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RESEARCH PAPER

Development and Characterization of Novel Guava Chips Using Vacuum Frying Technique

Savita Zambre* and M.G. Bhotmange

Department of Food Technology, Laxminarayan Institute of Technology, RTM Nagpur University, Nagpur-440033, India

*Corresponding author: savitazambre@gmail.com

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ABSTRACT

The objective of this study was to develop guava chips applying vacuum frying technique. Guava slices were vacuum fried at 85°C for 55 minutes, at 100°C for 50 minutes and 110°C for 40 minutes at 9 kPa pressure. The prepared chips were analyzed for quality attributes such as oil content, ascorbic acid content, total phenolic content, crude fibre, colour, texture, browning index. The guava chips fried at 85°C and 9 kPa pressure for 55 min demonstrated maximum acceptability to consumer panellists with 8.2 score on nine-point hedonic scale. The composition of vacuum fried guava chips showed 18.66% oil, 27.1% crude fibre, 5120 mg/100gm total phenolic content and 448.36mg /100gm ascorbic acid. The colour values L^*, a^* and b^* were 79.62, 1.74 and 20.95, respectively. The resistance force required to break chips was 1051 gm and fracturability 32.75 mm. The vacuum frying can be better alternative to produce guava chips with high nutritional values and desired quality attributes.

Keywords: Vacuum frying, guava chips, ascorbic acid, crude fibre, browning index

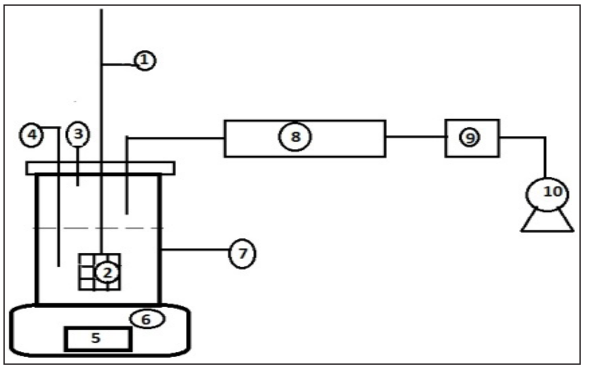
Frying is one of the oldest and most popular cooking method used by society (Varela and Bender, 1988). The fried products are sterile, dried and showed longer shelf-life. Recent trend of consumers towards healthier and low-fat products demonstrated the need to produce novel snacks with good sensory properties. Frying methods such as pressure frying, microwave frying, vacuum frying and radiant frying are studied for reduction in oil uptake by fried products and degradation of frying oil. Pressure frying has proven effective in reducing the cooking time and better textured products. However, this process is limited to meat, fish and poultry products (Das *et al.* 2013) juiciness of pressure fried chicken products was superior ($p \leq 0.05$). Microwave frying has the advantages of decreased processing time and oil uptake but the major challenges are non-uniform heating and deterioration of oil at high temperatures (Oztop *et al.* 2007). Studies on radiant frying, reported their foods to be tougher, drier in mouth feel, and slight resemblance to deep fat fried food (Pankaj and Keener, 2017). Vacuum frying represents the latest and effective preservation method applied to fruits and vegetables to produce snacks with better sensory and nutritional qualities. The frying process is usually carried out under pressure below the atmospheric level, lowering the boiling point of water and thus, significantly reducing the frying temperature (Garayo and Moreira, 2002). The low temperature and negligible exposure to oxygen in the vacuum frying provides several benefits, like nutrient preservation (Da Silva and Moreira, 2008), oil quality protection (Shyu *et al.* 2005), reduction of acrylamide content (Granda *et al.* 2004), retention of natural colour and flavours with lower moisture content. Thus, it is appropriate for high sugar content products like fruits. Vacuum frying has been used for different fruits, including apples, pineapple, mango, kiwi, jack fruit, apricots, papaya, banana and plantain. (Mariscal and Bouchon, 2008; Nunes and Moreira, 2009; Diamante *et al.* 2011; Sothornvit, 2011; Diamante *et al.* 2012a; Saxena *et al.* 2012; Lastriyanto *et al.* 2013; Akinpelu *et al.* 2014) in terms of oil uptake, moisture loss and color development. In addition, some apple slices were pre-dried (up to 64% w.b.).

Guava (*Psidium guajva* L.) is a tropical fruit of family-*Myrtaceae* (Chao *et al.* 2013). It is an important fruit produced in India after mango, banana, citrus and papaya and is considered as an ideal fruit for nutritional security (Chopda and Barrett, 2001). Further,it accounts for 2.51 lakh ha area with an annual production of 40.83 lakh MT and productivity 16.3 MT per ha in year 2014-15 (Jatinder Singh, 2017). It is rich source of ascorbic acid, pectin, fibres, phenols, flavonoids, tannins, saponins, essential oils and vitamins (Kamth *et al.* 2008). Substantial quantities of guava fruits are destroyed and rotten due to lack of proper storage facilities. The post-harvest losses are estimated to be 25-30% because of poor storage and infrastructure facilities(Jatinder Singh, 2017). Thus, it is necessary to produce the shelf-stable products from guava fruits and extend their period of availability in the market. In view of this background, the present study was designed to prepare guava chips having good quality in terms of colour, texture, reduced oil content, ascorbic acid, crude fibre and total phenolic content using novel vacuum frying technique.

MATERIALS AND METHODS

Vacuum frying system

A laboratory scale vacuum fryer was constructed with a reaction kettle of borosilicate glass having 2 litre capacity as a vacuum chamber, a heating mantle with thermostatic control as a heating source and two-stage vacuum pump (Edwards) which can generate the vacuum pressure up to 9 kPa. Figure (1) represents the schematic diagram of vacuum fryer. The complete system includes 2 litre reaction kettle and a lid with four standard joints, to connect to manometer, temperature sensor, basket lift rod and condenser. Vacuum pump was connected to reaction vessel through water condenser. Cold water was circulated through condenser throughout the process. The purpose of condenser was to prevent the mixing of water vapours emerging from the product to mix with the pump's oil, thus, liable to damage the pump (Garayo & Moreira, 2002). Stainless steel perforated basket was used for sample holding hung by steel rod with hook.



(1) Basket lift rod (2) Frying basket (3) Pressure gauge (4) Temperature probe (5) Thermostatic temperature controller (6) Heating mantle (7) Vacuum chamber (8) Water condenser (9) water collecting flask (10) Vacuum pump.

Fig. 1: Schematic diagram of Vacuum fryer

Experimental conditions

In this study guava slices were vacuum fried at three different temperatures 85°C, 100°C and 110°C using vacuum pressure 9 kPa to achieve final moisture content up to 1%.

Sample preparation

The Figure 2 represents the block diagram of vacuum frying process for preparation of guava chips. Fresh, fully ripened guava fruits were purchased from local market at Nagpur, India. Fruits were washed with water, blotted with tissue paper and cut into thin slices. Fresh vegetable oil, (sunflower oil) was used for frying with product to oil ratio 1:20 in all the experiments. 50 g of guava slices were loaded in a perforated basket and hanged with a stainless-steel lift rod. The perforated basket suspended through lift rod above the oil level and lid was closed. All the joints were sealed with vacuum grease to prevent the leakage if any. Once the vessel reaches desired temperature, it was evacuated. At this moment, the basket was submerged into the hot oil. Chips were fried for desired time and temperature. After frying, the basket was raised, stirred manually, the vessel was pressurized up to atmospheric pressure and the samples were blotted dry with paper towels to remove excess oil. Further to ensure removal of excess oil the sample was centrifuged for 5 min at 800 rpm, and stored in sealed metalized polyester bags in desiccators. Three replications (three batches of 50 g) were used in this study.

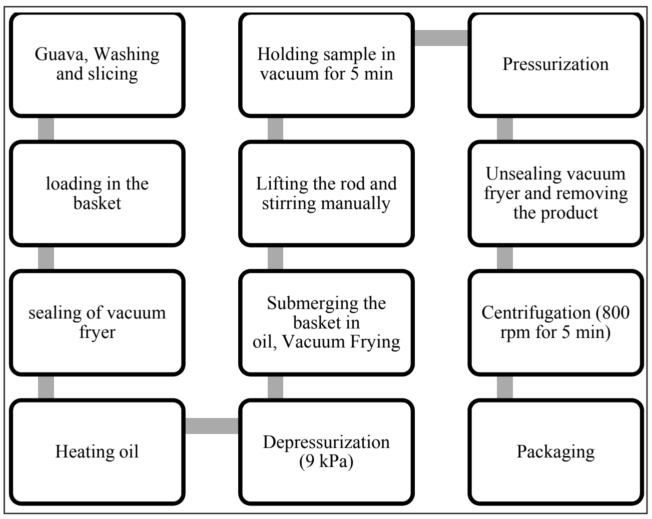


Fig. 2: Flow chart for preparation of Vacuum fried guava chips

Physico-chemical Analysis

Physical

Moisture content of the raw guava and vacuum fried guava chips was determined by hot air oven method (AOAC, 1995). Per cent moisture content was calculated by determining the extent of weight loss of raw guava and vacuum fried guava chips (4-5g) after drying in a hot air oven at 105^{o}C until there was no change in the dried mass of the sample. The test was performed in triplicate.

The colour was analyzed by Lovibond RT 300 portable reflectance spectrophotometer, using CIE $L^*a^*b^*$ (CIELAB) system**.** The measurements were made using D-65 illuminant. The instrument was calibrated using standard black and white tile. Colour was measured for guava chips of each condition and 3 readings were taken at different locations on the surface of each chip for each experimental condition. The colour was expressed in terms of L^* value [lightness, ranging from zero (black) to 100 (white)], a^* value is (+a) redness to (-a) greenness and b^* value is (+b) yellowness to (-b) blueness. The total colour change ΔE, and browning index (BI) were calculated from L^*, a^* and b^* values (Diamante *et al.* 2010).

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

Where L_0^*, a_0^*, b_0^* are the initial colour values of fresh samples and L^*, a^* and b^* are the final colour values of the guava chips.

$$BI = \frac{[100(X - 0.31)]}{0.17} \qquad \ldots(2)$$

$$\text{Where, } X = \frac{(a^* + 1.75L^*)}{(5.645L^* + a^* - 3.012b^*)}$$

The texture of the fried chips samples was measured by texture analyzer (TA XT; Stable Micro Systems, London, UK), by 2 mm Cylinder Probe (P/2) using 50 kg load cell and heavy-duty Platform (HDP/90) with a holed plate. Pre-test and post-test speeds were set at 1.5 mm/s and 5 mm/s, respectively, test speed 0.5 mm/s, and distance of penetration 2 mm. Test results obtained from 5 samples of each type.

Chemical methods

Total oil content determination was carried out by using soxhlet extraction apparatus (AOAC, 1995). It was measured by extracting the oil from the sample with petroleum ether as a solvent. The determinations were carried out in triplicate and mean value was reported.

Crude fibre estimation was conducted on crude fibre analyser (FIBRA Plus, Model FES2E Pelican equipment's) (Ranganna, 2001). 2-3 g defatted sample was weighed and extracted by 1.25% H_2SO_4 acid. The acid wash was followed by alkali wash with 1.25% NaOH. After washing with hot distilled water, the crucibles were dried in hot air oven at 100°C, weighed and were placed in muffle furnace at 500°C for 20 min. The loss of weight is taken as the weight of crude fibre.

Ascorbic acid content was analyzed by 2,6 Dichloroindophenol dye by titration method (Ranganna, 2001).

Total phenolics contents (TPC) of fresh guava slices and defatted guava chips were estimated calorimetrically using Folin-Ciocalteu (FC) reagent (Fang *et al.* 2011; Maity *et al.* 2017). 1ml of the methanolic extract was mixed with 9 ml of distilled water and 1 ml of FC reagent. After 6 minutes, 10 ml of 7% sodium carbonate solution was added, volume was made up to 25 ml, and incubated at room temperature for 90 min, and the absorbance was measured at 750 nm using a UV-visible spectrophotometer (LABMAN). The results were expressed as gallic acid equivalents in milligrams per hundred gram dry weight (mg GAE/100 g db).

Sensory evaluation

Fried guava chips were served to a semi trained panel of 10 members for sensory evaluation. Sensory evaluation was carried out by nine-point hedonic scale for different attributes like appearance, colour, flavour, taste, after taste, texture and overall acceptability (Joshi, 2006). The scores were assigned from Extremely liked (9), Like very much (8), Like Moderately (7), Like slightly (6), Neither like nor dislike (5), Dislike slightly (4), Dislike Moderately (3), Dislike very much (2), to Disliked extremely (1).

Statistical analysis

All the experiments were carried out in triplicates and the values were reported as mean ± standard deviation. Statistical analysis was carried out using one-way ANOVA procedure followed by Tukey's post test. Also the data of sensory evaluation was analysed by ANOVA- two factor replication and Bonferroni post tests. Mean values were considered statistically significant when P<0.05.

RESULTS AND DISCUSSION

Moisture content

Fig. 3 illustrates the moisture loss from vacuum fried guava slices at 9 kPa at three different frying oil temperatures (85°C, 100°C and 110°C). The loss of moisture during vacuum frying exhibited typical drying curve. Similar results were reported while studying vacuum frying of potato chips and jackfruit bulb slices (Garayo and Moreira, 2002; Maity *et al.* 2014).

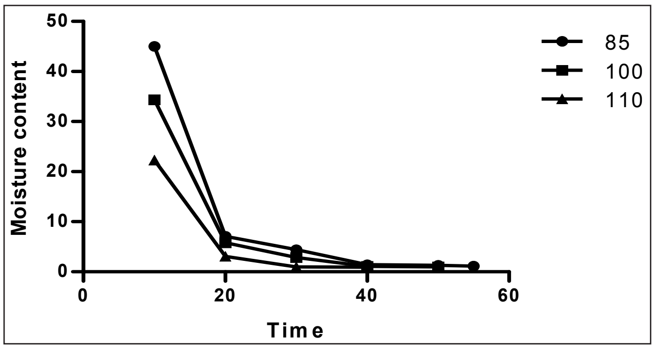


Fig. 3: Effect of different temperatures on Moisture content of vacuum fried guava chips

As observed from the table 1, moisture removal is faster at higher temperature. At frying temperatures 85°C, 100°C and 110°C almost 42%, 56%, 71% of moisture was removed initial content of 78% respectively within first 10 min of drying. It was observed that there was a sudden drop in moisture content after 10 min at all the drying temperatures, due to the reduced warm up time. Boiling point of water reduces instantly because of vacuum frying, enabling moisture removal immediately as the sample is submerged in the oil. The moisture content was not significantly affected (P>0.05) by frying temperature. Although moisture removal was faster at 110°C as compared to 85°C and 100°C and maximum moisture is removed within 20 min. The samples fried at higher temperature 110°C showed lowest moisture content followed by the samples fried at 100°C and 85°C. At the end of frying percent moisture removal

Table 1: Values of moisture content, oil content and ascorbic acid content, crude fibre content and total phenolic content (TPC) of vacuum fried guava chips

Sl. No.	Temp	Times (min)	Moisture content (%db)	Oil content (%db)	Ascorbic acid mg/100gms (db)	Crude fibre (%db)	TPC (mg GAE/100g)
	Raw guava		78.0 ± 0.8	1.23 ± 0.14	665 ± 1.56	30 ± 0.87	8950 ± 1.78
1	85°C	55	1.16ᵃ ± 0.14	18.66ᵃ ± 0.41	448.36ᵃ ± 1.66	27.1ᵃ ± 0.29	5120ᵃ ± 0.94
2	100°C	50	0.98ᵃ ± 0.08	18.56ᵃ ± 0.40	213.56ᵇ ± 1.18	20.49ᵇ ± 0.51	3916ᵇ ± 2.82
3	110°C	40	0.93ᵃ ± 0.02	17.06ᵃ ± 0.16	145.60ᶜ ± 1.57	18.54ᶜ ± 0.48	2828ᶜ ± 1.69

Values are average ±standard deviation, n=3; Values with the same superscripts for any given column are not significantly different (P>0.05).

was almost 98% from guava chips when fried at 85^0 C, 100°C and 110°C temperature.

Oil content

As depicted in figure 4 oil content of vacuum fried guava chips at 85°C to 110°C was found to be in the range of 17.06% to 18.66 % which was reasonably less than atmospherically fried products (Sobukola *et al.* 2013). The vacuum fried guava chips at 110^{0}C showed lower oil content as compared to samples when fried at temperatures 85°C and 100°C. During frying oil content in the guava chips increased initially but decreased with time for all frying temperatures. The results are in accordance with reported results for the vacuum frying of breaded shrimps (Pan *et al.* 2015). Oil content decreased progressively for lower temperature, 85°C as compared to higher temperature, 110°C.

Final oil content of guava chips was not significantly affected (P>0.05) by oil temperature. This means that final oil content of guava chips is not a function of oil temperature, but it depends on the frying time. But with decrease in oil temperature frying time increases. Similar results were observed while vacuum frying of potato (Garayo and Moreira, 2002) and vacuum frying of jackfruit chips (Maity *et al.* 2014). In vacuum frying oil absorption occurs at the pressurization step because the rapid increase in pressure after releasing vacuum is higher than atmospheric pressure forcing the surface oil into the product. Therefore centrifugation after frying is necessary in vacuum frying (Diamante *et al.* 2015).

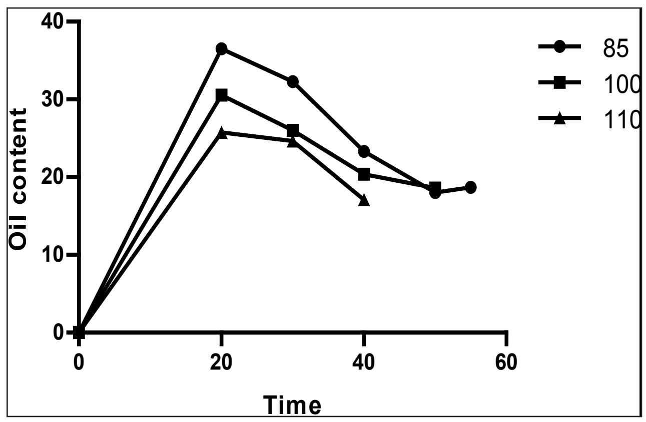


Fig. 4: Effect of different temperatures on Oil content of vacuum fried guava chips

Crude Fibre content

The crude fibre content of raw guava was found to be 30% on dry weight basis. As seen from table 1 crude fibre contents of vacuum fried guava chips at 85°C, 100°C and 110^{0}C were found to be 27.1%, 20.49%, and 18.54%, respectively. The decrease in crude fibre content of guava chips was 10%, 32% and 38% for chips fried at 85°C, 100°C, and110°C, respectively. Vacuum frying at 110^{0}C reduces the crude fibre content as a result of increased temperature which causes breakage of weak bonds between polysaccharide chains and glycosidic linkages in the dietary fibre polysaccharides (Lola, 2009). Significant decrease in crude fibre content (P<0.05) were observed during frying at higher temperature.

Ascorbic acid content

The vacuum fried guava samples at the 85°C for 55 min process showed higher ascorbic acid contents followed by the samples fried at the 100°C for 50 min and 110°C for 40 min as reported in the table 1. Ascorbic acid content was found to be decreased significantly ($P<0.05$) with frying temperature. The percent retention of ascorbic acid was 67%, 32%, and 22% when fried at temperature of 85°C, 100°C, and 110°C, respectively. Decrease in ascorbic acid content of fried guava chips at higher temperature is due to heat sensitivity of the vitamin. However, the results of our study are similar to that investigated by Diamante *et al.* (2012), for fried gold kiwi fruit at higher temperature (Diamante *et al.* 2012b). Dueik and Bouchon (2011) also reported less ascorbic acid retention for vacuum fried potato and apple slices at 160°C (Dueik and Bouchon, 2011) however, even health-conscious consumers are not willing to sacrifice organoleptic properties, and intense full-flavor snacks remain an important trend. The objective of this study was to examine most important quality parameters of vacuum (1.92 inHg).

Total Phenolic content

Phytochemicals such as phenolics play an important role in increasing health benefits (Simões *et al*. 2009). Results for total phenolic content (TPC) are shown in table 1. From the results it can be observed that there was high retention of TPC with the samples fried at 85°C. However it was found to be decreased when fried at higher temperature i.e. 100°C and 110°C. The percent loss of TPC was 56% and 68% when vacuum fried at 100°C and 110°C for 50 min and 40 min, respectively. Whereas it was only 43% loss when vacuum fried at 85°C. This limited loss could be credited to application of vacuum frying which might have retained maximum amount of phytochemicals in fried chips such as phenolic compounds by preventing their oxidation and thermal degradation (YT Chen, 2007; Materska, 2010).

Colour analysis

L^* is a critical parameter in the frying industry as it is the first observed and evaluated quality attribute by consumers when determining product acceptance (Dueik and Bouchon, 2011) however, even health-conscious consumers are not willing to sacrifice organoleptic properties, and intense full-flavor snacks remain an important trend. The objective of this study was to examine most important quality parameters of vacuum (1.92 inHg. As shown in Table 2, L^* value decreased from 79.62 to 75.97 with increase in temperature from 85°C to 110°C. Statistical analysis showed that there were significant differences ($P<0.05$) for L^* lightness and a^* redness values of vacuum fried guava chips. The L^* value of fried guava chips increased slightly during initial 10 min of frying at temperature 85°C and 100°C. This may be due to the glossiness acquired by guava slices due to immersion in frying oil (Maity *et al.* 2014). At 110°C, L^* value decreased with increasing frying time initially for first 10 min. Low L^* values indicate a dark colour and are mainly associated with non-enzymatic browning reactions. These reactions occur between reducing sugars and amino acids and also between ascorbic acid, dehydroascorbic acid (oxidized ascorbic acid) and other degradation products from ascorbic acid oxidation. Ascorbic acid oxidation is also delayed when fried under vacuum as oil temperature is reduced (Dueik *et al.* 2010; Mariscal

Table 2: Mean values of L^*, a^*, b^*, colour change and browning index values of vacuum fried guava chips

Sl. No.	Temperature	Times (min)	L^*	a^*	b^*	Colour change	Browning index
	Raw guava		**81.10** ±0.42	**-0.32** ±0.08	**7.57** ±0.48	—	**9.271** ±0.23
1	85°C	55	79.62^a ±0.24	1.74^a ±0.01	20.95^a ±0.43	13.57^a ±0.39	30.08^a ±0.33
2	100°C	50	78.46^b ±0.33	1.08^b ±0.03	20.90^a ±0.35	14.12^a ±0.42	32.05^b ±0.04
3	110°C	40	75.97^c ±0.10	2.77^c ±0.16	22.54^b ±0.08	16.52^a ±0.39	37.65^c ±0.50

Values are average ±standard deviation, n=3; Values with the same superscripts for any given column are not significantly different (P>0.05).

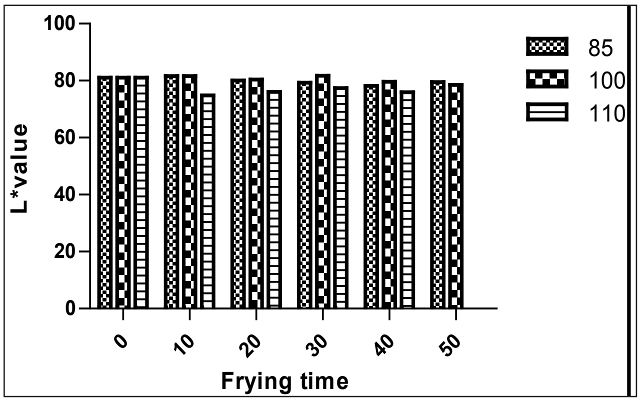


Fig. 5: (a) Effect of different temperatures on L^* values

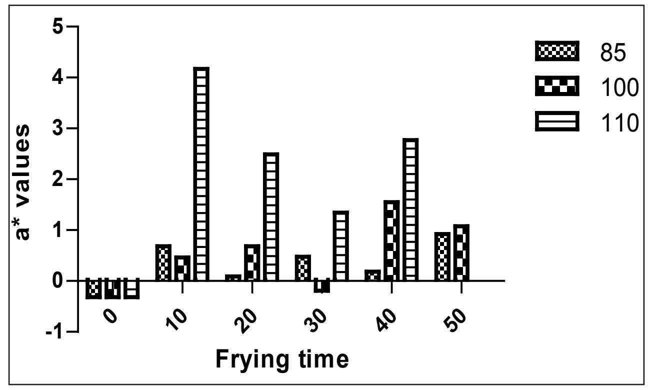


Fig. 5: (b) Effect of different temperatures on a^* values

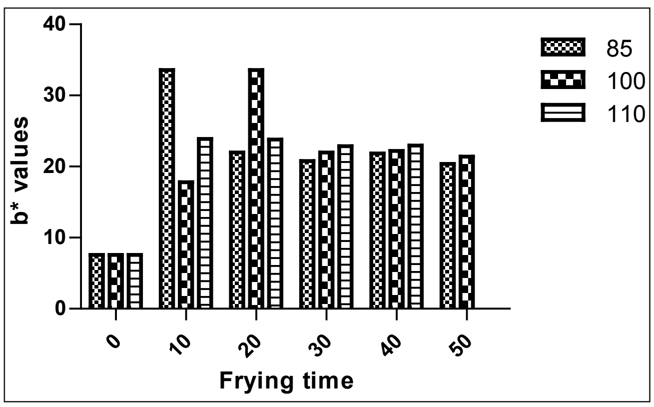


Fig. 5: (c) Effect of different temperatures on b^* values

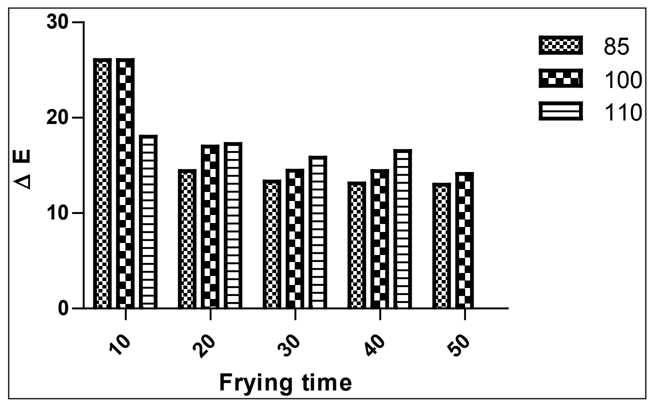


Fig. 5: (d) Effect of different temperatures on Δ E values

et al., 2008b). Table 2 depicts the results of a^* value, demonstrates the increase in value from 0.703 to 2.77 for temperature from 85°C to 110°C respectively. The a^* values of the vacuum fried guava chips increased significantly ($P<0.05$) with increase in frying temperature highly affecting browning reactions. Vacuum frying did not affect significantly b^* values ($P>0.05$) at temperature 85°C and 100°C, however differences were significant ($P<0.05$) for samples fried at 110°C. To analyze overall impact of frying process on colour of product, the change in colour between raw guava slices (L_0^*, a_0^*, b_0^*) and fried guava slices (L^*, a^*, b^*) was determined according to equation no (1). Lower ΔE values obtained for guava chips fried at 85°C, but the change in colour values were not affected significantly. Browning index calculated by formula (2) revealed significant increase in it with increase in frying temperature and frying time. The results of our study were similar to that reported by Diamante *et al.* (2012) of vacuum fried chips of kiwifruit (Diamante *et al.* 2012).

Texture analysis

Texture of a fried product determines its eating quality. Increase in crispiness positively affects the acceptability of product. The breaking force can be used to specify the crispiness of the guava chips; lower the breaking force higher will be the crispiness (Fan *et al.* 2005; Quan *et al.* 2014). As shown in table 3, breaking force related to hardness and linear distance related to fracturability was lowest at 85°C as compared to 110°C. Fracturability was increased with the temperature. During frying, most of the water was removed from the guava slices resulting in textural changes**.** Fig. 5 showed the effect of temperature on the texture quality of guava chips at the end of frying. The force required to break the chips (hardness) increased with the increase in oil temperature. However, the oil temperatures, 85°C, 100°C and 110°C did not affect the chip's texture significantly.

Table 3: Mean values of breaking force and fracturability of vacuum fried guava chips

Sl. No.	Temperature	Breaking Force (gms)	Fracturability (mm)
	Raw guava	**144.2±1.12**	**34.615±0.31**
1	85°C	1051^{a}±0.81	32.757^{b}±0.02
2	100°C	1098^{a}±1.24	32.968^{b}±0.02
3	110°C	1197^{a}±1.24	33.091^{b}±0.11

Values are average ±standard deviation, n=3; Values with the same superscripts for any given column are not significantly different (P>0.05).

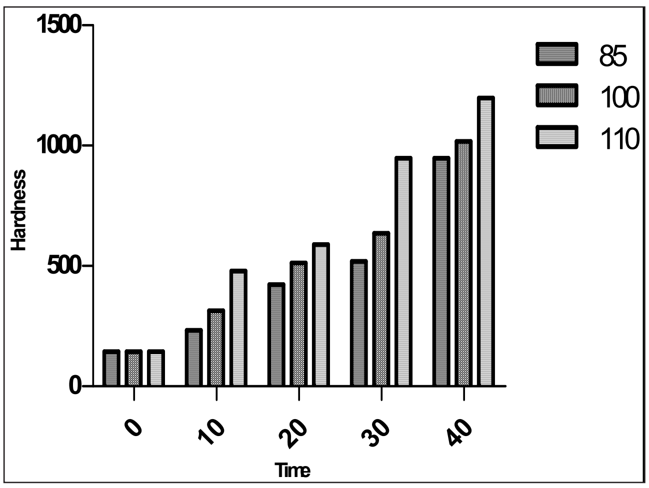


Fig. 6: Effect of different temperatures on hardness values

Sensory evaluation

A sensory analysis was performed to determine the consumer preference of vacuum-fried guava chips. Guava chips were assessed for sensory acceptability in terms of appearance, colour, flavour, taste, after taste, texture and overall acceptability. The panellists preferred the vacuum-fried guava chips for colour, texture, flavour, taste and overall quality for the sample fried at 85°C for 55 min. Fig. 7, showed overall acceptability scores of panellist. The results of sensory evaluation showed that most of the panellists considered colour of guava chips as the premium factor. Temperature of the process showed significant effect, P<0.05, on sensory scores for of guava chips. The sensory score for guava chips colour was found to increase from 6.10 to 8.22 for frying at higher temperature (110°C) to lower temperature (85°C).

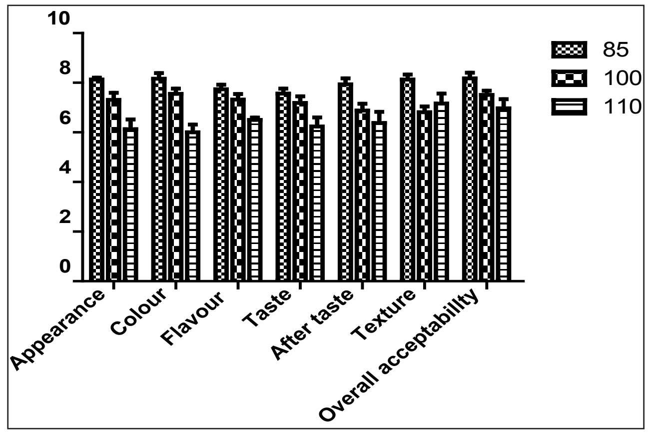


Fig. 7: Sensory evaluation of vacuum fried guava chips (1) 85°C for 55 min, (2) 100°C for 50 min and (3) 110°C for 40 min.

The results of colour analysis, lightness and redness determined by colorimeter were also confirmed by results of sensory evaluation given by the members of panellist. This might be due to reduced colour degradation because of absence of Maillard reactions and oxidation during vacuum frying. Crispiness is an important textural attribute which determines the quality of chips (Krokida *et al.* 2001). Sensory scores for texture were highest 8.13 on 9 point hedonic scale for chips fried at 85⁰C as compared to 7.16 at 110°C. The score of flavour was found to decrease during frying at all the temperatures. The sensory scores for flavour of guava chips fried at different temperatures were significantly affected, P<0.05. The sensory scores for flavour of guava chips were lowest, 6.5 for chips fried at 110°C. This may be due to degradation of volatile flavour compounds during frying at high temperature. Sensory evaluation results suggested that the overall acceptability of guava chips fried at 85°C for 55 min was highest with a score of 8.2 on the scale of 9.

CONCLUSION

The studies conducted on vacuum fried guava chips showed, the colour change, browning index and hardness of guava chips increased with increase in frying temperature and time. Higher retention of ascorbic acid and total phenolic content was found at lower temperature. Sensory scores were highest for guava chips vacuum fried at 85°C for 55min. The study indicated the feasibility of developing vacuum fried guava chips.

REFERENCES

Akinpelu, O.R., Idowu, M.A., Sobukola, O.P., Henshaw, F., Sanni, S.A., Bodunde, G., Agbonlahor, M. and Munoz, L. 2014. Optimization of processing conditions for vacuum frying of high quality fried plantain chips using response surface methodology (RSM). *Food Science and Biotechnology,* **23**: 1121–1128.

AOAC. 1995. Official methods of analysis (16th ed.) Washington DC: Association of Official Analytical Chemists.

Chao, H., Wu, P., Lo, D., Wu, W. and Wu, M. 2013. Effect of guava (*Psidium guajava* Linn.) fruit water extract on lipid peroxidation and serum lipid profiles of streptozotocin-nicotinamide induced diabetic rats. *African Journal of Pharmacy and Pharmacology,* **7**: 2299–2305.

Chen, Y.T. and Lin, K.L. 2007. Effects of heating temperature on the total phenolic compound, antioxidative ability and the stability of dioscorin of various yam cultivars. *Food Chemistry,* **101**: 955–963.

Chopda, C.A. and Barrett, D.M. 2001. Optimization of guava juice and powder production. *Journal of Food Processing and Preservation,* **25**: 411–430.

Da Silva, P.F. and Moreira, R.G. 2008. Vacuum frying of high-quality fruit and vegetable-based snacks. *LWT - Food Science and Technology,* **41**: 1758–1767.

Das, R., Pawar, D.P. and Modi, V.K. 2013. Quality characteristics of battered and fried chicken: Comparison of pressure frying and conventional frying. *Journal of Food Science and Technology,* **50**: 284–292.

Diamante, L., Durand, M., Savage, G. and Vanhanen, L. 2010. Effect of temperature on the drying characteristics, colour and ascorbic acid content of green and gold kiwifruits. *International Food Research Journal,* **17**: 441–451.

Diamante, L.M., Presswood, H.A., Savage, G.P. and Vanhanen, L. 2011. Vacuum fried gold kiwifruit : Effects of frying process and pre-treatment on the physico-chemical and nutritional qualities. *International Food Research Journal,* **18**: 632–638.

Diamante, L.M., Shi, S., Hellmann, A. and Busch, J. 2015. Vacuum frying foods : products, process and optimization. *International Food Research Journal,* **22**: 15–22.

Diamante, L.M., Savage, G.P. and Vanhanen, L. 2012. Optimisation of vacuum frying of gold kiwifruit slices: Application of response surface methodology. *International Journal of Food Science and Technology,* **47**: 518–524.

Diamante, L.M., Savage, G.P., Vanhanen, L. and Ihns, R. 2012a. Effects of maltodextrin level, frying temperature and time on the moisture, oil and beta-carotene contents of vacuum-fried apricot slices. *International Journal of Food Science and Technology,* **47**: 325–331.

Diamante, L.M., Savage, G.P., Vanhanen, L. and Ihns, R. 2012b. Vacuum-frying of apricot slices: Effects of frying temperature, time and maltodextrin levels on the moisture, color and texture properties. *Journal of Food Processing and Preservation,* **36**: 320–328.

Dueik, V. and Bouchon, P. 2011. Vacuum Frying as a Route to Produce Novel Snacks with Desired Quality Attributes According to New Health Trends. *Journal of Food Science,* **76**: 188-195.

Dueik, V., Robert, P. and Bouchon, P. 2010. Vacuum frying reduces oil uptake and improves the quality parameters of carrot crisps. *Food Chemistry,* **119**: 1143–1149.

Fan, L.P., Zhang, M. and Mujumdar, A.S. 2005. Vacuum frying of carrot chips. *Drying Technology,* **23**: 645–656.

Fang, Z., Wu, D., Y¨u, X., Ye, Liu, D. and J.C. 2011. Phenolic compounds in Chinese purple yam and changes during vacuum frying. *Food Chemistry,* **128**: 943–948.

Garayo, J. and Moreira, R. 2002. Vacuum frying of potato chips. *Journal of Food Engineering,* **55**: 181–191.

Granda, C., Moreira, R.G. and Tichy, S.E. 2004. Reduction of acrylamide formation in potato chips by low-temperature vacuum frying. *Journal of Food Science,* **69**: 405–411.

Kamath, J.V., Nair, R., Ashok, C.K. and Kumar, S.M.L. 2008. *Psidium guajava* L: A review. *International Journal of Green Pharmacy,* **2**: 9–12.

Jatinder Singh, K.S. and S.K.S. 2017. Effect of Post-harvest treatment of Guava fruits with 1- methylcyclopropene and Gibberellin on storage life and fruit quality. *International Rchive of Applied Sciences and Technology,* **8**: 35–40.

Joshi, V. K. 2006. Sensory Science: Principles and Applications in Evaluation of Food. Agro-Tech Publishers, Udaipur, pp. 527.

Krokida, M.K., Oreopoulou, V., Maroulis, Z.B. and Marinos-Kouris, D. 2001. Effect of pre-treatment on viscoelastic behaviour of potato strips. *Journal of Food Engineering,* **50**: 11–17.

Lastriyanto, A., Soeparman, S., Soenoko, R. and Sumardi, H.S. 2013. Determination of frying constant for vacuum fried pineapple at three levels of feeding capacity. *In Acta Horticulturae,* **1011**: 325–334.

Lola, A. 2009. The effect of boiling on the nutrients and anti-nutrients in two non conventional vegetables. *Pakistan Journal of Nutrition*, **8**: 1430–1433.

Maity, T., Bawa, A.S. and Raju, P.S. 2014. Effect of Vacuum Frying on Changes in Quality Attributes of Jackfruit (*Artocarpus heterophyllus*) Bulb Slices. *International Journal of Food Science*, pp. 1-8.

Maity, T., Bawa, A.S. and Raju, P.S. 2017. Effect of Pre-Conditioning on Physico-Chemical, Microstructural, and Sensory Quality of Vacuum Fried Jackfruit Chips. *Drying Technology*, **36**: 63-71.

Mariscal, M. and Bouchon, P. 2008a. Comparison between atmospheric and vacuum frying of apple slices. *Food Chemistry*, **107**: 1561–1569.

Mariscal, M. and Bouchon, P. 2008b. Food Chemistry Comparison between atmospheric and vacuum frying of apple slices. *Food Chemistry*, **107**: 1561–1569.

Materska, M. 2010. Evaluation of the Lipophilicity and Stability. *Acta Sci. Pol., Technol. Aliment.*, **9**: 61–69.

Nunes, Y. and Moreira, R.G. 2009. Effect of osmotic dehydration and vacuum-frying parameters to produce high-quality mango chips. *Journal of Food Science*, **74**: 356-362.

Oztop, M.H., Sahin, S. and Sumnu, G. 2007. Optimization of microwave frying of potato slices by using Taguchi technique. *Journal of Food Engineering*, **79**: 83–91.

Pan, G., Ji, H., Liu, S. and He, X. 2015. Vacuum frying of breaded shrimps. *LWT - Food Science and Technology*, **62**: 734–739.

Pankaj, S.K. and Keener, K.M. 2017. A review and research trends in alternate frying technologies. *Current Opinion in Food Science.*

Quan, X., Zhang, M., Zhang, W. and Adhikari, B. 2014. Effect of Microwave-Assisted Vacuum Frying on the Quality of Potato Chips. *Drying Technology*, **32**: 1812–1819.

Ranganna, S. 2001. Handbook of analysis and quality control for fruit and vegetable products. Tata McGraw-Hill Publishing Company Lt. New Delhi.

Saxena, A., Maity, T., Raju, P.S. and Bawa, A.S. 2012. Degradation Kinetics of Colour and Total Carotenoids in Jackfruit (*Artocarpus heterophyllus*) Bulb Slices During Hot Air Drying. *Food and Bioprocess Technology*, **5**: 672–679.

Shyu, S.L., Hau, L., Bin, and Hwang, L.S. 2005. Effects of processing conditions on the quality of vacuum-fried carrot chips. *Journal of the Science of Food and Agriculture*, **85**: 1903–1908.

Simões, A.D.N., Tudela, J.A., Allende, A., Puschmann, R. and Gil, M.I. 2009. Edible coatings containing chitosan and moderate modified atmospheres maintain quality and enhance phytochemicals of carrot sticks. *Post-harvest Biology and Technology*, **51**: 364–370.

Sobukola, O.P., Dueik, V., Munoz, L. and Bouchon, P. 2013. Comparison of vacuum and atmospheric deep-fat frying of wheat starch and gluten based snacks. *Food Science and Biotechnology*, **22**: 177–182.

Sothornvit, R. 2011. Edible coating and post-frying centrifuge step effect on quality of vacuum-fried banana chips. *Journal of Food Engineering*, **107**: 319–325.

Varela, G., Bender, A.B. and I.D.M. 1988. Current facts about the frying of food. In (Eds.), Frying of food: Principles, changes, new approach Chichester: Ellis Horwood., pp. 9–25.