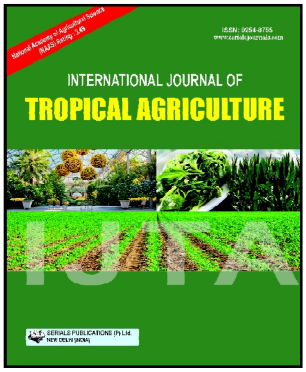

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Use of Vacuum Frying Technology for the Development of Strawberry Chips

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Abstract: Strawberries are perishable commodities having a very short shelf life. In the present study, vacuum frying technology was used for the development of chips from strawberries. Strawberries were cut in two halves and were vacuum fried as such as well as after freezing at -18ºC for 24 h. The vacuum frying was done at 90ºC for 35 min at 13.33 kPa. The chips were packed in metalized polyester pouches and kept for storage at ambient temperature. The samples were periodically analyzed for various physico-chemical and sensory attributes during storage. Freezing pretreatment significantly (p<0.05) reduced oil uptake and showed better retention of anthocyanin, total phenolics, flavonoids and antioxidant activity as compared to the control samples. The vacuum fried strawberries showed 22.32% fat, 5.53% moisture, 4.91% protein and 3.27% ash. Total phenolics, flavonoids and anthocyanin content were found to be 108.52 mg/100g gallic acid eq., 14.22 mg/100 g catechin eq. and 87.03 mg/100g, respectively. Sensory parameters like texture and color were found to be significantly (p<0.05) higher in the frozen and vacuum fried strawberries with higher overall sensory acceptability. The chips showed a shelf life of 3 months under ambient storage conditions. The developed process protocol could be used for commercialization by small or medium scale industries for making vacuum fried strawberry chips.

Keywords: Vacuum frying, Strawberry, Pre-treatment, Shelf-life, Quality

INTRODUCTION

Vacuum frying is a comparatively new deep-fat frying technique having advantages over traditional frying. It could be an option for development of novel snacks with superior product quality attributes from different fruits (Da Silva and Moreira 2008). In this, frying is done at reduced pressure well below the atmospheric level which prevents nutritional losses, discoloration and reduced oil absorption (Garayo and Moreira 2002). It plays an incredible role in reducing the formation of acrylamide (a potent toxic substance) which generally tends to occur during high temperature processing (Granda *et al.* 2004). The overall benefits of vacuum frying are basically associated with application of low temperature and low internal pressure along with minimal exposure to oxygen during process. Over the years, several fruits and vegetable commodities have been subjected for vacuum frying. These include banana (Sothornvit 2011), carrots (Dueik*et al.* 2010), apples (Mariscal and Bouchon 2008), sweet potato (Da Silva and Moreira, 2008), Gold kiwifruit (Diamante *et al.* 2011a), Chinese purple yam (Fang *et al.* 2011), Mushroom (Tarzi *et al.* 2011), Pineapples (Lastriyanto *et al.* 2013), Apricot (Diamante *et al.* 2012), pumpkin (Mehrjardi *et al.* 2012) etc. Pretreatments, such as freezing and soaking in maltodextrin (Fang *et al.* 2011; Diamante *et al.* 2011b), use of hydrocolloids (Maity *et al.* 2015), centrifugation (Sothornvit 2011), blanching (Krokida *et al.* 2001a), dehydration, osmotic dehydration (Kim and Moreira 2012), etc. have been found to affect the quality of vacuum fried products.

Strawberry fruit is a good source of antioxidants including vitamins, minerals, phenolics, flavonoids and anthocyanin content. Studies reported that strawberry fruit contain high radical scavenging activity and inhibiting oxidation of low-density lipoproteins in humans. However, strawberries are highly perishable and having short shelf life mainly due to loss of texture and high sensitivity towards microbial attack (Vicente *et al.* 2002; Ayala-Zavala *et al.* 2004; Erkana *et al.* 2008). As such literature is scarce regarding development of vacuum fried strawberry fruit chips. Therefore, this study was undertaken to see the effect of freezing pre-treatment on physico-chemical and nutritional qualities of vacuum fried strawberry chips and their storage stability.

MATERIALS AND METHODS

Raw material, sample preparation and vacuum frying

Fresh ripe strawberry fruits were procured from the local market of Mysore, India and stored below 8ºC overnight. Strawberries were selected manually to avoid physical blemishes and washed with 100ppm chlorine water to remove contamination. Fruits were cut in two halves and divided into 2 parts. First set was kept for freezing at -18°C for 24 h (Model no. URC-H-3402, Mfd. by Cryo Scientific Systems [P] Ltd., Chennai, India), whereas, the second set was used as such for vacuum frying and termed as control (CON).

Pre-treated and CON strawberry slices were fried in vacuum-fryer (Future Tech Foods Pvt. Ltd., Pune, India) using procedure as described by Pandey and Chauhan (2018) (Fig 1). Rice bran oil (120 L) was heated up to 90 ± 2°C followed by loading of samples and the frying chamber was vacuumized up to 13.33 kPa prior frying. The samples were removed after 35 minutes of frying and centrifuged at 750 RPM for 2 min followed by cooling for 5 min at room temperature (Fig 2). Samples were packed in metalized polyester pouches and stored at ambient temperature for further analysis.

Physico-chemical analysis

Proximate composition

The moisture and oil content of the sample was determined gravimetrically by following AOAC (1995) method. Protein content was determined through Kjeldahl method (AOAC 2003) using a nitrogen conversion factor of 6.25. The ash content of sample was also analyzed by burning the sample at 550ºC in a muffle furnace. The carbohydrate content was determined by the difference method. All experiments of the proximate analysis were performed in triplicates and the results were reported on % dry weight basis.

Texture

Textural properties of strawberry chips were analyzed using a Texture Analyzer (TA-Hdi, Stable Micro Systems™ Co, London, UK) fitted with a 25 kg load cell. The Sample was kept in a stable hollow stage with two parallel edges in order to apply load centrally. A 3 point bending rig was used to fracture the sample over a distance of 10 mm where pretest and posttest speeds were 5 mm/s and test speed was 2 mm/s. The firmness was used as a basic property to describe the texture of the samples which was defined as the force at maximum compression from the force deformation curves. Mean values are presented by recording the peak force values of 10 samples of each treatment after deformation test.

Colour

The colour of strawberry fruit chips was measured using tri-stimulus colourimeter (Miniscan XE plus, Model number 45/0-S, Hunter Associates Laboratory Inc., Reston, VA, USA) which was calibrated using white and black standard ceramic tiles before measurement. The total colour change was expressed in terms of L^* value (lightness-darkness), a^* value (redness-greenness), and b^* value (yellowness-blueness). Total color difference (ΔE), was calculated using following equation as described by Velickova *et al.* (2014).

$$\Delta E = \sqrt{[(L^* - L_0^*)^2 + (a^* - a_0^*)^2 + (b^* - b_0^*)^2]} \quad (1)$$

Where, L_0^*, a_0^* and b_0^* color values of control strawberry chips, whereas, L^*, a^* and b^* representing the individual values of pre-treated strawberry chips after vacuum frying.

Total Phenolics, Flavonoids and Anthocyanin contents

Total phenolics (TP) contents of strawberry chips were estimated colorimetrically using Folin-Ciocalteu (FC) reagent (Singleton and Rossi 1965) with 2 g of sample. The absorbance was taken at 750 nm using UV-visible spectrophotometer (Model-1609, Shimadzu Corporation, Tokyo, Japan) against reagent blank. Total flavonoids (TF) were determined according to the method of Zhishen *et al.* (1999). 2 g sample was extracted with 80% ethanol and volume was made up to a known level. The absorbance of the reaction mixture was measured at 510 nm against a reagent blank and results are expressed as mg catechin equivalents per 100 g fresh weight. Anthocyanin contentwas determined according to the procedure described by Ranganna (1986). The absorbance was measured at 535 nm using ethanolic HCL as blank.

Antioxidant activity

DPPH method was used for estimation of anti-oxidant activity (Blois 1958). 1 g sample was taken with 29 ml methanol, shaken vigorously, and centrifuged at 3000 RPM for 15 min at 4°C. Methanol was taken as blank and 3 mL methanol with 0.5 mL DPPH reagent was taken as control. The absorbance was measured at 517 nm using spectrophotometer (Shimadzu 1609, Tokyo, Japan).

$$\% \text{ DPPH Reduction} = \frac{OD_{Control} - OD_{Sample}}{OD_{Control}} \times 100 \quad (2)$$

Peroxide Value (PV), Free Fatty Acid (FFA) and Thio-Barbutyric Acid (TBA) Values

The PV and FFA content of vacuum fried strawberry chips was determined by AOCS (1973) and TBA content of strawberry chips was determined as method described by Tarledgis (1960).

Sensory evaluation

Twenty five semi-trained panelists were selected from the staff members of the laboratory to evaluate the sensory quality of vacuum fried strawberry chips in terms of colour, texture, flavor and overall acceptability. These quality attributes were rated using a 9-point hedonic scale, where 9 represented to "extremely like" and 1 represented to "extremely dislike". Samples were coded randomly and were served together to each sensory panelist separately.

RESULTS AND DISCUSSION

Proximate composition

Table 1 shows the effect of freezing pre-treatment on proximate composition of vacuum fried strawberry chips. Freezing pre-treated chips retained 30% more moisture content as compared to control. The moisture content of freezing pre-treated sample was increased upto 2.47% during storage of 3 months however the difference in moisture content between control and freezing pre-treated samples remained non significant (p<0.05). Reduction of oil uptake is considered as one of the important challenges in frying industry. The oil uptake of vacuum fried strawberry chips were found to be 27.46% and 22.32% in control and freezing pre-treated samples, respectively (Table 1). The oil uptake in freezing pre-treated sample was found 18.71% less as compared to control samples. The increase in rate of moisture evaporation due to sublimation of ice in freezing pre-treated sample might be leading to less oil uptake of sample. Moreover, formation of ice-crystals during freezing pre-treatment resulted in more porous structure of chips and therefore, resulting oil uptake during frying was come out easily during post centrifugation step. There was no significant (p<0.05) difference observed in oil content of control and freezing pre-treated chips during storage. While comparing the fat content of different vacuum fried products, such as apple slices (1.5 g/g; Mariscal and Bouchon 2008), carrot chips (30-40 g/100 g; Fan *et al.* 2005) and purple yam (33.3 g/100 g (*dw*); Fang *et al.* 2011), freezing pre-treated vacuum fried strawberry chips showed less fat content. The protein and ash content was found to be 4.79 and 4.91, 3.11 and 3.27 for control and freezing pre-treated samples, respectively. There was no significant (p<0.05) difference observed in protein and ash content of control and freezing pre-treated samples during both at initial stage and during storage. Total carbohydrate content of vacuum fried strawberry chips was found 4.98% higher in freezing pre-treated sample as compared to control chips which is due to high oil uptake in control chips as compared to freezing pre-treated sample. However, the difference in total carbohydrate content was not significant (p<0.05) and remained constant during storage in both control and freezing pre-treated chips.

Hardness (N)

Hardness is considered as one of the important parameters in snack industry. Table 2 shows the effect of pre-treatment on hardness of vacuum fried strawberry chips. The hardness value of strawberry chips was found to be significantly (p<0.05) less in freezing pre-treated sample as compared to control. However, the difference in hardness was not significant (p<0.05) during 3 months of storage in both control and freezing pre-treated samples. The reduced hardness value in freezing pre-treated strawberry chips may be due to ice formation during pre-treatment which might lead to more porous cell structure of the sample as compared to control after frying.

Color

Color is also considered as one of the important parameter in snack industry as it is directly associated with visual appearance and acceptance of product by consumers. Table 2 shows the change in color values including total color difference (ΔE) of the vacuum fried strawberry chips. The L^* value shows brightness or darkness of the sample, whereas, a^* value shows redness or greenness and b^* value yellow or blueness of the sample. The L^* and a^* values of freezing pre-treated sample were found to be

Table 1
Effect of freezing pre-treatment on chemical properties of vacuum fried strawberry chips

Changes in chemical properties of strawberry chips			
Parameters	*Storage time*	*Control chips*	*Frozen + vacuum fried chips*
Moisture %	Initial	3.86±0.13	5.53±0.34
	3 Months	3.98±0.26	5.67±0.22
Fat %	Initial	27.46±0.51	22.32±0.37
	3 Months	27.41±0.46	22.29±0.28
Protein %	Initial	4.79±0.25	4.91±0.19
	3 Months	4.75±0.21	4.89±0.11
Total Carbohydrate %	Initial	60.78±1.58	63.97±1.39
	3 Months	60.77±1.42	63.90±1.14
Ash %	Initial	3.11±0.32	3.27±0.12
	3 Months	3.09±0.27	3.25±0.18
Total phenolics (mg/100g GAE)	Initial	90.76±3.39	108.52±2.83
	3 Months	76.45±2.76	98.98±2.58
Total flavonoids (mg/100g catechineq)	Initial	12.47±1.34	14.22±1.41
	3 Months	10.96±1.21	12.76±1.17
Anthocyanin (mg/100g)	Initial	76.56±2.63	87.03±2.24
	3 Months	69.75±2.33	79.95±2.57
Antioxidant activity %	Initial	73.47±2.11	81.03±2.62
	3 Months	61.89±1.98	74.88±2.23

Table 2
Effect of freezing pre-treatment on physical properties of vacuum fried strawberry chips

Changes in physical properties of strawberry chips			
Parameters	*Storage time*	*Control chips*	*Frozen + vacuum fried chips*
Texture (*N*)	Initial	6.37±0.16	5.43±0.22
	3 Months	6.58±0.21	5.52±0.18
L^*	Initial	14.79±0.15	16.43±0.24
	3 Months	15.98±0.32	17.36±0.18
a^*	Initial	13.64±0.41	14.55±0.32
	3 Months	12.27±0.13	13.89±0.11
b^*	Initial	05.87±0.18	05.33±0.21
	3 Months	04.58±0.09	04.12±0.14
Total color difference (ΔE)	Initial	-	3.22±0.12
	3 Months	-	4.46±0.18

significantly ($p<0.05$) high as compared to control. The L^* value increased, whereas, a^* value decreased during storage of samples. The difference in $L^*$and a^* values of freezing pre-treated sample and control were not changed significantly ($p<0.05$) during storage of 3 months. The high L^* value of freezing pre-treated sample might be due to less oil uptake as compared to control. However, retention of more anthocyanin content as compared to control resulted in high a^* value in freezing pre-treated sample. The b^* value of freezing pre-treated sample was found less as compared to control, however, the difference was not significant ($p<0.05$) at both initial stage and during storage, high oil uptake in control chips might be responsible for high b^* value as compared to freezing pre-treated sample. The total color difference (ΔE) in freezing pre-treated sample was found to be 3.22 and 4.46 at initial stage and during storage. The increase in total color difference (ΔE) of the sample shows increase in lightness of the sample during storage. The loss of pigments including phenolics and flavonoids content during storage might be resulting in increased total color difference (ΔE) in freezing pre-treated sample as compared to control.

Change in total phenolics, flavonoids, anthocyanin content and antioxidant activity of vacuum fried strawberry chips

There was significant ($p<0.05$) difference observed in retention of phenolics and anthocyanin content of control and freezing pre-treated samples. Table 1 shows that total phenolics and anthocyanin contents were retained to a better extent in freezing pre-treated samples. Whereas,the retention of flavonoids content in freezing pre-treated vacuum fried strawberry chips was found more as compared to control sample, however the difference was not significant ($p<0.05$). Freezing pre-treatment might be responsible for reducing the thermal degradation of total phenolics, flavonoids and anthocyanin content of the sample and therefore, resulted in significantly ($p<0.05$) higher retention as compared to control. Shyu *et al.* (2005) mentioned earlier that freezing of natural products has no influence on total phenolic content. Therefore, reduction of phenolic content in control chips might be due to oxidation and more exposure to temperature for longer duration as reported by Kucner *et al.* (2014).

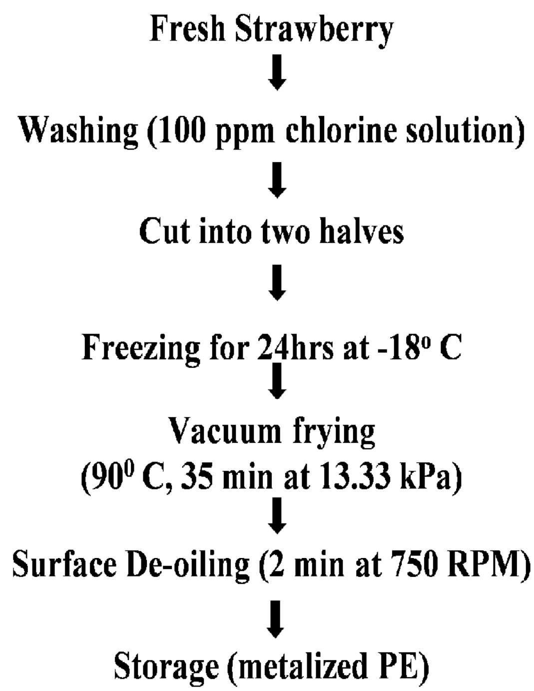

Figure 1: Process for making vacuum fried strawberry chips

Figure 2: Vacuum fried strawberry chips

The loss in total phenolics and anthocyanin content in both freezing pre-treated and control samples were also found to be significantly (p<0.05) high after 3 months storage, however, the flavonoids content was retained to a better extent during storage. The antioxidant activity in freezing pre-treated sample was significantly (p<0.05) high i.e. 81.03% as compared to control i.e. 73.47%. However, antioxidant activity was decreased significantly (p<0.05) in both control and freezing pre-treated samples after 3 months storage. The high antioxidant activity in freezing pre-treated samples was due to the retention of high phenolics, flavonoids and anthocyanin contents. However, reduction of total phenoics, flavonoids and anthocyanin might be resulting in decreased antioxidant activity during storage.

Changes in oxidative stability during storage

Peroxide value (PV) is considered as basic quality parameter to determine primary oxidation of fat (O'Brien and Timms 2004). The PV of developed vacuum fried strawberry chips increased significantly during storage, the freezing pre-treated sample showing maximum increase (Fig. 3a). This increase in PV of freezing pre-treated chips might be due to high moisture content and moderate oil uptake than control one. However, PV in pre-frozen chips was found highest; the gradual increase was observed during storage. The changes in initial PV of vacuum fried strawberry chips were due to repeated use of oil during frying.

Free fatty acid (FFA) value in freezing pre-treated chips was found highest at initial stage which might be due to repeated use of oil during frying. A gradual increase was observed in FFA values of pre-treated and untreated vacuum fried strawberry chips during storage (Fig. 3b), however, the increase was found to be in acceptable range. The control chips exhibited higher increase in FFA as compared to pre-treated one. An increase in PV and FFA values of samples might be due to interaction between moisture content, oil content, and temperature during storage period (de Alencar*et al.* 2010).

Thiobarbutyric acid (TBA) value is greatly associated with changes in PV and FFA value of products and is determined to investigate the extent of secondary oxidation products i.e. aldehydes, ketones, furans and lactones, which impart unacceptable taste and odor known as rancidity (Farhoosh *et al.,* 2009). The results showed that TBA value of all vacuum fried strawberry chips increased during storage (Fig. 3c), control showing the highest rate compared to pre-treated one.

Sensory evaluation

Table 3 shows the sensory acceptability of vacuum fried strawberry chips. The sensory acceptability in terms of color, flavor, texture and overall acceptability was found significantly (p<0.05) high

Table 3
Effect of freezing pre-treatment on sensory characteristics of vacuum fried strawberry chips

	Vacuum fried strawberry chips			
Sensory parameters	*Control*		*Freezing*	
	Initial	*3 Months*	*Initial*	*3 Months*
Color	7.0	7.0	8.0	8.0
Flavor	7.5	7.0	8.0	7.5
Texture	7.0	6.5	7.5	7.5
Overall acceptability (OAA)	7.0	7.0	8.0	7.5

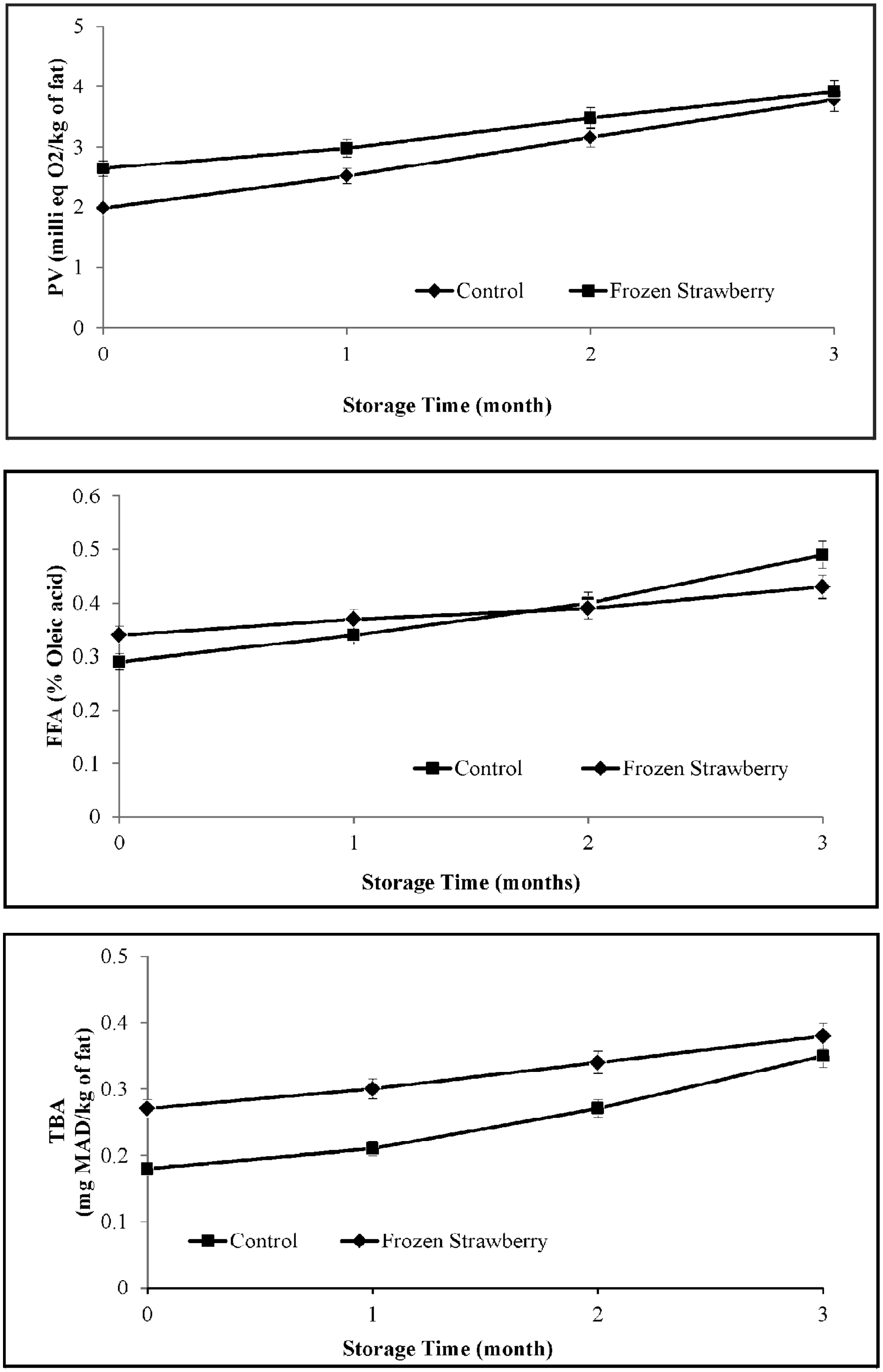

Figure 3: Effect of freezing on oxidative stability of vacuum fried strawberry chips (a) Peroxide value (PV), (b) Free fatty acid (FFA) and (c) Thio-barbutyric acid value (TBA)

in freezing pre-treated sample as compared to control. However, sensory acceptability for flavor, texture and overall acceptability was found to be decreased during storage. Whereas, color of strawberry chips were found to be retained in terms of hedonic scale rating and hunter L^*, a^* and b^* values, during storage.

CONCLUSION

Moisture loss and oil uptake was found to be significantly ($p<0.05$) affected by freezing pre-treatment. The oil uptake was found comparatively less in freezing pre-treated strawberry chips. Freezing pre-treatments caused significantly ($p<0.05$) better retention of anthocyanin, total phenolics and flavonoids as compared to the control samples. Fat oxidation was found to be significantly ($p<0.05$) high in the frozen and vacuum fried strawberries, showing comparatively less stability during storage. However, freezing before vacuum frying yielded excellent quality strawberry chips in terms of sensory acceptability, instrumental color and nutritional retention and therefore, can be used for commercial applications.

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