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Effect of vacuum frying process on some physico-chemical properties of jack fruit chips

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Abstract
Jackfruit (*Artocarpus heterophyllus* L.) is nutritious, poor man's fruit, rich in vitamins and minerals, mostly consumed as a fresh fruit. The jackfruit bulb can be used for preparation of value added products. Jackfruit chips, a popular snack, prepared by deep fat frying of matured, unripe jackfruit bulb fingers at different vacuum pressure. The quality of chips mainly depends on crispiness. It is the most important quality parameter of chips and is mainly depends on frying temperature, time and variety of fruit. Fully matured, unripe and deseeded jackfruit bulbs were cut into approximately 15×4 mm by using jackfruit cutting machine and were fried at different vacuum levels using refined sunflower oil at three different temperature and time such as 80, 90 and 100 °C for 15, 20 and 25 minutes respectively. The processed jackfruit chips were studied with the full factorial design (FFD). Results showed that the chips out-turn, oil absorption by chips and physicochemical characteristics like tristimulus color, and crispiness of fried jackfruit chips were significantly related to vacuum level, frying temperature and time. The results indicate that colour and crispiness were significantly correlated with frying temperature, time and vacuum level. The optimum conditions for the vacuum frying of jackfruit bulbs were found to be 400 mm Hg, 90 °C and 20 minutes, for frying of vacuum level, temperature and time, respectively.

Keywords: Vacuum frying, Jack chips, temperature and time

1. Introduction

Jackfruit (*Artocarpus heterophyllus* L.) belongs to the family Moraceae and it is a tropical evergreen tree. It is believed to be native of Western Ghats of India is widely cultivated in Bangladesh, India, Myanmar, Malaysia, Sri Lanka and other tropical countries. Bangladesh is the largest producer of jackfruit, producing 15 lakh tonnes of fruits in a cultivated area of around 1.45 lakh hectares. Jackfruit is the national fruit of Bangladesh. It is hardly recognized as a commercial fruit crop in India, though it is widely grown in the country. It is quite popular in eastern and southern India and widely cultivated in the states like Karnataka, Kerala, Tamil Nadu, Andhra Pradesh, West Bengal, Maharashtra, Assam, Andaman and Nicobar Islands. In India, the total area under jackfruit is approximately 1.02 lakh ha. In Karnataka, it is cultivated in an area of about 4,700 ha, and the annual production is about 1.65 lakh tonnes of produce. The productivity is about 35 tonnes per ha and the value of the produce is about 187 crores per year (Hittalmani, 2016) [6].

Vacuum frying is a new technology that might be an option for the production of novel snacks such as fruits and vegetables with lower oil content and desired quality attributes. It is the frying process carried out under pressures well below atmospheric levels, therefore lowering the boiling point of water, making possible to reduce substantially the frying temperature (Garayo and Moreira, 2002) [4].

Dueik *et al.* (2010) [3] studied the preservation of colour and flavours in vacuum fried foods. They concluded that the vacuum fried snacks retain more of their natural colour and flavour due to less oxidation and lower frying temperature. Vacuum frying is a frying process that is carried out at pressures well below atmospheric level. It has been used for different foods but mostly fruits and vegetables. The latest reports include apple, apricot, banana, jackfruit, green and gold kiwifruits, carrot, mushroom, potato, shallot, sweet potato and purple yam. Vacuum frying offers an alternative way to improve the quality of fried fruit and vegetables other than by atmospheric frying (Dueik and Bouchon, 2011) [2].

Yagua and Moreira (2011) [11] studied the physical and thermal properties of potato chips vacuum fried at different temperatures (120, 130 & 140 °C).

They found that the rate of change in product quality features was affected by temperature, whereas the final values of moisture content, bulk density, true density, porosity, diameter, shrinkage and thickness expansion were not affected by temperature. Frying time was another important factor which impacted the quality of vacuum fried product.

Maity *et al.* (2014) [7] evaluated the effect of frying temperature and duration on the quality of vacuum fried jackfruit chips. Under the vacuum frying conditions tested, the optimum frying times at 80, 90 and 100 °C were 30, 25 and 20 minutes, respectively. Moisture content and breaking force of jackfruit chips decreased with increase in frying temperature and time whereas chips oil content increased. Sensory evaluation of chips showed maximum acceptability for jackfruit chips fried at 90 °C for 25 minutes.

Garcia-Segovia *et al.* (2016) [5] studied the behaviour of cassava chips, blanched or unblanched and processed under either atmospheric or vacuum frying conditions, in order to determine the influence of these treatments on the mechanical and acoustic parameters, optical properties and oil absorption. Vacuum frying trials (17 kPa) were conducted at 120, 130 and 140 °C and compared with frying at atmospheric pressure (101.3 kPa) at 165 °C. Vacuum treated (130 °C) cassava chips improved the color of the samples, reduced the oil uptake and maintained crispness.

Jackfruit is considered as a healthy fruit but it is a seasonal fruit. It has short shelf life and hence it is associated with a lot of post-harvest losses. It will be beneficial if this fruit is processed and converted into ready-to-eat snacks so that it can reach to a larger section of our population. Though jack chips are available in the market for a long time, most of such chips are prepared by deep fat frying at high temperatures and at normal atmospheric pressure. Vacuum frying of food products are of recent origin and this will yield high quality fried products with less oil absorption. In this background, the present study aimed at optimizing vacuum level, temperature and time of vacuum frying to obtain low fat jackfruit chips.

2. Materials and Methods

2.1 Raw materials

Jackfruits for the present study were collected from same tree of Horticulture Farm, University of Agricultural Sciences, GKVK, Bangalore. During selection of fruits, care was taken to select fresh mature and unripe fruits for experimentation for chips production. Criteria for selection of fruits for chips production were: size, maturity level, spines, flattening of skin, hollow sound on tapping and fruit colour turning to pale yellow. Refined sunflower oil (Sunpure Brand), salt, chilli powder was procured from the local market. Different packaging materials used were procured from Bangalore City Market. The chemicals used for analysis in this study were of analytical grade.

2.2 Extraction and preparation of edible bulbs for jackfruit chips

The edible bulbs were extracted after cutting the jackfruit manually. The fruits were cut along equatorial axis with the help of a sharp stainless steel knife smeared with edible oil. The bulbs were carefully separated from the rind and placenta and care was taken to handle the bulbs with minimum damage. The freshly extracted bulbs were deseeded and then sliced. The jack bulb slices were used for chips production.

2.3 Vacuum frying

About 60 liters of frying oil was poured in the frying chamber and the same oil level was maintained for all frying experiments. At the beginning, the frying oil temperature was set 5 °C above the desired value. Required air pressure (≈ 4 kg/cm^2) was created in the external air compressor to operate the hydraulic cylinder using control levers. Air pressure actually helped to lower or lift the sample basket inside the vacuum frying chamber. When oil temperature is reached, the prepared raw jackfruit fingers (sample size- 500 g) were placed in the sample basket and it was loaded into the vacuum frying chamber. The sample door was closed air-tight and the pressure purge valve was closed. The control switch for vacuum pump and cooling water pump were switched on. Maximum vacuum that could be created in the unit was 640 mm Hg. When desired vacuum was created in the chamber, the sample basket was lowered into the oil for frying using hydraulic control lever. The frying oil temperature initially dropped by about 4-5 °C and that was the reason for setting the frying oil temperature slightly higher at the beginning. The frying temperature was immediately reset to the desired value in the temperature controller. At the beginning of frying, a lot of water vapour evolved, fogging the viewing glass. With time, the vapours were sucked away by the vacuum pump and the progress of frying could be early seen through the illuminated viewing glass window.

Frying was done for set duration and at the completion of frying time, the sample basket was lifted up from the oil using hydraulic lever and allowed to cool for about 5 minutes inside the chamber. Just before taking out the sample basket, the vacuum pump was shut, the purge valve was opened to normalize the inside chamber pressure with atmosphere and the sample door was opened. Immediately, the sample basket was removed and placed inside the basket centrifuge for residual surface oil removal from fried jack chips. Circulation of warm air at about 50 °C inside the centrifuge helped to expel out more oil from fried chips. The fried chip was again weighed to compute chips out-turn. Salt (@ 2%) and chilli powder (@1%) were added to chips, mixed thoroughly and stored in LDPE bags. Meanwhile a second sample basket was ready for loading into the vacuum fryer so that loss of heat energy was minimized. During operations, care was taken to maintain same oil level in the fryer. Also sufficient water level was maintained in the water reservoir for smooth functioning of vacuum pump and supply of cooling water to the condenser.

2.4 Process of preparation of vacuum fried jackfruit chips

The process flow chart of preparation of jack chips is presented in Fig 1. The fresh deseeded bulbs were taken for preparation of jackfruit chips. The fresh deseeded jackfruit bulbs were sliced to obtain finger chips of size approximately 15×4 mm by using a jackfruit cutting machine. The cut bulb slices were blanched in hot water (at 60 °C) containing 0.5% KMS for 5 minutes followed by drying at room temperature for 15 min to remove surface moisture. Then the slices were vacuum fried using refined sunflower oil. Frying was done under 2 different vacuum levels and three frying temperatures for three different durations. After frying the chips were deoiled by centrifugation at 500 rpm for 5 min.

Fully mature, unripe jackfruit

↓

Washing, Peeling, Deseeding

↓

Jackfruit deseeded bulbs

↓

Trimming & Cutting of bulbs into fingers in jackfruit cutting machine

↓

Jackfruit fingers (15x4 mm)

↓

Blanching in water @ 60 °C having 1% KMS for 5 min

↓

Air drying for 15 min

↓

Vacuum frying

↓

Centrifugation for deoiling fried chips (500 rpm @ 5 min) & cooling (@RT)

↓

Addition of salt

↓

(2%) & chilli powder (1%)

↓

Mixing & Packaging

↓

Vacuum fried jackfruit chips

Fig 1: Process flow chart for production of vacuum fried jackfruit chips

2.5 Experimental design

Full factorial design with 3 replications was followed throughout the experiment. The independent variables were vacuum levels (640 and 400 mm of Hg), frying temperatures (80, 90 and 100 °C) and frying times (15, 20 and 25 min) were selected. Independent variables and their combinations had been investigated for each attribute. After each experiment, the physicochemical properties viz color and crispiness were analyzed to know the effect of frying process parameters on its. Besides to this, the chips out-turn and oil absorption by chips were also estimated under this study.

2.6 Measurement of chips out-turn

Chips out turn indicate the yield per unit weight of raw materials used i.e, deseeded bulb fingers. It was calculated by using the following equation (1)

$$\text{Chip out turn } (\%) = \frac{\text{Weight of fried chips (g)}}{\text{Initial weight of raw fingers (g)}} \times 100 \ldots\ldots(1)$$

2.7 Measurement of oil absorption by chips

Moisture free chips sample was weighed in moisture free thimble and the crude fat of chips was extracted out by refluxing in Soxhlet apparatus using petroleum ether as solvent. The residual solvent was decanted from the chips and the weight of fat free chips sample was again determined. Then, the oil absorption by chips was calculated from weight difference (Anon., 1990) [1] using following equation (2)

$$\text{Oil absorption by jackchips } (\%) = \frac{\begin{bmatrix}\text{Initial weight(moisture free)of chips} \\ -\text{ Weight of chips after fat extraction}\end{bmatrix}}{\text{Initial weight of chips}} \times 100 \ldots\ldots(2)$$

2.8 Measurement of physicochemical characteristics of jackfruit chips

The physicochemical characteristics of chips measured in their study included tristimulus colour and crispiness.

2.8.1 Tristimulus colour

Tristimulus colour measurements of the vacuum fried jackfruit chips were made using a Spectrophotometer (Konica Minolta Instrument, Osaka, Japan, Model-CM5). It is a light weight, compact tristimulus colour analyzer for measuring reflected-light colour. It combines advanced electronic and optical technology to provide high accuracy and complete portability. Using an 8 mm diameter (measuring area) diffused illumination and 0^o viewing angle, the instrument takes accurate colour measurements instantaneously and the readings are displayed. The colour of the sample was measured in L*a*b* coordinate system where L* indicate lightness of the sample; a* value indicate greenness (-) or redness (+) of the sample and b* value indicate blueness (-) or yellowness (+) of the sample. Three readings were taken for each sample and the mean value was recorded.

2.8.2 Crispiness

Crispiness is most important textural property of fried chips. Crispiness is a characteristics of a product by which it resists compression force until it fractures into small pieces. It actually relates to the ease of fracture or factorability and brittleness of the product. Crispiness of jackfruit chips was studied using a Texture Analyzer (Make: Stable Microsystems Ltd, UK; Model – Hdi) and it was linked to a computer to record the data *via*., Texture Expert Exceed software supplied along with the instrument. The Texture Analyzer measures force and distance in real time thus providing three dimensional product analyses. The texture of a chips was expressed in terms of crispiness measured by conducting cutting test using blade set with knife supplied with texture analyser. The test procedure included the cutting of chips using the blade set with knife and measuring the force of cutting in real time. During cutting test, a single blade having 70 mm width and 90 mm length was used to cut through the samples under specified conditions. The heavy duty platform was secured to the base of the machine and slotted plate was placed on the platform. The jackfruit chip 0.5 mm wide were held manually against slotted base plate individually and the cutting test was conducted according to TA Settings mentioned in Table 3.1.

Table 3.1: Texture analyzer settings for cutting test to measure crispiness of jackfruit chips

TA Settings	
Mode	Measuring force in compression
Option	Return to start
Pre-test speed	1.5 mm/s
Test speed	2.0 mm/s
Post-test speed	10.0 mm/s
Distance (Compression)	5 mm
Data acquisition	400 pps

The maximum force was recorded in real time by the texture analyser and the data were transferred to a computer. Texture Expert Exceed software supplied with texture analyser was used to analyse the force/time data to identify the absolute peak force required for cutting. Each measurement was taken in two replicates and the mean maximum force of cutting was used to express the crispiness of the chips in grams 'g_f' (gram force).

2.9 Data analysis
Analysis of variance (ANOVA) test was conducted using Design expert version 7.0.0 software (State-Ease Inc., Minneapolis, USA) to evaluate the significance (at 95% confidence level) of the effect of independent variables and their interactions on the responses. Full factorial design was used to estimate the effect of independent variables (vacuum level, frying temperatures and frying times) on responses (color and crispiness).

3. Results and Discussion
3.1 Fried chips out-turn
The yield or out-turn of vacuum fried jackfruit chips under different combinations of processing parameters namely, vacuum level, frying temperature and frying time are presented in fig 2(a) and fig 2(b). The fried chips out-turn in case of jackfruit was roughly about 50%. There was a considerable variation in chips out-turn noticed during different processing conditions. For frying under 640 mm Hg vacuum, the mean chips out-turn was

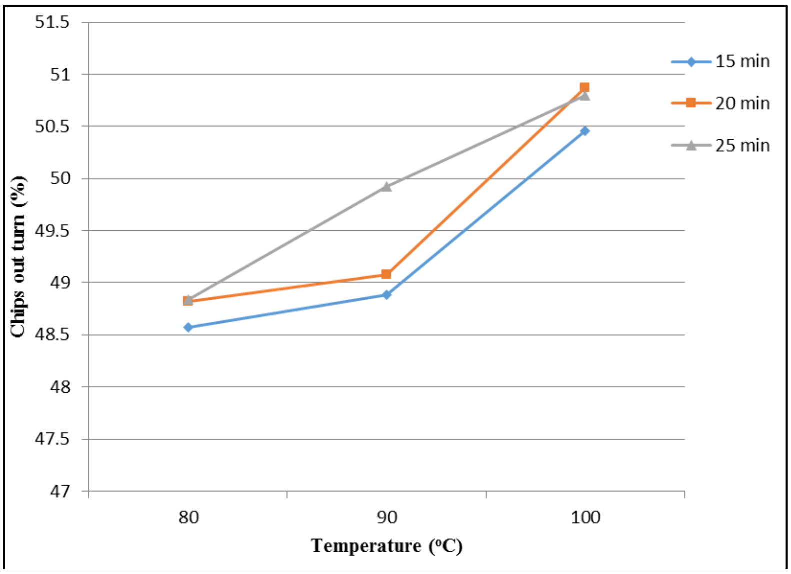

Fig 2(a): Chips out turn of vacuum fried jackfruit chips processed at 400 mm of Hg vacuum level

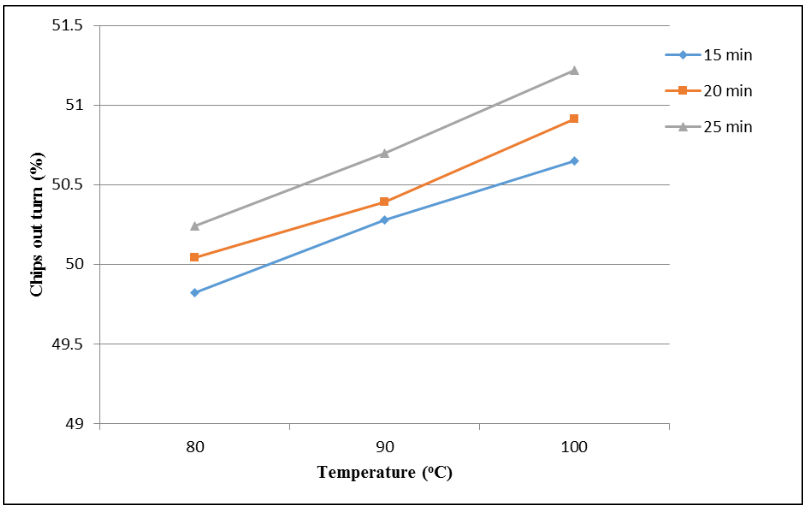

Fig 2(b): Chips out turn of vacuum fried jackfruit chips processed at 640 mm of Hg vacuum level

50.47% while at 400 mm Hg frying vacuum level, it was 49.58%. Statistical analysis showed that there was significant difference in out-turns of vacuum fried jackfruit chips with respect to vacuum level employed during frying. The chips out-turn under vacuum frying at 80, 90 and 100 °C were 49.39, 49.87 and 50.81%, respectively. Statistically significant difference was observed in out-turn of vacuum fried jackfruit chips fried at different temperatures. The jack fruit chips out-turn under vacuum frying were 49.78, 50.01 and 50.28% respectively for frying duration of 15, 20 and 25 minutes.

Statistical analysis showed that there was significant difference between out-turn of vacuum fried jackfruit chips fried at different time. The interaction effect of frying vacuum level, frying temperature and time was also significant

3.2 Oil absorption (uptake) by vacuum fried chips

The oil absorption of jackfruit chips fried under different combinations of processing parameters namely, vacuum level, frying temperature and frying time are presented in fig 3(a) and fig 3(b). The mean oil absorption of vacuum fried chips were 27.04 and 25.29% respectively for frying under 640 mm Hg and 400 mm Hg vacuum levels. Statistical analysis showed that there was significant difference between oil absorption of jackfruit chips with respect to vacuum level employed during frying. The oil absorption of vacuum fried chips at 80, 90 and 100 °C were 23.62, 25.64 and 29.28%, respectively. Statistically significant difference was observed in oil absorption of chips fried at different temperatures. The oil absorption of vacuum fried chips were 25.14, 26.11 and 27.28% respectively for frying duration of 15, 20 and 25 minutes.

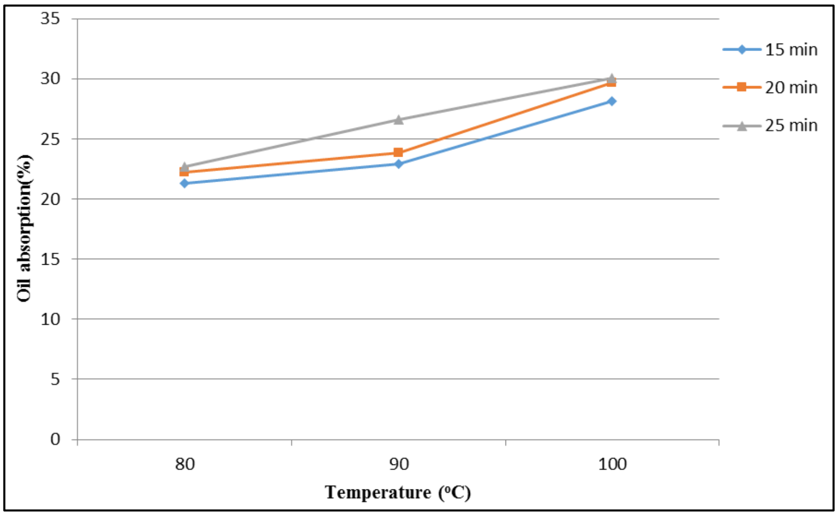

Fig 3(a): Oil absorption of vacuum fried jackfruit chips processed at 400 mm of Hg vacuum level

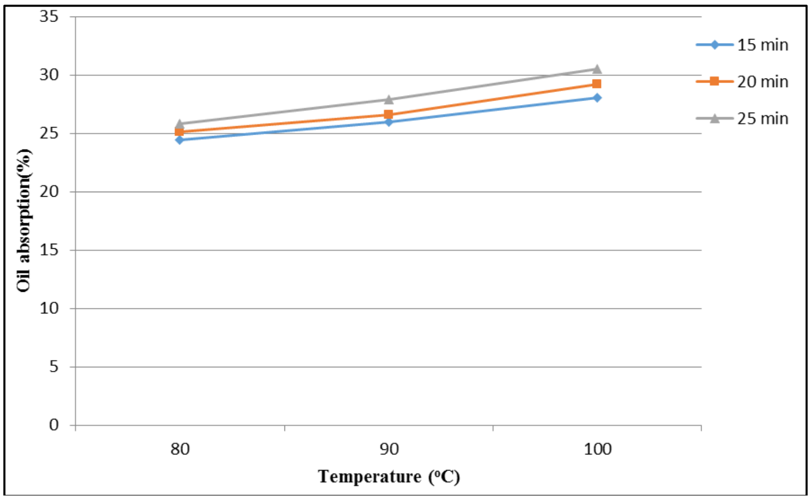

Fig 3(b): Oil absorption of vacuum fried jackfruit chips processed at 640 mm of Hg vacuum level

Statistical analysis showed that there was significant difference between oil absorption of jackfruit chips fried for different time periods. The interaction effect of frying vacuum level, frying temperature and frying time was also significant.

Garayo and Moreira (2002) [4] reported that during vacuum frying, the oil temperature and vacuum pressure had significant effect on oil absorption rate of potato chips. Faster the water loss rate during frying higher will be the surface oil adhesion which will encourage higher oil absorption. Pinthus *et al.* (1993) [9] observed that the oil absorption wass influenced by various factors such as frying temperature and time, food composition, pretreatment and oil quality. Molla *et al.* (2008) [8] reported that the jackfruit chips deep fat fried at 170 °C had oil content of 45% and in this study the oil absorption was much lower due to vacuum frying.

3.3 Physical characteristics

The two jackfruit chips' physical characteristics namely, (instrumental) tristimulus colour and crispiness were studied for the experimental vacuum fried jack chips and are presented below.

3.3.1 Tri-stimulus colour

The tristimulus colour of vacuum fried jackfruit chips in terms of L*a*b* values are presented in Table 1. Chips fried under the vacuum level 640 mm Hg were appeared to be brighter with: lightness L* value ranging from 63.02 to 69.77, the a* value ranging from 6.44 to 7.17 and b* value ranging from 34.43 to 35.72. Similarly, for the chips fried under 400 mm Hg vacuum, the L*, a* and b* values are ranged from 58.72 to 65.03, 6.78 to 9.30 and 28.36 to 33.06, respectively. Maity *et al.* (2014) [7] also reported decrease in L* values with increasing frying time.

3.3.2 Crispiness

Crispiness is the characteristics of a product by which it resists compression force until it fractures into small pieces. It is also related to the ease of fracture or factorability and brittleness of a product structure. During cutting test of the product, the number of peaks or total length of the Force-Deformation (Time) curve will give a measure of this property. In case of fried chips, the cutting strength may also give a measure of the crispiness. For fried jackfruit chips, crispiness was measured by using texture analyser and the results are given in fig 4(a) and fig 4(b). The mean values of crispiness of chips were 1950.41 and 2252.05 g_f respectively for chips fried under 640 mm Hg and 400 mm Hg vacuum levels. Statistical analysis showed that there was non-significant difference between crispiness of jackfruit chips with respect to vacuum level employed during frying. The mean crispiness of vacuum fried chips were 1471.95, 2587.61 and 2244.12 g_f for frying temperature of 80, 90 and 100 °C, respectively. Statistically significant difference was observed in crispiness of chips fried at different temperatures. The crispiness of vacuum fried chips were 1886.86, 2244.24 and 2172.59 g_f respectively for frying duration of 15, 20 and 25 minutes. Vacuum frying time within the experimental range did not influence the crispiness of fried chips. The interaction effects between frying vacuum level and frying temperature as well as frying temperature and frying time were significant. Maity *et al.* (2014) [7] reported lesser breaking force (more crispy) for vacuum fried jack chips fried relatively at higher temperatures. Satish kumar and Karthik (2015) [10] also reported the crispiness of fried jack chips depended on frying temperature and time.

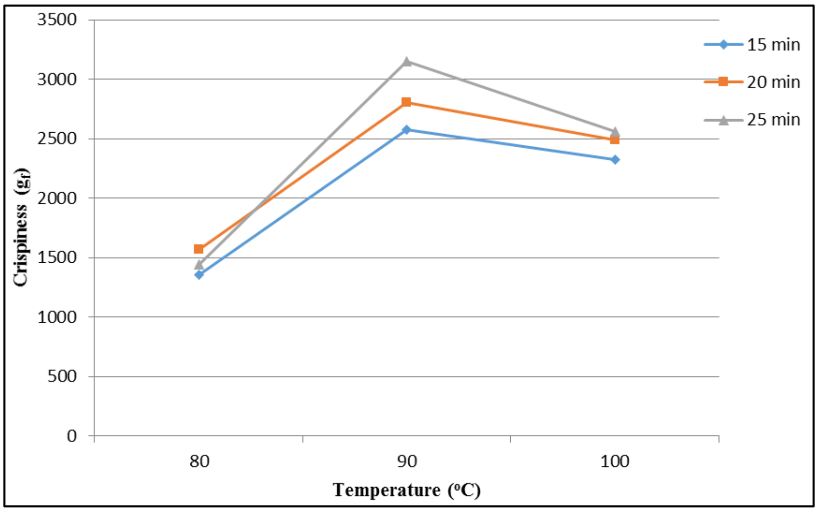

Fig 4(a): Crispiness of vacuum fried jackfruit chips processed at 400 mm of Hg vacuum level

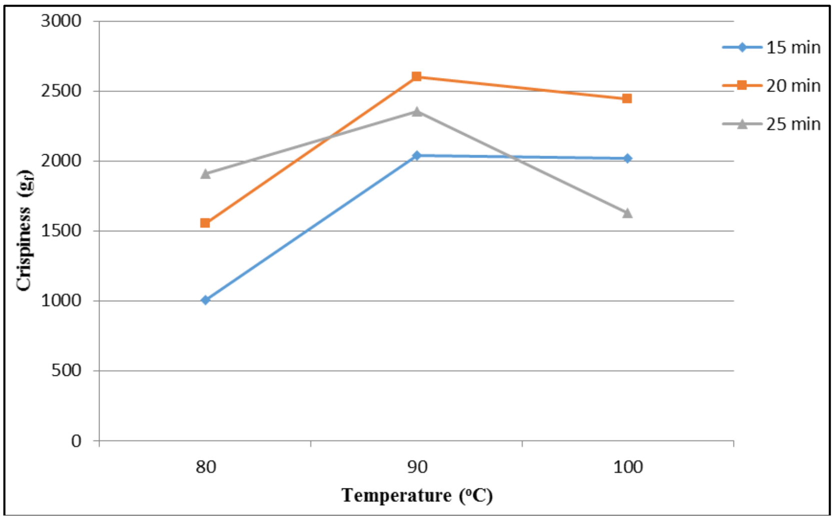

Fig 4(b): Crispiness of vacuum fried jackfruit chips processed at 640 mm of Hg vacuum level

Table 1: Tristimulus colour of vacuum fried jackfruit chips processed at various frying conditions

Frying conditions			Tri-stimulus colour		
Vacuum (mm Hg)	**Temperature (°C)**	**Time (min)**	**L***	**a***	**b***
640	80	15	69.77	6.47	35.72
		20	67.02	6.74	35.68
		25	66.95	6.81	35.64
	90	15	68.26	7.07	35.64
		20	67.26	6.82	35.51
		25	66.02	6.90	35.45
	100	15	65.32	6.44	35.16
		20	64.34	6.56	34.88
		25	63.02	7.17	34.43
400	80	15	65.03	6.78	33.06
		20	63.82	7.04	32.16
		25	61.42	7.78	30.58
	90	15	64.44	8.06	32.05
		20	64.19	8.28	31.24
		25	63.82	8.35	30.97
	100	15	62.97	8.36	29.90
		20	59.24	8.96	28.66
		25	58.72	9.30	28.36

4. Conclusion

The result of the study showed that the chip out turn was about 50%. For various vacuum frying combinations, the vacuum fried chips absorbed relatively lesser frying oil (23.62 to 29.28%). The tristimulus colour and crispiness of chips was better at among the vacuum fried chips prepared under different combinations of vacuum level, frying temperature and frying duration, the jackfruit chips prepared under 400 mm Hg vacuum at 90 °C frying temperature for 20 minutes frying time was adjudged to be best in terms of all quality parameters.

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