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Development and Quality Evaluation of Vacuum Fried Jackfruit (*Artocarpus heterophyllus*) Chips

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ABSTRACT

Background: Jackfruit is unique tropical fruit, increased popularity worldwide in recent years for its immense health benefits and its flavour. The high postharvest losses and the seasonal availability of jackfruit increase the scope of vacuum frying technology. Vacuum frying technology offers health benefits as well as attractive physical properties. As the boiling point and smoke point is decreased due to the reduced pressure applied during vacuum frying, thermal degradation of oil and loss of nutrients at high temperature can be checked and the absence of oxygen during the process inhibits the lipid oxidation and enzymatic browning which helps to maintain the color and flavor of the raw feed.

Methods: Different pre-treatments (blanching, drying, freezing and untreated) were done for vacuum fried jackfruit chips and compared with atmospheric fried sample in blended oil (rice bran and palm oil (80:20)).

Result: The Un-treated sample had the best qualities with less oil content (33.35%), moisture content (0.501%), hardness (1.04 N), water activity (0.487). The optimized treatment condition at 100°C, 9kPa vacuum for 20 min with de-oiling speed of 1000 rpm at 5 min. produced chips with good quality parameters like less oil content (20.73%), hardness (1.04N), water activity (0.473), moisture content (0.481%), L* (70.18), a* (2.71) and b* (35.41). The threshold level of TPC in edible oil was 25-27%.

Key words: Jackfruit, Pre-treatments, Vacuum fried chips, Vacuum frying.

INTRODUCTION

Jackfruit (*Artocarpus heterophyllus* L.) is the largest edible fruit in the world and it was considered as heavenly fruit in ancient people of Kerala because of its nutritive composition like vitamins A, B, C, potassium, calcium, iron, proteins and carbohydrates and offers numerous health benefits. The fruit's isoflavones, antioxidants and phytonutrients has cancer-fighting properties and also help to cure ulcers and indigestion. But a major constraint regarding jackfruit consumption is its limited availability to four to five months. For its extension of storage life and yearlong availability and utilization, many methods of processing are being used since ancient times. Though jackfruit is produced in large quantities, the income derived from jackfruits is minimal due to wastage of this fruit during post-harvest value chain. In jackfruit, the total postharvest losses is estimated approximately 43.5% of the total production (Ahmmad *et al*., 2010).

Value addition techniques have a great scope in jackfruit. There are so many value added products of jackfruit *viz.,* chips, pickles, curries, powder and medicinal products are already available in market. At present, fried snacks industry has developed as one of the prime sectors for modern consumers. Deep fat fried products have a key share in snack food production sector and have a better place in traditional celebrations of our country. All age group people like to have jackfruit due to its unique flavor and texture. There is chance of developing several health problems (hypertension, heart disease, obesity *etc*) due to the consumption of conventional deep fat fried products due to its high oil uptake during conventional deep fat frying. The degradation of oil quality during deep fat frying poses threat to consumer's health. Also, the traditional frying method is not feasible for ripened jackfruit due to higher sugar content. Higher frying temperature causes charring of fruit and negligible moisture removal from fruit. Vacuum frying is a novel technology that fulfills all these objectives. It is a promising alternative conventional frying to improve the quality of fried products. During vacuum frying, the sample is heated under a negative pressure that lowers the boiling and smoking points of water and oil (Troncoso *et al.* 2009). The unbound water in the fried food could be rapidly removed when oil temperature reach the boiling point of water. The products of vacuum frying have greater resemblance to the natural jackfruit in terms of nutritional qualities and color. The absence of air during frying inhibits lipid oxidation and

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enzymatic browning thus preserving the colour and nutrients of sample. Also, the formation of acrylamide, a potential carcinogenic agent could be reduced to negligible amount by adopting vacuum frying technology. Frying under vacuum, reduce the oil retention which offers less oily taste without compromising natural colour, flavour and nutrients of the products. Ripened or matured jackfruit chips are also can be prepared through vacuum frying. The current investigation on "Development and evaluation of vacuum fried jackfruit (*Artocarpus heterophyllus*) chips" was under taken in the Department of Processing and Food Engineering, KCAET, Tavanur. This study was to check the feasibility of vacuum frying in ripened jackfruit chips which contain high moisture and to optimize the pre-treatments and process parameters for vacuum fried jackfruit chips.

MATERIALS AND METHODS

The ripened *varikka* variety of jackfruit with suitable maturity indices were procured from the Instructional Farm, KCAET, Tavanur, Kerala. Ripened whole jackfruits of firm variety with an average weight of 8-10 kg, devoid of any visible microbial infection or mechanical fissures were chosen for the experiment. The bulbs were given a vertical cut to remove the seed. Each pitted bulb was vertically cut into uniform slices (4 × 0.5 × 0.5 cm).

Vacuum frying

Batch type vacuum frying system of 3 kg capacity was used for preparation of fried jackfruit chips. The vacuum frying system consists of two chambers *i.e*. frying and oil storage chamber. Frying chamber and oil storage chamber were made of stainless steel (SS 316) and chambers were provided with heaters of 3 kW and 1.5 kW. Vacuum frying system was controlled by a microprocessor and PID (Proportional Integral Derivative) controller.

The performance evaluation of vacuum frying of jackfruit chips and blend of rice bran (brand: PAVIZHAM, Kerala, India) and palm oil (brand: PALMSON, Kerala, India) (80:20) was done. The procedure is explained under various experiments, *viz*; Experiment I: To optimize the pre-treatments for vacuum fried jackfruit chips. Experiment II: Effects of process parameters on the physical properties of vacuum fried jackfruit chips.

Experiment I: Optimization of pre-treatments for vacuum fried jackfruit chips

Based on the preliminary studies of vacuum frying of jackfruit, a combination of temperature (100°C) (Shyi-Liang and Hwang, (2001); Diamante *et al.* (2012), pressure (6 KPa) (Dueik *et al.* (2010); Maity *et al.* (2014)) and time (12 min) (Ranasalva and Sudheer (2015); Tarzi *et al.* (2011) for the pre-treatment study were selected. The various pre-treatments were adopted for reducing oil uptake and to improve the quality parameters of the fried product. Pre-treatments like blanching (80°C for 1 min), freezing (-30°C for 8 h (Arlai *et al.,* 2012), drying (3 h at 105°C) and untreated (control) were selected for this study along with atmospheric frying (165°C, 101 kPa and 15 min). The pretreatments were optimized based on the quality parameters of vacuum fried jackfruit chips *viz.,* water activity, oil content, moisture content, colour and texture. The quality parameters were estimated based on the standard procedures. The optimized pre treatment was only considered for the next experiments.

Experiment II. Standardization of process parameters for the production of vacuum fried jackfruit chips

The experiment II was performed for optimization of process parameters *viz,* temperature, pressure and time of frying for the production of vacuum fried jackfruit chips. Based on previous reviews, blended rice bran and palm oil in the ratio of 80:20 was selected for vacuum frying. De-oiling was carried out by centrifugation at a speed of 1000 rpm for 5 min. The experiments were conducted with 2 frying temperatures (100°C and 110°C), 2 vacuum pressures (9 kPa and 12 kPa) and 2 time of frying (18 min and 20 min). The experiment consists of 8 treatments in 2 replications. The treatments were JF1 (100°C, 9 kPa and 18 min), JF2 (100°C, 12 kPa and 18 min), JF3 (100°C, 9 kPa and 20 min), JF4 (100°C, 12 kPa and 20 min), JF5 (110°C, 9 kPa and 18 min), JF6 (110°C, 12 kPa and18 min), JF7 (110ºC, 9 kPa and 20 min) and JF8 (110°C, 12 kPa and 20 min).

Quality parameters of vacuum fried jackfruit chips

Quality parameter *viz.,* Moisture content (gravimetric method, AOAC, 1986), Water activity (Aqua lab, Decagon Devices Inc., Pullman (Wa), USA), Oil content (Soxhlet apparatus (Pelican Equipments, Soc plus model: SOCS 06 ACS, India), hardness and crispiness (TA.XT Texture Analyser, stable micro system) with test condition Test Mode: Measuring force in compression, Option: Return to start, Pre-test speed: 1.50 mm/sec, Test speed: 2.00 mm/sec, Post-test speed: 10.00 mm/sec, Distance: 20.00 mm, Trigger type: Auto (force), Trigger force: 5.0 g, Probe: Blade set (HDP/BS), Bulk density (liquid displacement method), True density, Color values (L*, a* and b*, (Maity *et al.,* 2014) Hunter lab Colorimeter - Color flex EZ diffuse model, Total polar compounds (Testo 270°, Make: Italy) were measured. Based on these quality parameters of vacuum fried jackfruit chips, the best combination of product variables was standardized.

Economic analysis

The cost economics was done for the optimized vacuum fried product for commercialization of the product.

RESULTS AND DISSCUSSION

Experiment 1: Optimization of Pre-treatments for Vacuum frying of jackfruit chips

Effects of pre-treatments on quality parameters of vacuum fried jackfruit chips

The quality parameters (water activity, oil content, moisture content, hardness and colour values (L*, a* and b*)) of pre-treated and untreated samples at specific processing condition (100°C, 9kP and 20 min) were compared with consequent atmospheric fried jackfruit chips.

Water activity

Water activity of the pre-treated vacuum fried jackfruit chips significantly changed with different pre-treatments (Fig 1) The water activity of the VF- jackfruit chips was ranged between 0.444 and 0.557 a_w. The water activity of frozen (0.444) pre-treated sample was the least followed by dried (0.480), control (0.487), atmosphere (0.499) and blanched (0.557aw) VF-jackfruit chips. Perez-Tinoco *et al.* (2008) represented similar results of a_w values for vacuum fried pineapple chips.

Oil content

The oil uptake of VF-jackfruit chips was significantly affected by the pre-treatments. Oil content was considerably less in vacuum fried jackfruit chips than atmospheric fried jackfruit chips (Fig 2). The highest oil content of 40.25% was noticed in atmospheric chips followed by frozen (38.44%) pre-treated VF-jackfruit chips. During the evaporation of ice crystals during frying, there will be a rapid formation of microstructure pores and this promotes high oil uptake. The result was in agreement with Ranasalva and Sudheer (2017), who observed a high oil uptake in vacuum fried banana chips pre-treated with freezing. The lowest oil uptake of 33.35% was observed in untreated VF-jackfruit chips. The oil absorption in dried sample (34.25%) was found to be lesser than that of blanched sample (37.76%), this is because the loss of moisture is directly related to oil absorption. Moyanoa and Pedreschi (2006) observed the lowest oil content in drying pre-treated deep fat fried potato chips. Among the above treatments the untreated sample gave comparatively less oil content and better organoleptic quality.

Moisture content

Moisture content of pre-treated VF- jackfruit chips significantly varied with different pre-treatments (Fig 3). The highest moisture content (0.772%) was observed in frozen sample as well as blanched samples and the least moisture content of 0.472% was observed in dried sample. The highest moisture content in frozen sample was due to uniform removal of moisture during vacuum frying of frozen sample with high temperature difference. Fan *et al.* (2006) stated similar trend of moisture reduction in the frozen pre-treated vacuum fried carrot chips. The initial moisture removal of jackfruit slices through drying contributed to low moisture content in the VF-jackfruit chips. Low moisture content was observed in fried potato strips that were air dried prior to frying (Dehghannya *et al*., 2015). The moisture content of the control and blanched pre-treated VF-jackfruit chips were 0.501% and 0.735%, respectively. The atmospheric fried jackfruit chips had moisture content of 2.402% which was much higher than frozen pre-treated sample.

Colour values

The colour values of vacuum fried chips showed significant difference with various pre-treatments (Fig 4). The maximum L* of 69.18 was obtained in control sample followed by frozen (51.48) and blanched (41.59) sample. The minimum L* value of 21.12 was observed in atmospheric fried chips. Control jackfruit produced light coloured chips, which is a desirable character. However, dark coloured product was obtained from drying pre-treatment sample. The a* and b* value of vacuum fried jackfruit showed significant variation with pre-treatments. The a* value of VF-jackfruit chips pre-treated with drying had the highest value of 12.9, which indicates the high red colour in the product. The untreated sample had the lowest a* value (2.73). *i.e*, the untreated sample had the value almost similar to the fresh sample (2.31).

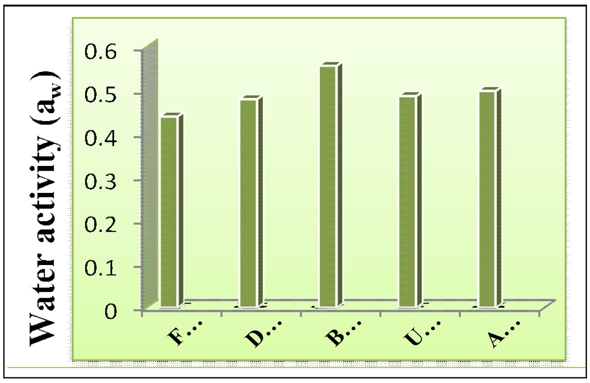

Fig 1: Water activity of pre-treated vacuum fried jackfruit chips.

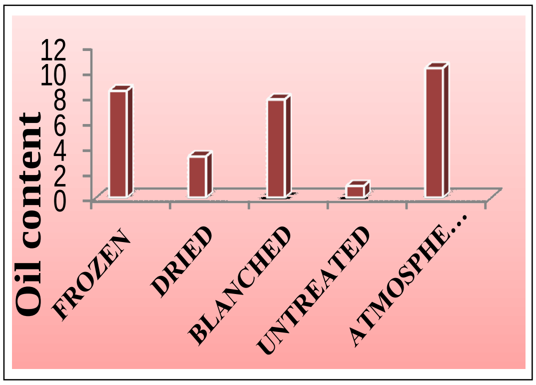

Fig 2: Oil content of pre-treated vacuum fried jackfruit chips.

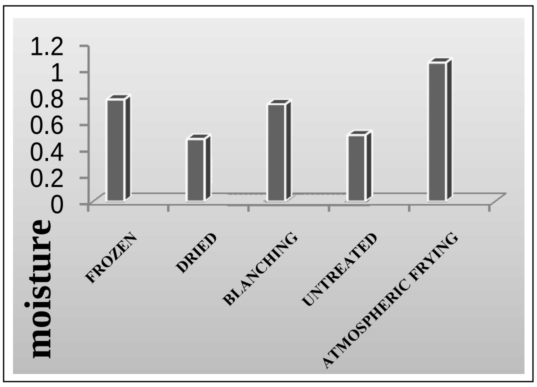

Fig 3: Moisture content of pre-treated Vacuum fried jack fruit chips.

The blanched (11.93) and frozen (12.67) samples also had high a* values. The highest b* value was recorded in frozen pre-treated vacuum fried jack fruit chips (45.05) followed by control (35.35) sample. The blanched and dried pre-treatment samples also had higher b* values, 33.71 and 3.022 respectively. The jackfruit chips fried under atmospheric conditions were turned darker. The change in colour in fried jackfruit chips is due to the interaction of an amine group with a reducing sugar, which is a non-oxidative browning also known as Maillard reaction (Garayo *et al*., 2002).

Texture

The textural changes of pre-treated VF-jackfruit chips exhibited significant difference within treatments (Fig 5). The higher hardness value of 2.6 N was observed in VF-jackfruit chips pre-treated with drying. The removal of moisture prior to frying made the product compact and hard in drying pre-treated sample (Debnath *et al.,* 2012). Fan *et al.* (2005) reported that lower breaking force correspond to higher crispiness and Fan *et al.* (2006) confirmed that crispiness value was higher in case of the drying compared to atmospheric fried and other pre-treatments of vacuum fried carrot chips. The VF jackfruit chips pre-treated with freezing had the lowest hardness value of about 1.65 N, followed by control (1.04N) products. The retention of moisture in the frozen jackfruit slices increased the rate of mass transfer with high oil absorption that lowered crispiness in the product. Arlai *et al.* (2012) had also reported that hardness value of vacuum fried okra chips was less when pre-treated with freezing. Hardness value of blanched VF-jackfruit chips was less compared to dried sample (1.76N) and higher than freezed and control VF jackfruit chips.

Optimization of pretreatments for the production of vacuum fried jackfruit chips

Vacuum fried products without any pretreatments (control) gave better quality parameters. Blanched products had a higher water activity, moisture content and oil content. The texture and color of fried products pretreated with drying was not appreciable. Frying done with frozen jackfruit slices had very high oil content even though its water activity was less. The untreated vacuum fried chips had the most desirable characteristics like low water activity, retention of color and texture, low moisture content and oil content. Hence untreated vacuum fried chips (control sample) were only considered for further studies.

Experiment - II

The experiment II was performed for optimization of process parameters *viz,* temperature, pressure and time of frying for the production of vacuum fried jackfruit chips. Based on previous reviews, blended rice bran and palm oil in the ratio of 80:20 was selected for vacuum frying. The experiment consists of 8 treatments in 3 replications.

Effects of process parameters on physical properties of vacuum fried jackfruit chips

Optimization of process parameters *viz,* temperature, pressure and time of frying was done based on the analysis of quality attributes such as moisture content, water activity, oil content, hardness, colour changes and acrylamide content of vacuum fried jackfruit chips.

Moisture content

The results indicated that frying conditions affected the moisture content (Fig 6). The moisture content ranged from 0.481% to 0.801% in vacuum fried jackfruit chips at different frying parameters. Moisture content of VF-jack fruit chips decreased with increased frying temperature and frying time. This is due to the fact that the more the frying temperature is increased, pressure is lowered and boiling point is

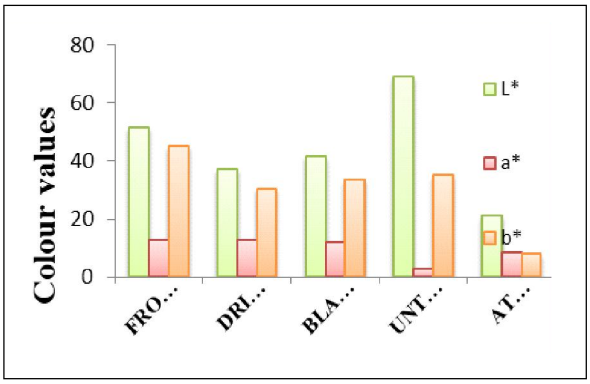

Fig 4: Colour values of pre-treated vacuum vacuum fried jackfruit chips

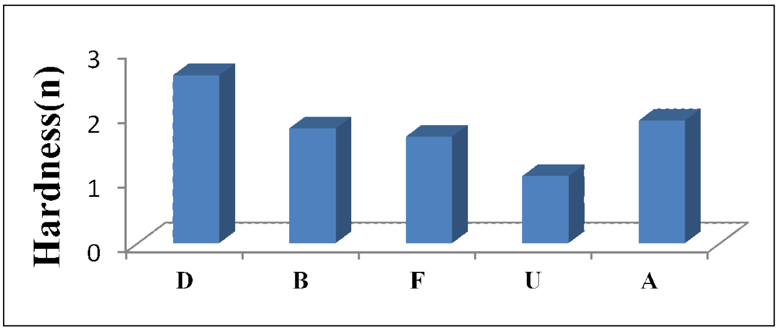

Fig 5: Hardness value of pre-treated vacuum fried jackfruit chips.

reduced. And as a consequence the water in the vacuum fried jackfruit chips will begin to vaporize faster at a higher vacuum level. The low moisture content of 0.481 was observed at frying temperature of 100°C, frying pressure of 9 kPa for a frying time of 20 min. Since the frying was carried out under vacuum which decreased the boiling point of water, the moisture removal was instantaneous without much warm up phase. High moisture content of 0.801% was observed in VF-jackfruit chips at frying temperature of 100°C, frying pressure of 12 kPa and frying time of 18 min. Similar results were observed in the vacuum frying of carrot chips at frying temperature of 118°C (Garayo and Moreira, 2002). There was significant difference in moisture content of VF-jackfruit chips subjected to different frying conditions. The same phenomena were also observed in vacuum fried carrot chips (Fan *et al*., 2005) and for vacuum fried apple chips (Shyi and Hwang, 2001) and vacuum fried banana chips (Ruttanadech and Chungcharoen, 2015).

Water activity

The water activity of VF-jackfruit chips with different frying conditions is represented in Fig 7. The minimum and maximum activity value of 0.473 and 0.613 was obtained at frying condition of 100°C, 9 kPa and 20 min (JF3) and 100°C, 12 kPa and 18 min (JF2), respectively. This might be due to high moisture retention at the respective frying temperature, pressure and time. Similar results were observed for vacuum fried carrot chips (Dueik *et al*., 2010), vacuum fried shiitake mushroom chips (Ren *et al*., 2018). The safe level of water activity for any fried product should be less than 0.6 (Fontana, 1998).

Oil content

Oil content of vacuum fried jackfruit chips is an important parameter in assessing the consumer accessibility of the product. Oil absorption is a complex phenomenon that happened mostly when the product is removed from the fryer during the cooling stage. The oil content of VF-jackfruit ranged from 28.85 to 34.73% at different frying conditions (Fig 8). The maximum oil content of 34.73% was noted at 110°C, 9 kPa and 20 min (JF7). Also, the minimum oil content of 20.73% (JF3) was observed in VF-jackfruit chips with frying conditions of 100°C, 9 kPa and 20 min.

The oil uptake increased at increased frying temperatures. Absorption of oil was found to be related to the loss of moisture from the jackfruit chips. This may be due to the diffusion gradient created by the loss of moisture through the surface making the surface dry (Tanushree *et al*., 2014). The same phenomenon was also observed by Segovia *et al,* (2016) for vacuum fried cassava chips at different frying temperature and frying time and Ranasalva and Sudheer (2017) for vacuum fried banana chips.

Colour values

The colour values of VF-jackfruit chips significantly varied with different process parameters (Fig 9). The L* values of the vacuum fried jackfruit chips ranged from 66.53 to 70.18. The L* values were seen to be inversely proportional to the frying temperature. A higher L* value was observed in VF-jackfruit chips at frying condition of 100°C, 9 kPa and 20

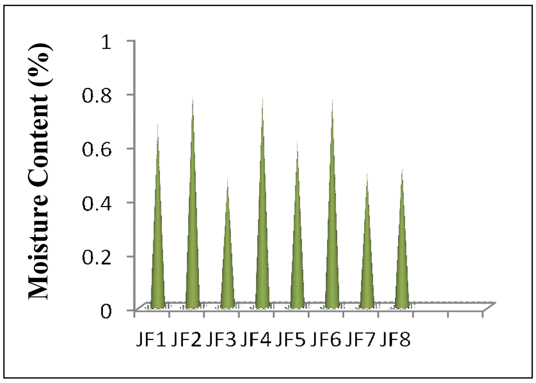

Fig 6: Changes in moisture content of VF jackfruit with process parameters.

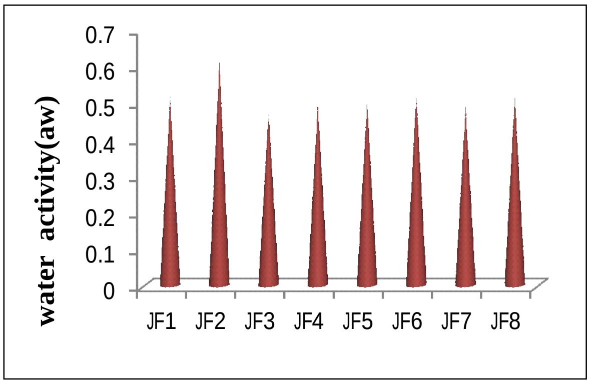

Fig 7: Changes in water activity of VF-Jackfruit with process parameters

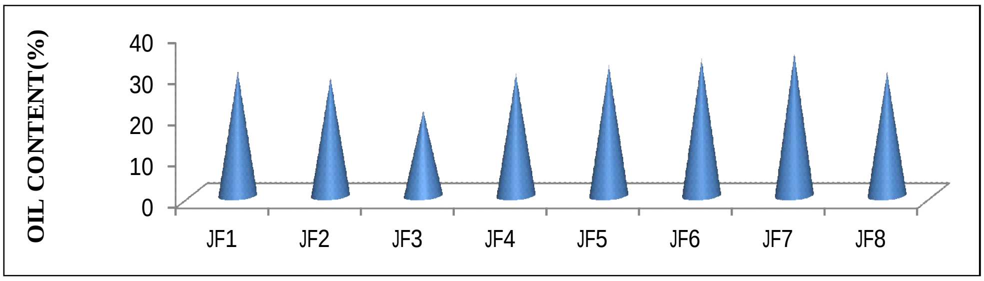

Fig 8: Changes in oil content of VF-jackfruit with process parameters.

min (JF3). Lower L* value of 66.53 was observed in the VF-jackfruit chips at processing conditions of 110°C, 9 kPa and 20 min (JF7). When frying time was further extended, the L* value decreased at all frying temperatures. Visual observations confirmed the results obtained from colorimeter, since the jackfruit chips fried under atmospheric conditions were darker, more red and yellowish than jackfruit chips under vacuum. The change in color was due to the interaction of an amine group with a reducing sugar, which is a non-oxidative browning reaction also known as Maillard reaction.

The maximum a* value of 3.26 was observed in the VF- jackfruit chips at frying condition of 110°C, 12 kPa and 20 min (JF8) and the minimum a* value of 2.71 was found in the at 100°C, 9 kPa and 20 min (JF8) (Fig 10). In VF-jackfruit chips, green colour was increased with a high negative value at lower frying temperature, whereas at high frying temperature, a* value changed from green to red colour due to browning reaction. The a* value of VF- jackfruit chips significantly varied with different frying conditions.

Higher b* value (35.41) was noted in VF-jackfruit chips at frying condition of 100°C, 9 kPa for 18 min (JF3) and lower b* value (29.46) was noticed at 110°C, 9 kPa for 20 min (Fig 11). A lower value of b* was observed by the increase in frying temperatures. The same phenomenon was also observed, for vacuum fried chicken nugget (Teruel *et al.,* 2014). The b* value significantly varied with different combinations of frying temperature, pressure and time.

The L*, a* and b* values of fresh ripened jackfruit bulb slices was 75.37, 2.31 and 36.66 respectively. The sample of jackfruit chips fried at a frying temperature of 100°C, a frying pressure of 9kPa and frying time of 20 min showed most precise values of L*(70.18), a*(2.71) and b*(35.41) to fresh sample.

Textural changes

The effect of process parameters on texture in VF-jackfruit chips is highly significant (Fig 12). The hardness value of VF-jackfruit chips increased with frying temperatures. Hardness value of vacuum fried chips ranged between 1.01N to 2.37N at different frying temperature (100°C and 110°C), frying pressure (9 and 12kPa) and frying time (18 and 20 min). The lower hardness value of 1.01 N was noted in VF-jackfruit chips at frying condition of 100°C, 9 kPa for 18 min (JF1) and the higher hardness value of 2.37 N was observed in 110°C, 12 kPa for 20 min (JF8). In case of the VF- jackfruit chips, the hardness value was inversely proportional to the crispiness. The hardness value was high at higher temperature during frying and this is due to loss of moisture. Similar results were observed for increased hardness value

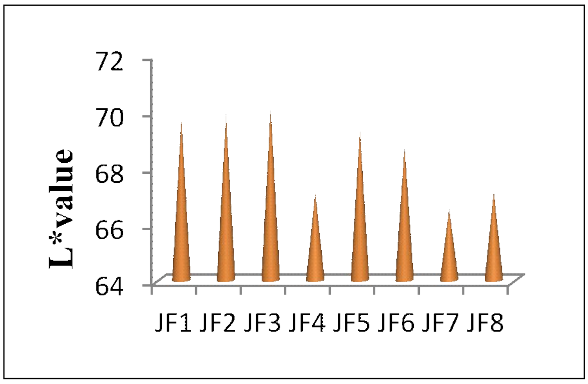

Fig 9: Changes in L* value of VF- jackfruit with process parameter.

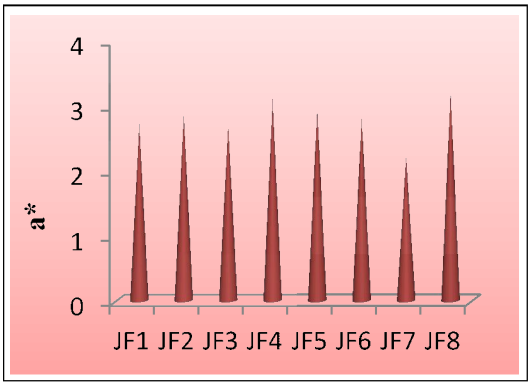

Fig 10: Changes in a* value of VF- jackfruit with process parameter.

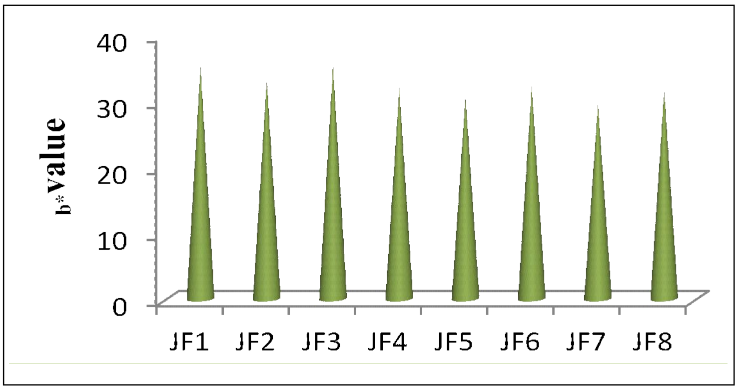

Fig 11: Changes in b* value of VF jackfruit with process parameter.

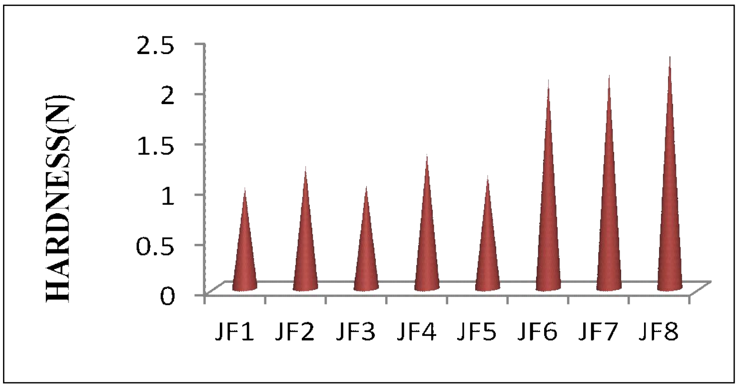

Fig 12: Changes in hardness value of VF jackfruit with process parameter.

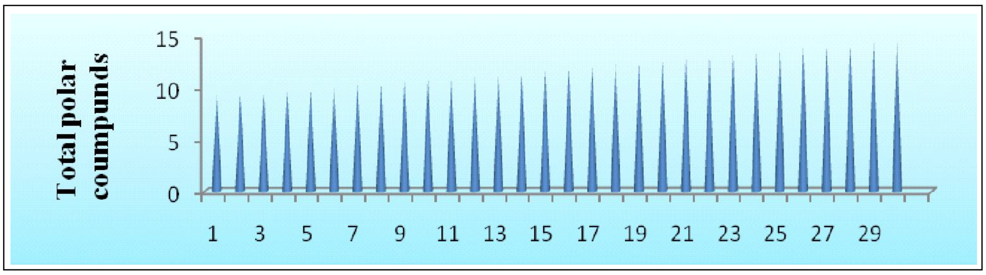

Fig 13: Changes of the total polar compounds during vacuum frying.

of vacuum fried banana chips at 120°C for 14 min (Yamsaengsung *et al.,* 2011) and vacuum fried potato chips at 144ºC (gara).

Optimization of process parameters for the production of vacuum fried jackfruit chips

Different quality attributes such as moisture content, water activity, oil content, hardness, colour changes and acrylamide content of vacuum fried jackfruit chips were analysed in the study. 8 different combinations of temperature, time and pressure were taken and aforesaid quality attributes were studied. Of these JF3 sample fried at 100°C, 9 kPa and 20 min gave better result in terms of quality.

Changes in the total polar compounds blended oil during vacuum frying

The determination of total polar compounds in frying oil contributes the most important measure of the extent of oxidative deterioration. The oil was evaluated for total polar compounds after its repeated use for several batches of vacuum frying. Total polar compound was determined after every batch of vacuum frying (100°C, 12KPa for 20 min) after cooling. The threshold level of TPC in edible oil was 25-27%. The TPC of blended oil was increased from 9.3% to 14.5% after 30th batch of vacuum frying, which is well below the threshold limit Fig 13. This made help to recommended for reuse the oil upto 30 times of vacuum frying. The increased in the extent of polar compounds in the oil indicates the formation of compounds such as triacylglycerols, secondary oxidation of oil (Latha and Nasirullah, 2011).

Cost analysis

From the cost analysis, vacuum fried jackfruit chips was found to be Rs. 617.54/- per kg.

CONCLUSION

Based on the results, it was concluded that vacuum frying technology is a promising technology for production of jackfruit chips. The control (un-treated) VF-jackfruit chips had better quality attributes compared to other pretreated jackfruit chips. The process conditions at 100°C and 9 kPa for 20 min has produced novel healthy snacks with low oil content. Cost of vacuum fried jackfruit chips was found to be Rs. 617.54/- per kg.

Conflict of interest: None.

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