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Research article

Effect of pretreatments and solar tunnel dryer zones on functional properties, proximate composition, and bioactive components of pumpkin (*Cucurbita maxima*) pulp powder

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ABSTRACT

Pumpkin fruits are large in size and need to be cut into pieces for use. The quality and storage life of cuts rapidly deteriorated. Big size fruits can be converted to shelf stable product to minimize postharvest loss using solar driers. However, drying temperature and RH in long solar tunnel drier not uniform and may affects quality of dried products. Therefore this research work aimed to investigate the effects of pre-drying treatments and solar tunnel dryer zones on the functional properties, proximate composition, and bioactive components of pumpkin pulp powder. Three groups of pumpkin slices were pre-treated in 1% citric acid (20 min), 2% salt (20 min) solutions, and the other group blanched at 65 °C in 1% salt solution (2 min), untreated sample used as a control. Pre-treated samples then dried in three zones of tunnel solar drier (zone I, zone II and zone III). Treatment combinations were laid down in factorial RCBD replicated 3 times. Results showed that pulp powder from salt pre-treated slice and dried at zone III results in the highest values of shrinkage, rehydration ratio, water holding capacity, and bulk density. Moisture content decreased from zone I to III, and with salt blanching in range of 8.2 to 6.4%, no effect in crude fat content, slices pre-treated in 2% salt solution results is better crude protein and fiber contents in zones. Better retention of total polyphones, beta-carotene, ascorbic acid, with high DPPH scavenging activity and lowest IC_{50} values were observed for salt pre-treated sample but dried in zone II of the drier. In general relatively better functional properties, proximate composition and bioactive compounds of the powder can be preserved when slices pre-treated in 2% salt solution and dried in zone II of solar tunnel drier characterized by 54.9 ± 3.7 °C, RH value of 31.4 ± 3.4% and air velocity of 0.45 m/s.

1. Introduction

Pumpkin (*Cucurbita maxima*) is a fruit vegetable native to South America but has been domesticated in several tropical and subtropical countries (Achu et al., 2005). The crop is rich in nutrients, adapts well to local conditions, and grows in a wide range of agro-ecological zones. It has a great economic potential for use both as a food and as a cash crop. It is a good source of vitamin C, minerals, beta and alpha carotenes, dietary fiber, phenolic compounds with good antioxidant potential (Ahmad and Khan, 2019).

The fruit is profoundly rich in minerals, vitamins, pectin, dietary fibers, and vital antioxidants like carotenoids, lutein, and other abundant polyphenolic compounds (Aziah and Komathi, 2009). The fruit pulp is also good source of minerals like potassium, copper, iron, magnesium, phosphorus, and manganese (Nwofia et al., 2012). According to Zhou et al., (2017), β-caroten content, DPPH scavenging capacity, total phenolic contents, vitamin C and E are important constituents of the pulp of the fruit to select among species. From functional point of view, recent studies also show that addition of Pumpkin powder in Yoghurt formulation can reduce the syneresis of the product, increase the nutritional value (Johari et al., 2022), it is also a good candidate for better nutrition, growth and wellbeing of poultry species (Oloyede 2021).

Compared to other perishable crops, the fruit is relatively quite stable after harvest for one to three months (Guiné et al., 2011). Large size local variety Pumpkins (approximately 20–35 kg/fruit), have less consumer acceptance as a fresh vegetable (Mala et al., 2018); difficult for transportation and marketing (Dirim and Caliskan, 2012), but they are good to produce value added shelf stable products. It is also difficult to store for a long period of time in sliced form due to its perishable nature. Particularly after peeling it is susceptible to moisture loss, softening, color

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changes, and microbial spoilage (Sojak et al., 2014). Such problems made pumpkin underutilized vegetables and made it be as poor's man food.

To increase the consumption of pumpkins some attempts have been tried. This includes, processing to obtain juice, puree, pickles, seeds, and drying that allow longer shelf life and convenience (Que et al., 2008). Drying is one of the oldest and very important unit operations, it involves the application of heat to a material to remove free water and make the product more stable by reducing its water activity. It constitutes an alternative to the consumption of fresh fruits and vegetables and allows its use during the off-production season. Besides giving longer shelf life, it brings about a substantial reduction in weight, volume, minimizing packaging, storage, and transportation cost, and enables storability of the product under ambient temperature (Guine ́ et al., 2011).

So far, several methods of drying such as sun drying, convective hot air drying, freeze drying, microwave drying, and vacuum drying have been studied on the quality of pumpkin (Tunde and Ogunlakin, 2013; Sojak et al., 2014; Workneh et al., 2014). In Ethiopia, any of them were not used to preserve pumpkin, now a day, solar drying is attracting many scholars in terms of production of relatively better quality dried products as compared to open sun drying; less expensive running cost as compared to convective, freeze, and other advanced drying methods. Solar dryers are environmentally sound (reduce the emission of carbon to the environment) and save other fuel or electrical energy to generate heat. However, the temperature and relative humidity of the drying medium in long solar tunnel driers are not uniform. Variations in temperature and relative humidity in the drier and sample preparation prior to drying may have an impact on the quality of the product at the end of drying.

Pre-treatment prior to drying is one of the most important factors that have a positive effect on the final product quality in terms of physicochemical properties produced whilst drying. Pre-treatments would help to inhibit the impact of spoilage enzymes, degradation of vitamins, and other health promoting bioactive compounds through reducing oxidative degradation. Reports indicated that use of pre-treatments (blanching and dipping in food grade chemicals: such as citric acid, sodium metabisulfite, and salt)), before drying results in minimum quality degradation (Sathiya et al., 2016). For instance salt dipping treatment combined with low temperature (60 °C) oven air circulation drying is recommended to maintain quality of dried pumpkin slices (Workneh et al., 2014). Furthermore, pre-treatments can extend product shelf life and reduce the drying time of products (Workneh et al., 2014). Workneh and others (2014) also recommended that the need to have optimum solar drying condition combined with salt treatment or blanching. Therefore, this study aimed at to investigate the effect of selected pre-treatments and drier zone in solar tunnel drier to produce better quality of Pumpkin pulp powder.

2. Materials and methods

2.1. Description of experimental site and materials

The study was conducted at Jimma University College of Agriculture and Veterinary Medicine (JUCAVM), Food Science and Postharvest Technology research field, located at 356 km southwest of Addis Ababa at about 70 33″N latitude and 360 57″E longitudes and altitude of 1710 m above sea level (m.a.s.l). The mean annual maximum and minimum ambient temperatures were 26.8 °C and 11.4 °C, respectively, and the average annual maximum and minimum ambient relative humidity were 91.45% and 39.92%, respectively. Local variety Pumpkins (*C. maxima*)

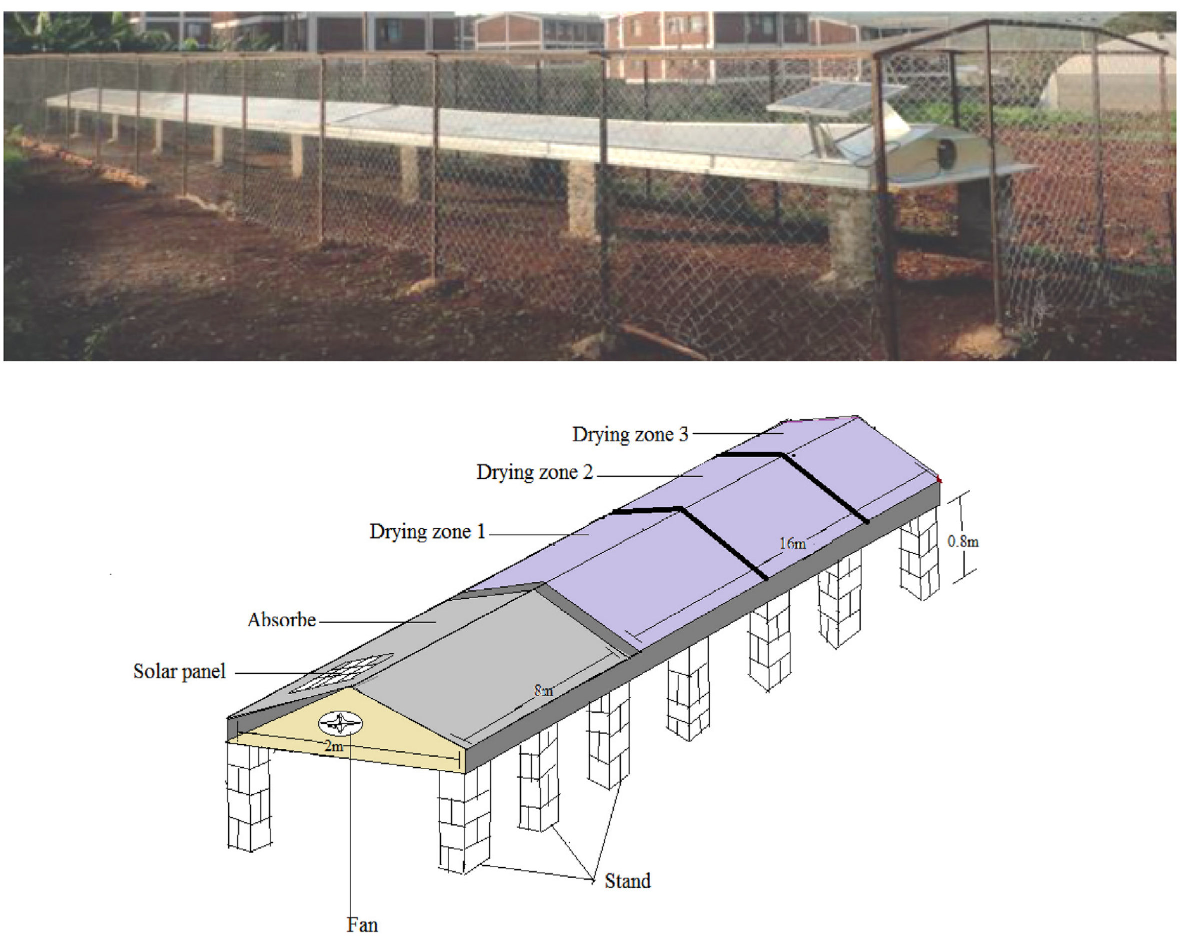

Figure 1. Picture showing tunnel solar tunnel dryer (the absorber is black in color 8 m. long and 2 m wide drier area with length of 16 m).

fruits were purchased from the roadside market of Woliso, Oromia region, Ethiopia.

2.2. Characteristics of solar tunnel dryer

The solar tunnel dryer has a length of 24 m and a width of 2 m (Figure 1). It is laid on brick stands which have a height of 0.8 m. The solar absorber is 8-meters-long and the drying zone is 16 m. The fan located at the entrance of the solar dryer has a capacity of 75 W to suck and push ambient air to the absorber section. The fan operated by power collected from a solar panel (WS 80/85 Mono RHA/D, Germany) attached at the top of the front side of the absorber. The total dryer zone of 16 m subdivided into three zones each having 5.33 m long to categorize as drier zone I, II and III (Figure 1). The temperature and relative humidity were recorded by using data loggers (Testo-184H1, Germany). The data loggers were placed at the inlet of each zone and additional data loggers were placed outside to the drier to record ambient air temperature and relative humidity. Process flow chart showing the production of pumpkin powder from fresh fruit using tunnel solar drier is presented in Figure 2.

2.3. Experimental sample preparation

The experiment was performed by selecting three pumpkins of equal sizes to avoid variation due to size differences. Then the selected ones were washed with sufficient tap water. The clean pumpkins were splinted and the rind, seeds, and peeled were removed using a hand knife manually. Then pumpkin pulps were uniformly sliced into 2 mm thickness using a vegetable slicer Then the slices were treated at a ratio of 1:2 (g of sample to mL of solution) (Aydin and Duigu, 2015); in salt solution (2%) for 20 min (Workneh et al., 2014); in 1% citric acid solution for 20 min (Doymaz and Ismail, 2013) and blanched in (1%) salt solution at about 65 °C (the temperature was checked by glass thermometer) for 2 min (Sathiya et al., 2016). The treated and untreated samples were randomly distributed in three zones of solar tunnel drier. The dried slices were milled into the flour using a laboratory mill (Karl Kolb D-6072 Germany) followed by sieving (0.5mm) to produce fine flour. The dried slices and the flour samples were packed in polyethylene bags for further laboratory tests.

2.4. Solar tunnel drying process

The drying experiment was conducted from April 16 to April 17, 2019, when the condition was full sunny. After preparing the samples and applying pre-treatments; about 0.7 kg of each sample were placed randomly in the three solar tunnel dryer zones. During the drying process temperature and relative humidity of the solar tunnel dryer and the surrounding environment were recorded by using data loggers (Testo-184H1, Germany).

2.5. Experimental design

Two factorial experiments were laid out, considering two factors dryer zones and pretreatments. Three level of solar tunnel dryer zones namely: zone I, zone II and zone III, and four level of pre-drying treatments (untreated (control), 1% citric acid and 2% salt solutions soaked for 20 min and blanched at 65 °C in 1% salt solution) were used. The experiment was laid as a 3 × 4 factorial combination arranged in Randomised Complete Block Design (RCBD) and replicated three times in 36 experimental units.

Figure 2. Process flow chart showing the production of pumpkin powder from fresh fruit using tunnel solar drier.

2.6. Data collected

2.6.1. Shrinkage

Shrinkage (S) of pumpkin was determined according to the method described by Dissa et al. (2010). The percentage of shrinkage of the pumpkin flake was calculated as shown in Eq. (1).

$$S\ (\%) = \frac{V_i - V_f}{V_i} * 100 \quad (1)$$

where S (%) is shrinkage, Vi (cm^3) is the apparent volume of the fresh sample before drying, and V_f (cm^3) is the apparent volume of the sample after drying.

2.6.2. Rehydration ratio

Methods used by Joshi et al. (2009) were followed to determine the rehydration ratio of dried samples. The dehydrated sample (5 g) was taken in a 100 mL beaker and 50 mL water was added to it. The contents were heated to boil for 5 min. The excess water was taken out and drained using laboratory tissue paper. Then, weight was recorded by using an analytical balance, and the ratio was calculated as indicated in Eq. (2).

$$RR = \frac{\text{Weight of dehydrated sample}}{\text{Drained weight of the rehydrated sample}} \quad (2)$$

where RR = rehydration ratio.

2.6.3. Bulk density

The bulk density (BD) of the powder was determined according to the method described by Makinde and Ladipo (2012). The bulk density (g/mL) was calculated as the weight of the flour (g) divided by flour volume (mL) as indicated in Eq. (3).

$$BD\left(\frac{g}{mL}\right) = \frac{\text{Weight of dried sample}}{\text{Volume of dried sample after tapping}} \quad (3)$$

2.6.3.1. Water hydration capacity (WHC).

Water hydration capacity was determined using the method of Robertson et al. (2000). The Water hydration capacity/mL/g) were calculated by using Eq. (4)

$$WHC\ \ (mL/g) = 10 - \text{Supernatant} \quad (4)$$

where WHC = water hydration capacity, g is gram and mL is a milliliter.

2.6.3.2. Water solubility index.

The water solubility index was determined following the method of Robertson et al. (2000). The percentage of residue, with respect to the amount of pumpkin powder used in the test, was taken as water solubility, with the formula given in Eq. (5).

$$\textit{Water solubility}(\%) = \frac{WR}{WS} * 100 \quad (5)$$

where: WR = Weight of Residue after and WS = weight of sample.

2.6.4. Determination of proximate composition

The proximate composition of pumpkin pulp powder was determined using standard analytical methods of AOAC (2010) (methods for moisture (925.09), ash (923.03), dietary fiber (993.21)), fat (920.85), and protein (960.52)).

2.6.5. Bioactive components determination

2.6.5.1. Beta (β) carotene.

Extraction of total beta carotene content was following the method described by Rodriguez-Amaya et al. (2008). Absorbance was read at 450 nm using UV–Vis spectrophotometer (T80 Jiangsu, China) and estimated against with concentration of *β*-carotene standard curve (Sigma-Aldrich).

2.6.5.2. Determination of total phenolic content.

The total polyphenol contents were determined according to Wolde et al. (2014) which involved the reduction of Folin-Ciocalteu reagent by phenolic compounds. Absorbance of extracted samples was measured at 765 nm using a UV–Vis spectrophotometer (T80 Jiangsu, China). Gallic acid was used as the standard, and the total phenolic contents were expressed as mg of gallic acid equivalent (GAE) per 100 g of sample (mg GAE/100 g sample).

2.6.5.3. L-ascorbic acid.

The L-ascorbic acid content of powder was determined by the 2, 6-dichloroindophenol visual titration method according to (Pancham et al., 2020). The first extracting solution was prepared from 15 g of met phosphoric acid (HPO_3) and 40 mL acetic acid (Ac) which made a total of 500 mL with deionized water. About 2.00 g of sample powder was extracted with 50 mL of in the prepared extracting solution, following filtration with what man No 1. Filter paper. The extracted sample was titrated against the standard indophenol solution which was prepared by dissolving 50 mg of 2,6-indophenol sodium salt containing 42 mg of $NaCO_3$ to 200 ml deionized water to a light pink color and calculated using Eq. (6).

$$L - \text{Ascorbic acid}\ \ (mg/g) = \frac{(A - B) * C * 50}{10S} \quad (6)$$

where:

A = volume in ML of 2, 6-dichloroindophenol sodium salt solution used for the sample.

B = volume in ml of 2, 6-dichloroindophenol solution used for the blank.

C = Mass in mg of L-ascorbic acid equivalent to 1.0 ml of indophenol solution

S = weight of the sample (g)

50/10: 50 = volume of extract and 10 = volume of extract used for titration.

2.6.5.4. Antioxidant activity potential and IC50 capacity.

DPPH *(2,2′-diphenyl-1-picrylhydrazyl)* scavenging activity of the methanolic extract of the sample was determined according to the procedure of Wolde et al. (2014). Scavenging capacity was read spectrophotometrically (UV–Vis spectrophotometer (T80 Jiangsu, China) by monitoring the decrease in absorbance at 517 nm. The percentage of absorbance was calculated according to Eq. (2). The scavenging activity was expressed as the 50% effective concentration (IC_{50}), which was defined as the sample concentration (mg) necessary to inhibit the DPPH radical activity by 50% calculated from the graph of DPPH scavenging activity percentage against extract concentration.

$$\text{Antioxidant activity}\ \ (\%) = \frac{AB_{(C)} - AB_S}{AC} * 100 \quad (7)$$

where $Ab_{(C)}$ is the absorbance of control $AB_{(S)}$ is the absorbance of the sample.

2.7. Statistical analysis

Then the effect of solar tunnel dryer and pretreatments on drying on the quality of pumpkin pulp powder was analyzed using Minitab version 16 whereas ANOVA of a 3 × 4 factorial design for identifying the presence of a significant difference or not. Differences between the samples mean were conducted using Tukey's test at $\alpha = 0.05$ level of significance.

3. Results and discussion

3.1. Temperature and relative humidity in solar tunnel dryer

The temperature and relative humidity of different drier zones are presented in Table 1. The average temperature of zone I, II, III, and ambient were 45.6 ± 3.4, 54.8 ± 3.7, 64.9 ± 6.2 and 28.9 ± 2.5 °C

Table 1. Average temperature, velocity and relative humidity at three zones and ambient recorded during drying.

Zones of drier	Average temperature (°C)	RH (%)	Air velocity (m/s)
Ambient	28.3 ± 2.5	45.7 ± 5.7	0.30
Zone I	45.6 ± 3.4	34.6 ± 3.6	0.55
Zone II	54.9 ± 3.7	31.4 ± 3.4	0.45
Zone III	65.0 ± 6.2	24.2 ± 9.4	0.43

Note: for both temperature and relative humidity the minimum values were observed in the morning (10:00 PM) whereas maximum values were observed from 12:00–15:00 AM. The sample mean expressed ±standard deviation.

respectively whereas the average relative humidity was recorded as 34.6 ± 3.7, 31.4 ± 3.4, 24.2 ± 9.4 and 45.8 ± 5.7% for zone I, II, III, and ambient air during drying respectively. As the air moved from dryer zone I, to zone III, an increase in its temperature and reduction of relative humidity were observed.

3.2. Physical and functional properties

The interaction effect of solar tunnel dryer zones and pretreatments has a significant effect on physical and functional properties such as; shrinkage, bulk density, water hydration capacity, and water solubility index as indicated in Table 2. The lowest values of shrinkage, bulk density, water hydration capacity, and water solubility index were recorded for the control samples dried in drying zone I. This implies that, both pretreatment and drying zone II and III had an impact in terms of modifying the physical and functional properties of pumpkin powder. Results in this work for functional and physical parameters were in line with what reported by Aydin and Duygu (2015). However, blanched samples in salt solution and dried in zone III results in highest value of shrinkage, bulk density, water hydration capacity, and water solubility index. The higher air temperature combined with lowest relative humidity in zone III of the drier with salt blanching could partial damaged the intact tissue structures of the slices for inferior results of functional parameters the powder.

Both pre-treatment and drier zones showed a significant difference ($p < 0.05$) on shrinkage change. The lowest shrinkage was observed for control sample and the percentage of shrinkage increases with pre-treatment and drier zone. As indicated in Table 2, the highest shrinkage change salt blanched samples in all drier zones, however, the highest was in zrier zone III. The removal of water during the drying of biological products leads to cellular structural modifications due to reduced tension inside the cells and causes alterations in the shape and dimension of products including volume shrinkage (Brasiello et al., 2017). In similar work it is indicated that the shrinkage of dried products depends on structural deformation during the dehydration process (Mahiuddin et al., 2018). This highly affected by drying air temperature and relative humid which might be associated variation these parameters among drier zones. Onwude and others (2016) indicated that the migration of free water has little effect on material shrinkage; however, transport of intracellular and cell wall water strongly affects the material shrinkage, pore formation and collapse of the cell during drying.

Rehydration is the process of refreshing the dried material in water prior to consumption. The rehydration characteristics indicate the physical and chemical changes during drying as influenced by processing conditions, sample pretreatment, and composition (Feng and Tang, 1998). The lowest value of RR of pumpkin powder was recorded for the control sample. This might be due to the exposure of the sample at low temperature, higher relative humidity, and absence of pretreatment of the samples prior to drying. The highest RR value of pumpkin powder was obtained for the sample pretreated with salt blanched and dried in drying zone III. This may be associated with the lower residual moisture content of the dried slices exposed to a higher temperature which could allow re-hydrating more as compared to samples with relatively higher moisture content. The RR of the pumpkin slice was found between 5.91 and 7.06, which is higher as compared to papaya (4.1) and mango (3.93) pulp powders dried in a solar tunnel dryer (60 °C) (Ghan et al., 2014).

The WHC of pumpkin powders from different treatment combinations varied from 4.29 (mL/g) and 6.41 (mL/g). The lowest value recorded for the control sample with no-pre-treatment. From the result of this study it is observed that there was an increase in WHC for samples dried from zone I to zone III. This might be associated with an increase in drying temperature as indicated in Seifu et al. (2018). The higher drying temperature could modify certain tissue structures of samples and could enhance the hygroscopic behavior and WAC ((Udensi, 2006). The higher the fiber content of pumpkin powder might contribute for high WHC. An increase in WHC of pumpkin powder with an increase its proportion in food formulations also reported in different works (Adubufor et al., 2018; Eke-Ejiofor and Victor-Uku, 2021). The higher the value is the better since it is an indication of the amount of water available for gelatinization to use the powder in aqueous food formulations.

Water solubility index (WSI) is one of the most utilized parameters to verify the capacity of a powder to remain in a homogenous mixture with water (Sango et al., 2019). Both pre-treatment and drier zones showed s significant difference ($p < 0.05$) in WSI. In all drier zones both citric acid and salt treated samples showed relatively better WSI values

Table 2. Mean of shrinkage (S) in, Rehydration ratio (RR), bulk density (BD), water hydration capacity (WHC), and water solubility (WSI) of pumpkin powder obtained from combination of drier zones and pretreatments.

Zones	Pretreatment	S (%)	RR	WHC (mL/g)	WSI (%)	BD (g/L)
Zone I	C	32.58 ± 0.05^{i}	5.91 ± 03^{c}	4.29 ± 0.04^{h}	29.2 ± 0.002^{h}	0.52 ± 0.006^{g}
	CA	34.6 ± 0.3^{h}	5.96 ± 0.01^{c}	5.55 ± 0.04^{de}	42.1 ± 0.02^{a}	0.68 ± 0.003^{e}
	S	41.04 ± 0.03^{f}	6.08 ± 0.07^{c}	4.69 ± 0.03^{g}	40.8 ± 0.05^{b}	0.67 ± 0.009^{e}
	SB	46.33 ± 0.1^{e}	6.15 ± 0.07^{c}	5.51 ± 0.08^{de}	33.7 ± 0.5^{f}	0.70 ± 0.01^{de}
Zone II	C	47.09 ± 0.5 ^{de}	6.08 ± 0.3^{c}	5.12 ± 0.03^{f}	27.4 ± 0.2^{i}	0.53 ± 0.003^{fg}
	CA	37.26 ± 0.3^{g}	6.16 ± 0.01^{c}	5.85 ± 0.04^{c}	40.3 ± 0.004^{bc}	0.72 ± 0.006^{cd}
	S	48.08 ± 0.4^{d}	6.32 ± 0.03^{bc}	5.70 ± 0.02^{cd}	37.8 ± 0.1^{d}	0.69 ± 0.007^{de}
	SB	54.51 ± 0.02^{b}	7.02 ± 0.08^{ab}	5.81 ± 0.02^{c}	31.1 ± 0.07^{g}	0.74 ± 0.001^{bc}
Zone III	C	52.22 ± 0.3^{c}	6.61 ± 0.02^{abc}	5.34 ± 0.07^{ef}	25.7 ± 0.01^{j}	0.56 ± 0.003^{f}
	CA	51.93 ± 0.6^{c}	6.43 ± 0.02^{abc}	6.15 ± 0.06^{b}	39.5 ± 0.2^{c}	0.74 ± 0.006^{bc}
	S	52.65 ± 0.2^{c}	6.62 ± 0.3^{abc}	6.22 ± 0.03^{ab}	35.8 ± 0.6^{e}	0.75 ± 0.003^{ab}
	SB	65.06 ± 0.9^{a}	7.06 ± 0.01^{a}	6.41 ± 0.009^{a}	28.2 ± 0.01^{hi}	0.78 ± 0.002^{a}
	CV (%)	1.16	2.56	1.12	2.43	1.34..

Values expressed are mean values of three replicates ±standard error. All mean scores, bearing different superscript in columns differ significantly ($P \leq 0.05$). C=Control, S=Salt treated, SB = Salt blanched, CA = Citric acid treated.

(35.8–42.1%) as compared with control and salt blanched ones (25.7–33.7%) (Table 2). However, when drier zones considered, with a move from zone I to zone II the WSI showed a decreasing trend. This may be due to decomposition of starch with an increase in drying temperature from zone I to II since water solubility reflects the extent of starch degradation (Que et al., 2008). This result was in close agreement with Roongruangsri and Bronlund (2016) who reported that WSI of 54, 50, and 43% for pumpkin flour dried at temperature of 50, 60, and 70 °C. Aydin and Gocmen (2015) also reported WSI of pumpkin flour for oven-dried (21.22%) and freeze dried (4.0%) samples showing the significant impact of drying temperature in terms on WSI.

Bulk density (BD) is a measure of the heaviness or lightness of dried powder sample. The value of BD was in the range of 0.52–0.78 (g/mL) due to combined effect of pre-treatment and zones of drier. Pre-treatment showed relatively little impact on BD as compared to zones of drier. The highest BD value was observed for samples dried in zone II after salt pre-treatment and salt blanching of slices. An increase in shrinkage contributed for decrease in volume and results in an increase in BD. Results indicated in this study slightly lower than BD of hot air-dried pumpkin powder (0.62–0.91 g/mL) (Roongruangsri and Bronlund 2015). However, the values were higher than freeze-dried (0.33 (g/mL)) and hot air-dried (0.59 (g/mL)) pumpkin flour as reported by Que et al. (2008). The difference might be associated with varietal difference, agronomic practices and drying conditions. However, both high and low bulk density of powders suggests their suitability for use in food preparations (Chandra et al., 2015).

3.3. Proximate composition of pumpkin pulp powder

The mean proximate composition of pumpkin powder obtained from a combination of drying zones and pretreatments is presented in Table 3.

3.3.1. Moisture content (MC)

The lower optimum MC is an indication of the better storage stability of the powder under proper packaging and storage conditions. The combined pre-treatment and drier zone temperature and RH leads to a high reduction in MC of samples from 90.63% of the pulp to 6.4–8.2% of the powder. Both pre-treatment and drier zones showed significant effect ($p < 0.05$) to reduce the MC. Pre-treated samples showed better moisture reduction as compared with the control. In addition to pre-treatment effects a reduction trend in MC was observed from drier zone I to III. The lowest value of moisture content was recorded for the pumpkin powder produced from salt blanched and dried in zone III. Relatively higher heat exposure of samples during salt blanching and exposure in zone III. The combined effect could contribute for tissue modification and relatively release of extra moisture from the samples as compared with others. MC of samples in this study is slightly lower than results reported by Sathiya et al., (2016), 6.40% for untreated and 13.8% for steam blanched both dried at 55 ± 2 °C. However, the values in this study are sufficient enough to ensure relatively stable storage.

3.3.2. Total ash

Total ash refers to the inorganic residue remaining after complete oxidation of organic matter. It is an important quality attributes for some food ingredients (Ismail, 2017) since it is correlated with minerals content of the food. The values in this study are significantly affected by both factors and varied in the range of 4.7–6.1%. Samples pre-treated with citric acid solution results in better total ash content for samples dried in zone I and II. This might be due to osmotic balance maintained by citric acid solution to minimize the leakage out of minerals from the pumpkin slice during soaking. However, the values in this study were approximately the same as for the pumpkin powder (4.7%) as reported by Baltacıoğlu and Ülker (2017), less than the value of 7.31% of eggplant flour dried in a tunnel dryer and 6.47% dried in the oven as reported by Rodriguez-Jimenez et al. (2018). Citric acid-treated pumpkin powder showed a decrease in total ash from 6.2% to 5.1% when dried in zone I and zone III respectively. Excluding control and salt (2%) pretreatments, this pattern also works for salt-blanched treated samples.

3.3.3. Crude fat

Crude fat in a food determines the amount of energy available in addition to its role to contribute essential fatty acids. A diet providing 1–2% of its caloric energy as fat is said to be sufficient for human beings. Unlike other proximate compositions both pre-treatments and drier zone showed no significant difference ($p > 0.05$) in crude fat content except the control sample in zone I. Lesser impact of different drying methods in crude fat content of pumpkin powder also indicated in Lim et al. (2021). In addition to this the recent work of Carlos and others (2021) confirmed that drying temperature from 55 to 70 °C showed no significant effect ($p < 0.05$) on crude fat content for both fresh and heat pretreated pulp. This implies that crude fat of pumpkin powder has relatively stable for optimum drying temperatures of biological materials and pre-treatment conditions.

3.3.4. Crude fiber

Dietary fiber has recently gained much importance since it can reduce the incidence of cardiovascular and certain digestive diseases. The value of Crude fiber was obtained in the range of 4.7–5.0%. Both pre-treatments and drier zone showed significant effect on crude fiber

Table 3. Mean proximate composition of pumpkin of pumpkin powder obtained from combination of drier zones and pretreatments.

Zone	Prtm	Moisture content (%)	Total Ash (%)	Crude Fat (%)	Crude Fiber (%)	Crude Protein (%)	Utilizable carbohydrate (%)
Zone I	C	8.22 ± 0.03^{a}	5.90 ± 0.06^{b}	0.81 ± 0.01^{b}	4.91 ± 0.03^{cd}	3.23 ± 0.01^{e}	77.5 ± 0.07^{f}
	CA	6.89 ± 0.02^{g}	6.14 ± 0.006^{a}	0.99 ± 0.05^{ab}	4.88 ± 0.1^{cd}	2.83 ± 0.02^{e}	76.4 ± 0.08^{g}
	Sl	7.24 ± 0.05^{de}	5.00 ± 0.03^{g}	0.96 ± 0.06^{ab}	5.03 ± 0.2^{a}	3.70 ± 0.07^{b}	77.9 ± 0.1^{f}
	SB	6.65 ± 0.02^{h}	5.72 ± 0.05^{bcd}	0.97 ± 0.03^{ab}	5.04 ± 0.04^{a}	2.94 ± 0.03^{f}	78.5 ± 0.124^{e}
Zone II	C	7.75 ± 0.02^{b}	$5.62 \pm .05^{cd}$	0.96 ± 0.04^{ab}	4.84 ± 0.4^{d}	3.71 ± 0.02^{b}	79.0 ± 0.2^{cde}
	CA	7.40 ± 0.06^{cd}	5.79 ± 0.03^{bc}	1.01 ± 0.05^{ab}	4.89 ± 0.1^{cd}	3.59 ± 0.01^{bc}	78.7 ± 0.06^{de}
	Sl	7.14 ± 0.08^{ef}	$5.6 \pm 0.04d^{e}$	1.03 ± 0.03^{a}	5.98 ± 0.09^{ab}	4.23 ± 0.05^{a}	78.8 ± 0.2^{cde}
	SB	7.57 ± 0.02^{bc}	5.42 ± 0.008^{ef}	0.97 ± 0.006^{ab}	5.96 ± 0.2^{ab}	2.98 ± 0.02^{f}	79.2 ± 0.1^{cd}
Zone III	C	7.00 ± 0.04^{fg}	5.57 ± 0.01^{de}	0.91 ± 0.02^{ab}	4.69 ± 0.07^{e}	2.52 ± 0.02^{g}	80.5 ± 0.1^{b}
	CA	6.76 ± 0.04^{gh}	5.06 ± 0.04^{g}	0.99 ± 0.02^{ab}	4.89 ± 0.2^{cd}	3.21 ± 0.01^{e}	81.4 ± 0.02^{a}
	Sl	$6.96 \pm 0.04f^{g}$	4.70 ± 0.02^{h}	1.01 ± 0.01^{ab}	4.87 ± 0.2^{bc}	3.45 ± 0.02^{d}	79.3 ± 0.1^{cd}
	SB	6.38 ± 0.04^{i}	5.31 ± 0.01^{ef}	0.89 ± 0.05^{ab}	4.87 ± 0.2^{cd}	3.53 ± 0.03^{cd}	79.3 ± 0.1^{c}
	CV(%)	1.02	1.00	6.26	6.42	1.20	0.25

Values expressed are mean values of three replicates ±standard error. All mean scores, bearing different superscripts in columns differ significantly ($P \leq 0.05$); C: control, CA: citric acid treated Sl: Salt treated, SB: Salt blanched.

content (Table 3). The better crude fiber was observed for salt pre-treated and samples blanched in salt solution and dried in zone I and II. Controlled sample dried in zone III showed the lowest value in crude fiber content. Values observed in this work were less than the value reported by Sathiya et al. (2016), with a crude fiber content of 6.58 (control) and 12. 01 % (hot water blanching) pumpkin slices. In contrary to this similar work on pumpkin showed that the insignificant effect of drying temperature on crude fiber content of pumpkin powder (Carlos et al., 2021). The World Health Organization (WHO) has recommended an intake of 22–23 g of fiber for every 1000 kcal of diet (Kanwar and Shah, 1997). Accordingly consumption of 100 g pumpkin powder from our study could supply close to 25% of the recommended amount according to WHO.

3.3.5. Crude protein

Like other vegetables crude protein content of pumpkin pulp powder as such not significant. However, the existing small amount is significantly affected by pre-treatment and drier zones.

As indicated in Table 3, the values were ranged from 2 .43 %–4.23%. Better results observed for salt pre-treated sample but dried in drier zone II (4.23%) and the lowest for control sample dried in zone III. This might be the higher the drying temperature in zone III results in degradation or denaturation of available protein. The trend of crude protein values was similar to those obtained by Lydia and Zinash (2017) who studied the effect of pretreatments and drying methods on some qualities of dried mango fruit. However, according to recently conducted study drying temperature showed no significant effect on pumpkin powder (Carlos et al., 2021). The variation among different studies might be due to variation in genetic makeup, pre-drying treatments and drying methods and conditions applied. However, according to this study better crude protein of pumpkin powder can be preserved in zone II of the drier after treatment with salt solution.

3.3.6. Utilizable carbohydrate

The values of the utilizable carbohydrate content of dried powder of pumpkin ranged from 76.4 to 81.4%. Both the maximum and minimum values were obtained for the sample pretreated in citric acid and dried in zone III and zone I respectively. The probable reasons for carbohydrate difference may arise from changes in other components such as moisture content, fiber, fat, ash, and protein. Previous findings by Pongjanta et al. (2006) reported 78.77 % of carbohydrates for hot air (65 °C) dried pumpkin flour which was within a range of present results.

3.4. Bioactive components of pumpkin pulp powder

The mean of Total Phenolic, β-carotene, Ascorbic acid, and antioxidant activity of pumpkin powder obtained from the combination of drying zones and pretreatments are presented in Table 4.

3.4.1. Extractable phenolic content (EPC)

Phenolic compounds are currently receiving much attention because of their beneficial health effects related to their antioxidant, anti-inflammatory, cardioprotective, cancer chemo-preventive, and neuro-protective properties (Landete, 2013). Both pre-treatment and drier zones showed significant difference in EPC values as indicated in Table 4. Citric acid and salt pre-treated samples showed better EPC preservation as compared with the control and salt solution blanched samples. This might be associated with protective nature of the solutions as compared with the control. The heat effect during salt solution blanching could negatively contribute for degradation and reduction of EPC. Among drier zones, a sample drier in zone II showed better retention. In particular the highest EPC value (286.43 mgGAE/100 g) was recorded for salt solution pumpkin slice and dried in zone II. The relative milder temperature and relative humidity in zone II might contribute for better result. However, the decrease I the value as compared with fresh sample might be associated with the effect of drying temperature in different zones of the drier. This is the trade-off to produce the shelf stable powder by minimizing the potential postharvest loss.

3.4.2. Beta-carotene

Beta-carotene, is a fat-soluble pigment, lipophilic radical scavenger, and has a protective function against oxidative damage and pre-cursor for vitamin A synthesis in our body. Both treatment factors showed significant impact ($p < 0.05$) on beta-carotene contents. Regardless of drier zones pre-treated samples showed better beta-carotene retention as compared to the control. Particularly powders from citric acid and salt solution showed better retention of the compound. This might be due to protective nature of the pre-treatment solutions from oxidative damage of the compound during drying process as compared to the control. Drier zones also showed a significant difference with better retention in zone II followed by zone III. Similar to most of other parameters drier zone II results in better retention of quality parameters might be associated with optimum drying temperature and relative humidity. Studies show that beta-carotene is sensitive to heat, oxygen, light, and enzymes (Rawson et al., 2011) and a relative increase in drying temperature in zone III

Table 4. Mean of Total Phenols, β-carotene, Ascorbic acid, DPPH scavenging activity and IC_{50} values of pumpkin powder obtained from combination of drier zones and pretreatments.

Zone	Prtm	Extractable Phenolic Content (mg GAE/100 g d.w)	β-carotene (mg/100 g d.w)	Ascorbic acid (mg/100 g d.w)	DPPH scavenging activity and IC_{50} values	
					% Inhibition	IC_{50}
zone I	C	99.59 ± 3.9^{e}	25.45 ± 0.8^{i}	12.74 ± 0.07^{hi}	44.0 ± 0.45^{i}	5.20 ± 0.2^{b}
	CA	182.52 ± 4.6^{bcd}	38.96 ± 0.7^{e}	17.35 ± 0.02^{e}	59.6 ± 0.54^{ef}	3.16 ± 0.5^{de}
	Sl	164.63 ± 5.5^{cd}	42.50 ± 0.1^{d}	22.77 ± 0.2^{b}	72.40 ± 0.5^{b}	2.21 ± 0.1^{fg}
	SB	152.40 ± 6.7^{cde}	31.43 ± 0.2^{g}	18.34 ± 0.2^{d}	66.9 ± 0.26^{d}	2.61 ± 0.1^{ef}
zone II	C	237.36 ± 4.6^{ab}	33.08 ± 0.6^{g}	14.61 ± 0.2^{g}	57.0 ± 0.1^{f}	3.42 ± 0.3^{d}
	CA	241.07 ± 5.1^{bc}	47.71 ± 0.2^{b}	18.93 ± 0.1^{cd}	61.6 ± 0.12^{e}	2.62 ± 0.08^{ef}
	Sl	286.43 ± 4.8^{a}	52.36 ± 0.2^{a}	24.15 ± 0.1^{a}	79.60 ± 0.28^{a}	1.70 ± 0.01^{g}
	SB	208.00 ± 4.9^{bc}	35.60 ± 0.1^{f}	19.57 ± 0.07^{c}	70.6 ± 0.36^{c}	2.30 ± 0.04^{fg}
zone III	C	131.13 ± 3.0^{de}	29.27 ± 0.6^{h}	12.17 ± 0.02^{i}	38.8 ± 0.52^{j}	6.12 ± 0.2^{a}
	CA	207.41 ± 3.5^{bc}	44.70 ± 0.3^{c}	13.11 ± 0.2^{h}	48.0 ± 0.65^{h}	4.47 ± 0.2^{bc}
	Sl	201.37 ± 5.1^{bc}	51.33 ± 0.1^{a}	15.33 ± 0.1^{f}	53.5 ± 0.12^{g}	3.67 ± 0.03^{d}
	SB	177.60 ± 6.9^{bcd}	42.40 ± 0.2^{d}	14.18 ± 0.02^{g}	52.5 ± 0.09^{g}	3.72 ± 0.08^{cd}
	Fresh	314.72 ± 3.3	63.4 ± 0.06	33.86 ± 0.08	82.67 ± 0.18	1.15 ± 0.03
	CV(%)	4.56	1.52	1.2	1.60	6.50

Values expressed are mean values of three replicates ±standard error. All mean scores, bearing different superscripts in columns differ significantly ($P \leq 0.05$). C=Control, Sl = Salt treated, SB = Salt blanched, CA = citric acid treated.

could contribute for reduction in concentration. The negative impact of drying temperature on pumpkin powder beta-carotene content also indicated in the work of Warawaran and Bronlund (2016). They reported a 56% reduction for sample powder dried at 70 °C. The recent work of Carlos et al. (2021) also confirmed that enhanced degradation of beta carotene with an increase in drying temperature from 55 to 70 °C. As compared to similar work of Sojak, (2014), better retention of beta-carotene was observed in this study. Further report by Prakash et al. (2004) observed maximum β-carotene content was retained in carrots dried by air drying at 50 °C, when compared with the product dried by a microwave oven or a solar cabinet dryer, with the latter presenting the higher loss.

3.4.3. L-ascorbic acid

L-ascorbic acid is an essential exogenous nutrient, mainly available from fruits and vegetables that play an important role in human development and health. It is considered as an indicator of food processing quality because of its low stability during thermal treatments (Podsędek, 2007). The values of l-ascorbic acid in pumpkin powder of this study varied in the range of 12.17–24.15 (mg/100 g d.w). Both pre-treatment and drier zones imparted significant effect on l-ascorbic acid content. In all drier zones, pumpkin powder from salt solution exhibited better ascorbic acid content (24.15 mg/100 g d.w). Drier zone II and I provided better ascorbic acid retention with combined use of salt solution as a pre-treatment. Control samples showed the lowest value (12.17 mg/100 g d.w) which might be associated with lack of protection of ascorbic acid oxidative degradation.

When drier zones compared the highest degradation of ascorbic acid was observed in zone III followed by zone I and II. For instance samples from salt solution exhibited $24.15 + 0.1$, 22.77 ± 0.2 and 15.33 ± 0.1 mg/100 g d.w for direr zone II, I and III respectively. The significant reduction in zone III might be correlated with relative higher drier medium temperature as compared to others. In similar pattern a recent study showed that, as the drying temperature increases the retention of ascorbic acid significantly decreased (Mengyun et al., 2021). However, as compared with other studies for a similar crop, the loss of l-ascorbic acid in this study was lower than what was reported in Henriques et al. (2012). They estimated a reduction of 91.3%, 92%, and 92.7%, of ascorbic acid in cucumber for tunnel drier (60 °C), chamber dryer (40 °C) and chamber dryer (60 °C) respectively. In similar work l-ascorbic acid content of pumpkin powder of 3.0–5.0 mg/100g also reported (Workneh et al., 2014) which is by far lower than what reported in this study.

3.4.4. Antioxidant activity

Antioxidant activity is a quality parameter often determined in dried vegetables, is mainly related to the presence of vitamins and polyphenols (Landete, 2013). IC_{50} value was determined from the plotted graph of scavenging activity against various concentrations of extracts, which is defined as the efficient concentration of antioxidant necessary to decrease the initial DPPH radical's concentration by 50% and presented together with percent inhibition.

Similar to other parameters both pre-treatment and drier zones significantly influenced ($p < 0.05$) the antioxidant potential of the powders. In all three drier zones powder samples from pre-treated salt solution ensured better antioxidant activity as compared with others (Table 4). When drier zones compared better activity was observed in drier zone II > zone I > zone III. The maximum percent inhibition values (72.40%) of pumpkin powder were produced from salt treated and dried in zone II. Whereas the minimum values (44.0%) was for pumpkin powder prepared from the control sample and dried in a zone I. The result of this study is in agreement with what reported by Carlos et al. (2021). In similar pattern the antioxidant capacity of pumpkin powder increased with an increase in drying temperature from direr zone I to II. They indicated that an increase in total antioxidant capacity of pumpkin powder with an increase in drying temperature. However, their result also in disagreement in drier zone III. Drying medium temperature in zone III relatively higher than that of drier zone II, but the antioxidant potential of the powders from different pre-treatments showed a decreasing trend.

4. Conclusion

Both pretreatment of pumpkin slices before drying and solar tunnel drier zones showed a significant effect on functional properties, proximate composition, and bioactive compounds. Among pretreatment methods pumpkin powder from 2% salt pretreatment showed better results for most of measured parameters. Long tunnel solar drier exhibited non-uniform drying conditions and rate along the drier length. This has a limitation in terms of determining similar drying time and to maintain the desired quality parameters for samples dried at different zones of the drier. Samples dried in zone I and III showed inferior results for most of measured quality parameters as compared to zone II of the drier. However, drier zone II provided better results for most of investigated quality parameters. According to tunnel solar drier used for this study, zone II characterized by drying air medium temperature of 54.9 ± 3.7 °C, relative humidity of 31.4 ± 3.4 % and air velocity of 0.45 m/s. Therefore it is necessary to create this drying condition throughout the tunnel drier zones through developing a mechanism to mix the drying air medium. Best results can be obtained for most of studied quality parameters if drier zone II condition is combined with pretreatment of 2% salt solution of pumpkin slices.

Declarations

Author contribution statement

Hayat Hassen Mohammed; Yetenayet Bekele Tola; Addisalem Hailu Taye; Zeneba Kedir Abdisa: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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