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Preservation of Chayote (*Sechium Edule L*) Using Different Drying Methods

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Abstract

Chayote (*Sechium edule L*) has a short shelf life due to its high moisture content (87-95%). This study aimed at prolonging the shelf life of chayote by using different drying methods: convective hot oven drying (OV), and osmo-dehydration (OD) with salt or sugar. Dried samples (at 20% moisture content) were analysed for their nutritional, rehydration, textural and sensory properties. Dried chayote was stored for three months while determining total plate count (TPC), coliforms, *Staphylococcus*, yeasts and moulds and sensory acceptability. The time to attain 20% moisture in chayote varied significantly ($p < 0.05$) from 9 h (OV and OD sugar) and 12h for osmo-dried chayote in salt. Ash, total sugar, starch and fiber increased significantly ($p < 0.05$) from fresh sample as follows 5.2 - 28.3 g/100g (OD salt), 5.8 - 18.5 g/100g (OD sugar), 18.4 - 21.3 g/100g (OD sugar), 49.1 - 52.9 g/100g (OD sugar), respectively after drying. Vitamin C decreased from 232.5 - 38.4 mg/100g (OV) whereas zinc decreased from 1442.9 - 29.5 mg/100g (OV). Rehydration ratio varied from 2.0 $\pm$ 0.26 (OD salt after 30 min) to 2.9 $\pm$ 0.05 (OV after 20 min). Osmotically dehydrated samples were softer than air dried samples after rehydration and cooking. Total plate counts decreased from log 5.14 to non-detected. *Staphylococcus aureus* counts decreased from log 4.29 to non-detected. Coliform counts deceased from log 4.91 non detected respectively. Osmotic dehydration contributed to the preservation of the nutritional, textural and sensory properties of dried chayote with salt achieving better preservation than sugar. Drying increased the shelf life of chayote from days to three months with high microbial quality and sensory acceptability.

Keywords: chayote, osmotic dehydration, convective hot oven drying, shelf-life

1. Introduction

Chayote (*Sechium edule L*) is one of the seasonal edible vegetables mainly grown in tropical and subtropical regions. Chayote is native to Mexico and was introduced as a crop in Latin America and the world since the 1970s (Kumar et al., 2014). The edible chayote fruit has different names worldwide: *Chuchu* in Brazil, *Cho-cho* in Jamaica, *Sayote* in the Philippines, and *Güisquil* in El Salvador (Vieira et al., 2018). In Uganda, the fruit is called *Surisuti* in Runyoro, *Ensusuti* in Luganda and *Munete* in Runyankole (Tumuhe et al., 2020).

Chayote fruit is neglected or underutilized as a food/ raw material in the food industry because of its bland taste (Sangma et al., 2019). However, it is a good source of fiber, starch, minerals and vitamins and thus must be processed in order to be preserved (Mishra et Das, 2015). Chayote's nutritional composition is influenced by climate, region, growing conditions, plant age, and processing methods (Vieira et al., 2018). Sangma et al. (2019) stated that chayote provides several health benefits due to its phytochemical potential, including the prevention of cardiovascular disease, anti-inflammatory, chronic kidney disease, cancer, overweight and obesity, and blood sugar control. Other potential applications of the different parts of the chayote plant are the cosmetic, and nanomaterials industries, as well as its use in biotechnological processes (Vieira et al., 2018).

According to the WFP (2016) and FRA (2020) reports, postharvest losses in Uganda were estimated to reach 40% due to inadequate postharvest management procedures which facilitate spoilage by diseases, decay or pests. Fresh fruits and vegetables are perishable and difficult to preserve for long due to their high moisture content and tender texture (Deng et al., 2017). Chayote has a rather short shelf life at room temperature (a few days to two weeks). This is attributed to its very moisture content (87% to 95% wet basis) which contributes highly to postharvest losses by microbial and chemical agents during distribution and storage (Islam et al., 2018).

Ruiz-López et al. (2010) stated that a feasible way to extend the shelf life of chayote is by drying to reduce its moisture content. Afolabi (2014) stated that drying not only allows the product to be kept at room temperature for a long time but also lowers the expenses of packing, storage, and transportation by reducing the weight and volume of the product. With a minor impact on the food's nutritional value, dried fruits and vegetables are abundant in fiber and carbohydrates, and low in fat, making them nutritious product options playing an essential part in the food supply chain in today’s market. This study aimed at evaluating the effect of different drying methods (convective hot oven and Osmo-dehydration) on the physicochemical properties, sensory acceptability and shelf-life stability of chayote fruit.

2. Material and Methods

2.1 Study Design

A Completely Randomised Design (CRD) was used to determine the effect of drying methods on the nutritional and textural properties, sensory acceptability and shelf stability of dried chayote. In order to assess the rehydration capacity, a factorial design was used with five-time levels (20, 30, 40, 50 and 60 minutes) and three different chayote treatments (convective hot oven, solar drying and Osmo-dehydration). The temperature was kept constant (25℃).

2.2 Sample Preparation

Samples (fresh chayote) were purchased from Nakasero market, Kampala City. The fruits were prepared as described by Islam et al. (2018). To disinfect the fruit, they were washed using portable water containing 100 mg/l sodium hypochlorite, peeled and cut into 1 cm^3 cubes of about 1 cm using dicer. The diced cubes were then subjected to different drying techniques in order to achieve a moisture content of 20% (Afolabi (2014). Prior to drying, the fresh chayote cubes were placed in water containing 0.03 g of potassium sorbate and 0.01 g of sodium benzoate per 1000 ml for five minutes as antimicrobial agents (Heydaryinia et al., 2011).

2.3 Drying

Convective hot oven drying (OV) was carried out at 60 ℃ for 3, 6, 9, 24, and 27 hours in an oven (JW-650ED/JW-1350ED, Jinwoo, Korea). For osmotic dehydration (OD), chopped fresh cubes (5 kg) were soaked in solutions containing either 10% sugar or 10% salt for three hours (Ruiz-López et al., 2010). Thereafter samples were soaked in a solution containing 0.03 g potassium sorbate and 0.01 g sodium benzoate for five minutes before convective oven drying. Samples obtained after drying were stored in zip-lip high-density polyethylene (HDPE) bags at ambient temperature for proximate and shelf-life stability analysis.

2.4 Determination of Physicochemical Properties of Chayote

Moisture content was determined using the standard AOAC method (AOAC, 2000). A sample (5 g) of fresh chayote was weighed into pre-conditioned crucibles and dried in a hot air oven (MRC model; DFO-150, s/n AL18112901-1; China) at 100℃ for sixteen hours. The ash content was determined as described by AOAC (2000), method 942.05. A sample (5 g) of fresh chayote was weighed into pre-conditioned and weighed crucibles and placed in a cool muffle furnace. Ashing was carried out in a muffle furnace (Carbolite CWF 1300 (S/N 20-503092, TYPE 13/5, Hope Valley, England) at 550 ℃ for six hours. Total sugars and starch were determined using the phenol-sulphuric acid method (Nielsen, 2010). The dietary fiber of fresh and dried chayote was determined as described by the method of Busuttil-Griffin et al. (2015). Vitamin C content was determined using the titration method using 2,6-dichlorophenolindophenol (DCPIP) as described by Riviello-Flores et al. (2018). The zinc content was determined using an Atomic Absorption Spectrophotometer (Perkin Elmer 2000series) as described by AOAC (2000) method 999.11.

2.5 Determination of Rehydration Capacity and Texture Properties

The rehydration capacity was determined by submerging 0.5 g of the dehydrated sample in 150 ml of water at room temperature. The samples were then taken out at 20, 30, 40, 50 and 60 minutes. Rehydration capacity (RC) was determined according to Doymaz (2008). The texture of hardness on the rehydrated sample was determined using a Texture Analyser (TA-XT plus; S/N 42095, Stable Micro Systems, UK). The probe used was a 5 mm needle (P/2N). The pre-test speed was 1 mm/s, the test speed was 2 mm/s and the post-test speed was 10 mm/s. For each test, the sample was subjected to a penetration of 5 mm from the platform and each given sample was placed on the working platform and compressed up to a penetration depth of 5 mm

2.6 Sensory Evaluation

A semi-trained panel (n=30) comprising students and staff of the School of Food Technology, Nutrition and

Bioengineering, Makerere University, Uganda was used to determine the acceptability of the dried chayote. Dehydrated samples were first reconstituted by soaking in tap water for 40 minutes. The samples were then shallow fried with onions, tomatoes, turmeric powder and salt for 30 min. Samples were coded and served to the panelists randomly. Panelists were asked to score colour, aroma, taste, mouth feel and overall acceptability using a 9-point hedonic scale with 1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, and 9 = like extremely. Panelists were given portable water to rinse the palate in between tasing of samples.

2.7 Evaluation of Shelf-life of Dried Chayote

The shelf life of dried chayote was determined using both microbial and sensory evaluation during the 3 months of storage. The shelf life of 3 months of storage depended on the previous experiment conducted in our lab where fresh chayote was stored at room temperature under the table before it started sprouting.

Samples for microbial quality of dried chayote were subjected to total plate Count (TPC), yeast and molds, *Staphylococcus aureus* and total coliform counts during storage for 3 months (at intervals of 1 month) to determine their shelf stability. For microbial determination, ten-fold serial dilutions of the samples were prepared using ¼ strength Ringer's solution. Pour plate technique using plate count agar and violet red bile lactose agar (VRBL) was used to determine total plate count and total coliforms, respectively. For both determinations, the plates were incubated (Incubator: Binder GmbH; model BF 240; S/N 08-44565) at 37 ℃ for 24 hours. Enumeration of yeasts and molds was done on pre-set potato dextrose agar containing 1% lactic acid followed with incubation at 30 ℃ (Incubator: Memmert G-mmert GmbH+ Co. KG; model IN55; S/N D216.1388, Germany) for 3 days. *Staphylococcus aureus* counts were determined by spread plating on Baird Parker Agar (BPA) containing tellurite egg yolk supplement followed by incubating (Incubator: Binder GmbH; model BF 240; S/N 08-44565, Germany) at 37 ℃ for 48 hours. The colony-forming units were calculated using the IDF method (1991).

2.8 Statistical Analysis

Data analysis was performed using statistical software IBM® SPSS® Statistics (Version 26. One-way analysis of variance (ANOVA) was used to determine differences among means generated using Tukey's test. The differences were considered statistically significant at $p \leq 0.05$. For microbial analysis, the concentrations were converted into log10 and graphs were generated appropriately.

3. Results and Discussion

3.1 Changes in Moisture Content of Chayote during Drying

The drying curves for fresh chayote subjected to different drying methods are shown in figure 1. Time to dry to a moisture content of 20% varied significantly ($p < 0.05$) with method of drying. A moisture content of 20% was obtained after drying at 60℃ for 9 h for OV and OD sugar and 12 h for OD salt.

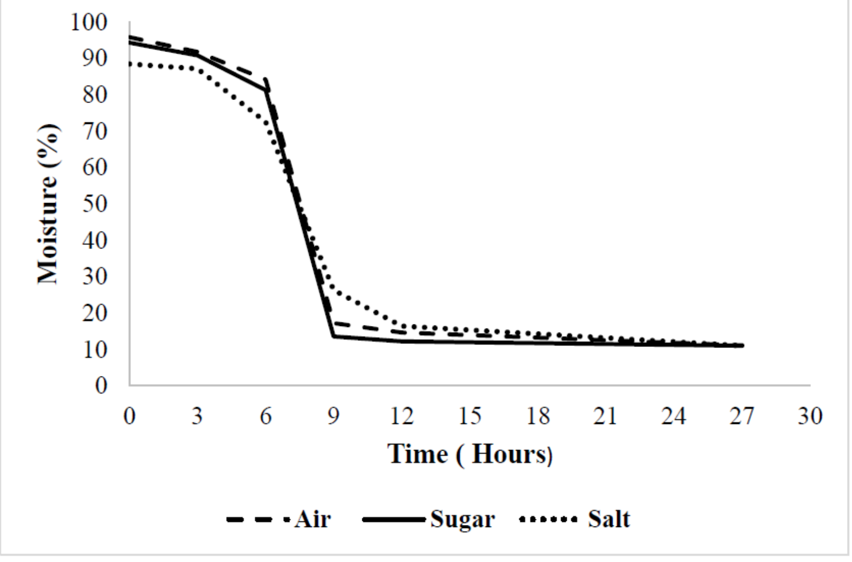

Figure 1. Drying curves of chayote obtained after drying using different methods of drying Convective hot oven (OV), osmotic dehydration (OD) with sugar or salt

The difference in the time taken using the different drying methods to achieve the 20% moisture content indicated that drying methods have a significant effect on the drying rate of chayote. Initially, the moisture content of the convective oven drying samples (95.8% wet basis) was higher than that of OD chayote with sugar (94.4% wet basis) and OD chayote with salt (88.5% wet basis). This is because osmotically dehydrated chayote lost some of its water due to the flux of water from the food and influx of salt and sugar into the fruit binding available water thus reducing the moisture content of the food slightly (Falade & Igbeka, 2007). The difference in the moisture content of the osmotically dehydrated samples was due to the effect of the solute used. Chandra & Kumari, (2015) reported that during osmotic drying, sugar accumulates on the thin sub-surface layer of the food matrix which results in a barrier for mass transport whereas salt hinders the formation of the later layer and penetrates the deeper tissues of the food matrix allowing higher water loss and solid gain. Furthermore, due to this mechanism, the rate of moisture removal in salt solutions was higher than in sugar solution as depicted in figure 1.

3.2 Nutritional Composition of Fresh and Dried Chayote

The ash, total sugars, starch, dietary fiber, vitamin C and zinc composition of the samples are presented in table 1. Ash, total sugars, starch and dietary fiber generally increased significantly ($p < 0.05$) while vitamin C and zinc decreased significantly ($p < 0.05$) as a result of drying. Ash content increased significantly ($p < 0.05$) from 5.2 to 28.3 g/100g (OD with salt). Total sugars ranged from 5.8 to 18.5 g/100g (OD with sugar). Starch content increased from 18.4 to 21.3 g/100g (OD with salt). Dietary fiber ranged from 49.1 to 52.9 g/100g (OD with sugar). Vitamin C decreased from 232.5 to 38.4 g/100g (air dried). Zinc content ranged from 1442 to 29.5 mg/100g (Oven dried).

Table 1. Nutritional composition of fresh and dried chayote per 100 g of dry matter

Treatment	Ash (g)	Total sugars (g)	Starch (g)	Dietary Fiber (g)	Vitamin C (mg)	Zinc (mg)
Fresh	$5.2^{d} \pm 0.3$	$5.8^{d} \pm 0.21$	$18.4^{c} \pm 0.06$	$49.1^{c} \pm 1.82$	$232.5^{a} \pm 0.00$	$1442.9^{a} \pm 1.08$
Oven drying	$5.5^{c} \pm 0.00$	$8.2^{c} \pm 0.5$	$18.7^{b} \pm 0.26$	$49.6^{b} \pm 0.08$	$38.4^{d} \pm 0.00$	$29.5^{d} \pm 0.00$
OD with sugar	$7.0^{b} \pm 0.00$	$18.5^{a} \pm 0.04$	$21.3^{a} \pm 0.29$	$52.9^{a} \pm 0.33$	$86.9^{c} \pm 0.00$	$48.1^{b} \pm 1.38$
OD with salt	$28.3^{a} \pm 0.01$	$8.9^{b} \pm 0.13$	$7.9^{d} \pm 1.54$	$19.1^{d} \pm 0.02$	$103.5^{b} \pm 0.23$	$36.1^{c} \pm 0.31$

Values are averages of triplicate readings except for total sugars and starch which were in duplicate (mean ± standard deviation). Means followed by a different superscript letter within the same column indicate that there was a significant difference between the dried chayote using the different drying methods ($p < 0.05$). OD - Osmotically-dehydrated. n=9

From the findings, drying appears to have led to an increase in ash, total sugars, starch and dietary fiber content. These findings were in agreement with Islam et al.(2018) who reported the same effect of oven drying and osmo-dehydrated chayote on the nutritional composition of chayote. The observed increase in ash content of osmo-dehydrated chayote can be attributed to the fact that salt and sugar contain minerals including Na, Ca, Mg, P and Fe. These minerals can be deposited on the fruit surface during drying. The increase of ash was also reported by Olabode et al.(2015), stating that the concentration of the osmotic solution caused by the elimination of moisture raises the level of total soluble solids in the samples, resulting in an increase in ash content with increasing drying temperature. The increase of ash in OD with salt has been reported by Tolera & Abera (2017) stating that the salt from the solution might have moved into the sample when the water was drained and probably cause a rise in ash level. This results from the simultaneous water and solute diffusion process in osmotic dehydration. Similarly increase in total sugars in the osmo-dehydrated sample with sugar could be attributed to deposition of sugars on the fruit surface.

The increase in starch of OD with sugar was due to the presence of starch in the raw sugar. Raw sugar contains starch, a natural component of the sugar cane plant, as a result of starch being squeezed into cane juice during milling. All sugarcane products, including raw and refined sugar, as well as sugarcane mills and refineries, contain starch, though its concentration varies widely depending on the season, variety, illnesses, maturity, processing conditions, and analysis method. (Figueira et al., 2011).The decrease of starch content in OD with salt was due to the presence of salt. Moreau et al. (2011) reported that salt enhances starch breakdown at all organizational levels, including depolymerization of the glucose chains to generate smaller molecules, such as glucose. Chayote pre-treated with salt prior to drying was observed to have lower fiber content (19.1 g/100 g). It has been reported that salt facilitates the solubility of fiber. Li et al. (2017) reported that salts disrupt hydrogen bonds, changing solution characteristics including viscosity, electric conductivity, and surface tension as well as the physical characteristics of the resulting fiber, such as appearance, size, and melting temperature. The further increase of salt could have led to flat fiber with larger diameter sizes and defects, and this is an aspect which requires further investigation. Tolera et al. (2017) studied the effect of salt concentration on the decrease of fiber content. These authors reported that salt concentration has a significant influence on the interaction between the drying method and fiber content. The fiber content is strongly affected by the combination of osmotic treatments and drying techniques. Fiber content was observed to decrease with increase in the concentration of salt solution**.** The reduction in vitamin C and zinc content can be attributed to leaching during the osmotic process thus reducing their concentration in the product (Yadav & Singh, 2014). These reductions in zinc and vitamin C concentrations were also reported by Araya-Farias et al., (2014) after osmotic dehydration and convective oven drying. Dağhan et al. (2018) also reported that vitamin C is a temperature sensitive nutrient.

3.3 Rehydration and Textural Properties of Dried Chayote

The minimum rehydration ratio, 2.0 ± 0.26 was obtained from OD chayote with salt after 30 minutes while the maximum rehydration ratio, 2.9 ± 0.05 observed in the convection oven dried after 20 minutes of rehydration (Table 2). An increase in rehydration was observed in the first 20 minutes that later reduced gradually. OD chayote with salt indicated no significant difference ($p > 0.05$) in its rehydration capacity for the entire 60 minutes whereas the convection oven dried and OD chayote with sugar reported a significant difference ($p < 0.05$) in their rehydration capacities as time progressed.

Rehydration ratios are intended to measure the water absorption capacity of the osmotically dehydrated chayote (Kumar et al., 2017). Convective oven dried without pre-treatment showed higher rehydration ability than did the osmotically dehydrated one. Osmotically dehydrated chayote presented lower rehydration capacities because there was a high rate of mass transfer. This is due to the high difference between the solid concentration in rehydrated dried chayote and rehydrating water (Górnicki et al., 2020). Initial increase in rehydration ratio and a later decrease in the process was because at the start, food matrix capillaries and cavities were rapidly filling up with water near the surface, cell walls soften due to the water absorption and the cell regains initial shape according to the natural cellular structure elasticity by moving water into the inner cavities (Górnicki et al., 2020). In the further stage of the process, water absorption slows down because the rehydrated sample gets close to the state of equilibrium.

Table 2. Rehydration capacity of dried chayote

Sample	20 minutes	30 minutes	40 minutes	50 minutes	60 minutes
Oven dried	$2.9^{b} \pm 0.05$	$2.8^{c} \pm 0.04$	$2.6^{c} \pm 0.13$	$2.5^{a} \pm 0.35^{a}$	$2.2^{b} \pm 0.17$
OD with sugar	$2.4^{a} \pm 0.19$	$2.3^{b} \pm 0.08$	$2.3^{b} \pm 0.26$	$2.2^{a} \pm 0.09^{a}$	$2.1^{a} \pm 0.09$
OD with salt	$2.1^{a} \pm 0.12$	$2.0^{a} \pm 0.26$	$2.2^{a} \pm 0.17$	$2.6^{a} \pm 0.04$	$2.2^{a} \pm 0.4$

Values are averages of triplicate readings (mean ± standard deviation). Means followed by a different superscript letter within the same row indicated that there was a significant difference in rehydration capacity of the sample as time progressed ($p < 0.05$). In addition, means followed by a different superscript letter within the same column indicated that there was a significant difference in rehydration capacities based on the drying method used ($p < 0.05$). Oven dried chayote without any pre-treatment; OD - Osmotically-dehydrated. n=9

The hardness values were derived from the peak value of force-deformation curves collected during the compression test. Figure 2 shows a slight force of OD chayote with sugar and OD chayote with salt at 20 - 30 minutes. The forces then peaked at 40 minutes and decreased gradually after 50 minutes reaching equilibrium. OD chayote with sugar did not show any significant effect on hardness ($p > 0.05$) whereas OD chayote with salt and convective oven drying did.

Rehydrated chayote dried without treatment required significantly more force to penetrated than the osmotically dehydrated chayote because the loss of water and heating during drying caused stress on the food cell structure resulting in shape alterations, volume loss, and an increase in hardness (Barragán-Iglesias et al., 2016). However, there was no significant difference between the texture of OD chayote with salt and OD chayote with sugar because solute provide sufficient mechanical and structural strength to withstand the shock during drying which prevent cell rupture and improve water uptake during rehydration. Furthermore mechanical resistance of the tissues often increases during osmotic dehydration thus the initial process of dewatering could have influenced positively the process of drying and rehydration (Kowalska et al., 2018).

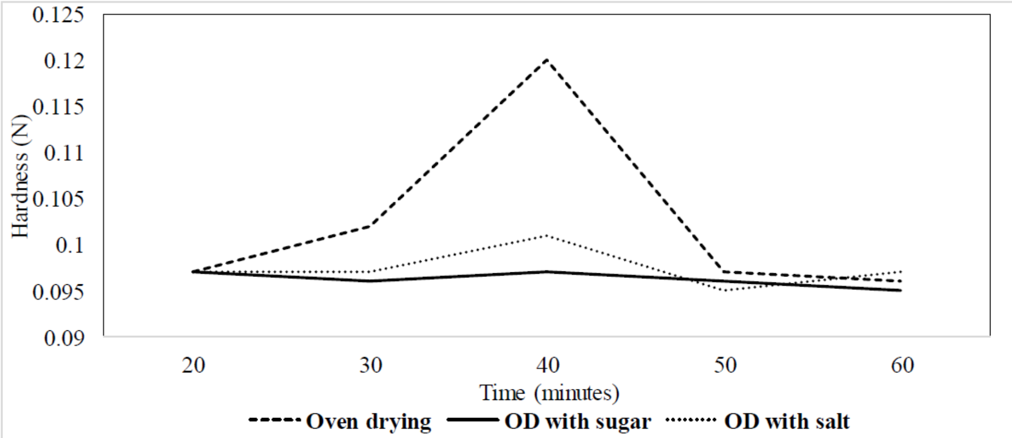

Figure 2. A graph of hardness with time for dried chayote using different drying methods OD - Osmotically dehydrated

3.4 Sensory Acceptability of Dried Chayote

The acceptability scores of dried chayote are presented in table 3. There was no significant difference in sensory acceptability scores for appearance and colour for all the samples ($p > 0.05$). However, taste, aroma and overall acceptability of convective oven drying (OV) and OD chayote with salt had significantly ($p < 0.05$) higher scores compared to the fresh and OD chayote with sugar. All attributes for the different treatments were generally acceptable with scores ranging from 5 (neither like nor dislike) to 7 (like moderately).

Table 3. Acceptability scores of chayote dried using different drying methods

Sample	Appearance	Colour	Taste	Aroma	Mouth-feel	Overall acceptability
Fresh (control)	$6.5^a \pm 1.95$	$6.4^a \pm 1.83$	$6.6^a \pm 1.64$	$6.8^a \pm 1.44$	$6.7^a \pm 1.87$	$6.7^a \pm 1.61$
Oven drying	$6.7^a \pm 1.39$	$6.8^a \pm 1.46$	$5.1^b \pm 1.46$	$5.6^a \pm 1.55$	$5.1^b \pm 2.04$	$5.6^b \pm 1.53$
OD with Sugar	$7.1^a \pm 1.42$	$7.3^a \pm 1.14$	$5.3^b \pm 1.94$	$6.2^a \pm 1.42$	$5.2^b \pm 2.06$	$6.0^b \pm 1.89$
OD with Salt	$7.1^a \pm 1.06$	$6.9^a \pm 1.33$	$6.7^a \pm 1.74$	$6.7^a \pm 1.15$	$7.1^a \pm 1.68$	$7.1^a \pm 1.25$

Convection oven dried chayote without any pre-treatment; OD - Osmotically-dehydrated. Values are average scores of 30 panellist (mean ± standard deviation). Means followed by a different superscript letter within the same column indicated that there was a significant difference in the acceptability of the dried samples ($p < 0.05$). n=9

Osmotically dehydrated chayote had the highest acceptability score for appearance and colour because osmotic dehydration maximizes the sugar-to-acid ratio and enhances the stability of pigments and texture during drying and storage (Ahmed et al., 2016). In addition, Kerr (2013) reported that drying without any pre-treatment tends to discolour dried products considerably more quickly even after the dehydration process. As such, appearance and colour of convective oven dried chayote was slightly appreciated by the panellists. Bekele & Ramaswamy (2010) also stated that before convective oven drying, immersing products in osmotic solutions prevents oxidative browning, and loss of oxidative flavours thus enhancing the quality of the final product. Therefore, fruit products are recommended to mainly undergo pre-treatments prior to drying to minimize the negative effects of drying such as textural, unpleasant colour and flavour changes (Nyangena et al., 2019). There was no significant difference in all the sensory acceptability scores of fresh chayote and OD chayote with salt because osmotic dehydration produces a gentle processing of fruits and vegetables which results in greater sensory similarity between the dehydrated and the natural product (Yadav & Singh, 2014).

3.5 Shelf-life Stability of Dried Chayote

Results of microbial counts of dried chayote during storage are shown in figure 3. There was a decrease in TPC, coliform and *Staphylococcus aureus* counts during the three months of storage at ambient temperature. After drying, no trace of yeasts and molds was detected in the samples during storage. After one month, *Staphylococcus aureus* counts were not detected in all the samples. It was also determined that no microbial counts for TPC, coliforms and staphylococcus were detected after one month in OD with salt.

Generally, the average microbial population of total plate counts, coliform and *Staphylococcus aureus* in the initial population was high in chayote due to different process conditions of the drying methods. This suggests the need for including a pretreatment step for example blanching or use of antibacterial preservatives prior to drying. Yeasts and molds were not detected in dried chayote due to the use of sodium benzoate and potassium sorbate during the preparation of samples before drying. Sodium benzoate and potassium sorbate are antimicrobial agents (García-García & Searle, 2015) and are active against yeasts and molds (Marshall et al., 2016). Alp & Bulantekin (2021) reported also the decrease of microbial populations during storage due to the low water activity in the dried sample that prevented microorganisms from growing. Osmotic dehydrated (OD) chayote exhibited more stability in microbial properties than convective oven dried chayote. This is attributed to the low water activity caused by high sugar concentrations thus inhibiting microbial growth during storage (Gani et al., 2018). The absence of the micro-organisms after one month in OD chayote with salt may be attributed to the effectiveness of salt as an inhibitory preservative against pathogenic and spoilage microorganisms thus contributing to the microbial quality of the dried product (Taormina, 2010).

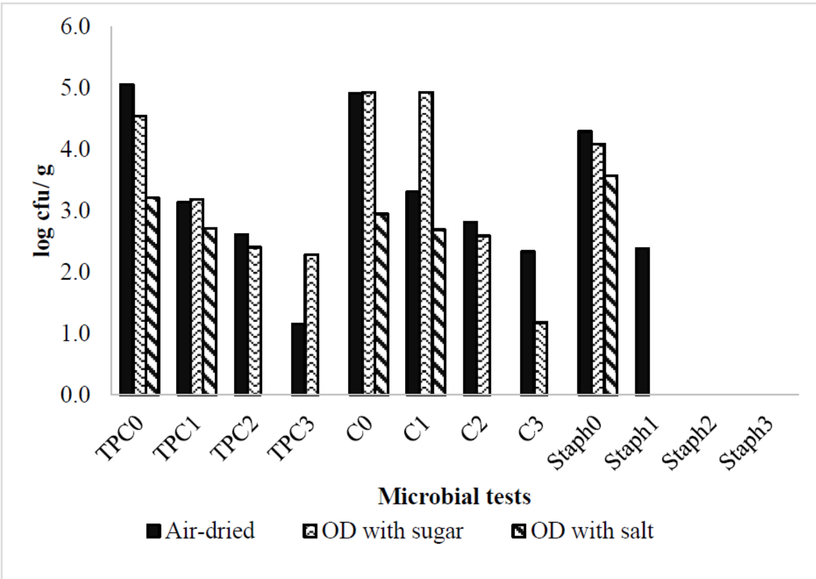

Figure 3. Microbial counts for the dried chayote during the three months of storage

TPC0, TPC1; TPC 2, C0 - Coliforms at zero months; C1 - Coliforms at one month, C2 - Coliforms at two months, C3 - Coliforms at three months; Staph0 - *Staphylococcus aureus* counts at zero months, Staph1 - *Staphylococcus aureus* counts at one month, Staph2 - *Staphylococcus aureus* counts at two months, and Staph3 - Staphylococcus counts at three months.

The changes in the sensory acceptability scores of the samples during three months of storage are show in table 4. There was no significant difference ($p > 0.05$) in the acceptability scores of the different attributes in air-dried and OD chayote with sugar except for their overall acceptability in the third month. There were also no significant differences ($p > 0.05$) in the sensory acceptability scores for appearance, colour and aroma for all samples. However, OD chayote with salt had significantly ($p < 0.05$) high acceptability scores during the three months of storage. Overall, OD chayote with salt was highly scored by panellists compared to the other samples.

Table 4. Acceptability scores of dried chayote during the three months of storage

Month	Treatment	Appearance	Colour	Taste	Aroma	Mouth-feel	Overall acceptability
	Fresh (control)*	$6.5^{a} \pm 1.95$	$6.4^{a} \pm 1.83$	$6.6^{a} \pm 1.64$	$6.8^{a} \pm 1.44$	$6.7^{a} \pm 1.87$	$6.7^{a} \pm 1.61$
1	Oven dried	$6.7^{a} \pm 1.4$	$6.8^{a} \pm 1.5$	$5.1^{b} \pm 1.5$	$5.6^{a} \pm 1.6$	$5.1^{b} \pm 2.0$	$5.6^{b} \pm 1.5$
	OD with sugar	$7.1^{a} \pm 1.4$	$7.3^{a} \pm 1.1$	$5.3^{b} \pm 1.9$	$6.2^{a} \pm 1.4$	$5.2^{b} \pm 2.1$	$6.0^{b} \pm 1.9$
	OD with salt	$7.1^{a} \pm 1.1$	$6.9^{a} \pm 1.3$	$6.7^{a} \pm 1.7$	$6.7^{a} \pm 1.2$	$7.1^{a} \pm 1.7$	$7.1^{a} \pm 1.3$
2	Oven dried	$7.2^{a} \pm 1.2$	$7.2^{a} \pm 1.1^{a}$	$5.8^{b} \pm 1.2$	$6.6^{a} \pm 1.1$	$5.9^{b} \pm 1.1$	$6.3^{b} \pm 1.0$
	OD with sugar	$6.7^{a} \pm 1.5$	$6.8^{a} \pm 1.3$	$5.8^{b} \pm 1.2$	$6.2^{a} \pm 1.3$	$5.7^{b} \pm 1.5$	$6.0^{b} \pm 1.3$
	OD with salt	$7.2^{a} \pm 1.2$	$7.4^{a} \pm 0.9$	$7.1^{a} \pm 1.2$	$6.9^{a} \pm 1.1$	$7.1^{a} \pm 1.4$	$7.3^{a} \pm 1.2$
3	Oven dried	$7.2^{a} \pm 0.9$	$7.3^{a} \pm 1.0$	$6.7^{b} \pm 1.1$	$6.7^{a} \pm 1.1$	$6.5^{b} \pm 1.4$	$6.5^{b} \pm 1.0$
	OD with sugar	$7.4^{a} \pm 1.2$	$7.5^{a} \pm 1.1$	$6.5^{b} \pm 1.2$	$6.7^{a} \pm 1.0$	$5.7^{b} \pm 1.4$	$6.8^{ab} \pm 1.2$
	OD with salt	$7.1^{a} \pm 1.0$	$7.2^{a} \pm 0.8$	$7.7^{a} \pm 0.8$	$7.5^{a} \pm 1.1$	$6.3^{a} \pm 1.2$	$7.6^{a} \pm 0.9$

Value are average scores (means ± standard deviation) of 30 panellists. Means followed by a different superscript letter within the same column indicated that there was a significant difference in the sensory acceptability of the differently treated dried sample during the three months of storage ($p < 0.05$). Oven dried chayote without any pre-treatment; OD - Osmotically-dehydrated. n=9. Fresh (control)* values obtained for each month of sensory evaluation during storage were similar as indicated in table 3 and 4.

During the three months of storage, there was no significant change in acceptability scores of appearance, colour and aroma in the dried chayote due to the closed zip lock bags which perfectly sealed the product thus preventing entry of oxygen. Dehydrated fruit and vegetable packaging must demonstrate that the material is an effective barrier against water vapor as well as, depending on the specific product, against O_2, SO_2, and other volatiles. Oxygen interaction also has an effect on the Maillard reaction products (Miranda et al., 2019). Conversely, oxygen is needed for the survival and growth of microorganisms that cause preserved foods and beverages to degrade. Thus, the oxygen content has a significant impact on the preserved food product's quality (Cichello, 2015). In addition, Fasogbon et al. (2013) reported that a combination of osmotic dehydration and air drying produces a variety of shelf-stable fruit products and lengthens the storage life of the product in question.

4. Conclusion

This study evaluated two different drying methods for drying chayote to extend its shelf-life. The use of OD as a pre-treatment before Convective oven dried contributed positively to the nutritional properties (ash, total sugars, starch and dietary fiber), rehydration capacities and the textural properties of dried chayote. The use of salt in osmotic dehydration should be encouraged as it produced the most acceptable dried chayote. Using osmotic dehydration, the shelf life of chayote was improved to at least three months under ambient storage. Dried chayote can promote a good health due the retention of nutrients after drying but also higher consumption can increase the intake of dietary fiber, vitamin C and zinc. Further studies should focus on the antioxidant capacity of the dried chayote. Furthermore, the studies suggest the need to extend the drying technology of osmotic dehydration to others vegetables that suffer high post-harvest losses in order to extent their shelf life.

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Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Informed consent

Obtained.

Ethics approval

The Publication Ethics Committee of the Canadian Center of Science and Education.

The journal’s policies adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

Provenance and peer review

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

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