated at the same temperature which appeared rougher and crispy. This result is possible as there was no heat built-up in the dehumidifier and the contents. Moreso, cooking is prevented by the constant withdrawal of the water mists from the medium. Hence, a dehydrator with dehumidification produced samples earlier retained more moisture for tenderness and when applied to leafy vegetables would not only retain the leafy characteristics but would also reduce the weight and enhance transportation and storage.

IV. CONCLUSION

Osmotic dehydration of fruits and vegetables is capable of extending the shelf life of food materials but for a few days. Further dehydration is required to make samples shelf-stable without losing the contents. The dehumidification mechanism introduced into a dehydrator reduced water content at a faster rate compared to the dehydrator without dehumification. The temperature of operation and dehumidifying of the chamber mists determine the texture of the final product. The mechanism of dehumidification reduced the water content in the samples at a faster rate to attain constant weight at about 400 hrs compared with 550 hrsof treatment without dehumidification to attain relatively different moisture contents. The dehydrator with dehumidifier produced samples that were leathery to touch and retained the organoleptic features better.

V. ACKNOWLEDGEMENTS

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