Indian Journal of Science and Technology, *Vol 8(3), 287–295, February 2015*
ISSN (Online) : 0974-5645
ISSN (Print) : 0974-6846
DOI : 10.17485/ijst/2015/v8i3/59863

Bioactive Components and Quality Assessment of *Jamun* (*Syzygium cumini L.*) Powder Supplemented *Chapatti*

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Abstract

'*Jamun*' or Indian blackberry is a minor fruit crop with robust medical benefits and possess antioxidant, anticancer and anti-diabetic properties. The objective of the present study was to determine the bioactive components and quality of '*jamun*' powder incorporated '*chapatti*'. '*Jamun*' fruit powder was prepared by two drying methods (hot air drying and freeze drying). '*Jamun*' powder was then incorporated in the whole wheat flour at 1, 2, 3, 4 and 5 % level for preparation of supplemented '*chapattis*'. Freeze dried '*jamun*' powder resulted in higher retention of ascorbic acid, anthocyanins, total phenols and antioxidant activity compared to hot air dried powder. Bioactive components improved significantly upon incorporation of '*jamun*' powder in '*chapattis*'. Freeze dried '*jamun*' powder supplemented '*chapattis*' showed 24.20% increase of total phenols and 33.21% increase of antioxidant activity. Quality assessment studies depicted non-sticky behavior of dough supplemented with hot air dried '*jamun*' powder at 1–4 % level and 1–3 % level for freeze dried '*jamun*' powder. Supplemented '*chapattis*' depicted full puffing at all the levels except at 5%. Sensory scores were found to be highest for *chapattis* supplemented with 3% '*jamun*' powder from both the drying methods. Color characteristics were affected by both supplementation level and drying methods. Freeze dried powder supplemented '*chapattis*' resulted in softer '*chapattis*' compared to hot air dried powder supplemented '*chapattis*'.

Keywords: Antioxidant Activity, Chapatti, Freeze Drying, Hot Air Drying, Sensory Score

1. Introduction

'*Jamun*' fruit is native to South-East Asian countries and has been entitled as herbal medicine by Ayurveda[1] due to medicinal properties served by it. This fruit have always been the choice of consumers due to its recognition as an important source of antioxidants particularly anthocyanins[2] besides anti-diabetic properties. The flavonoids like anthocyanins play an important role as attractive natural colorants and also add nutritive value to the food consumed by the consumers, thus acting as a nutraceutical. '*Jamun*' fruit has been reported to be rich in carbohydrates, minerals and vitamins. It contains glucose and fructose as primary sugars with no traces of sucrose and is therefore, the only fruit with minimum calories[2].

Dehydration of fruits and vegetables during the main growing season is one of the fundamental methods of preservation and helps in reduction of post harvest losses. Dried products can be used as such after rehydration or can be used to develop value added products during off season. Conventional air drying is the most frequently used dehydration operation in food industry which often results in degradation of phytochemical compounds present in fruits. In lieu to this various drying techniques are emerging to better preserve phytochemicals and this includes infrared drying, vacuum drying, microwave drying and freeze drying. Amongst all, freeze drying technique best preserves the phytochemical compounds with minimal shrinkage of products[3]. Special care is being given to preserve original components of fruit by adequate

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drying techniques so as to minimize deleterious processing effects on phytochemical components.

'*Chapatti*' is one of the oldest and most common unleavened flat bread consumed in the Asian countries. Majority of the wheat grown in India approximately 80.7 million tonnes is consumed mainly in the form of unleavened flat bread known as '*chapatti*'[4-5]. Bakery products including '*chapatti*' can be used an effective carrier of phytochemicals derived from fruits and vegetables. The upcoming trends in the food industry focus on the theme of health and wellness of consumers in addition to demand of attractive and tasty food products. The ability to include meaningful amounts of real fruit in cereal products creates excellent opportunities for new product development. The combination of cereals and fruits can help improve food quality by providing nutritionally active components and making diet rich in functional ingredients that are beneficial for human health.

The aim of this study was to process '*jamun*' fruit into '*jamun*' powder using hot air drying and freeze drying process, utilization of '*jamun*' powder in whole wheat flour '*chapatti*' and to study the antioxidant, qualitative and physico-chemical properties of '*jamun*' powder supplemented '*chapattis*'.

2. Materials and Methods

Fresh '*jamun*' (*Syzygium cumini* L.) fruit was obtained from the orchards of Department of Horticulture, Punjab Agricultural University (PAU), Ludhiana, Punjab. Whole wheat flour was obtained from the local market of Punjab Agricultural University, Ludhiana, Punjab.

2.1 Hot Air Drying and Freeze Drying of *Jamun*

Fresh and fully ripe '*jamun*' fruit was washed thoroughly under running tap water. '*Jamun*' fruit was gently heated in its own juice on hot plate maintained at 60^{O}C for 10 min. Seeds were removed manually and pulp was collected by passing the seedless material through fruit strainer. The pulp was spread as a thin layer on trays of dimension 40–80 cm and dried in cabinet hot air drier (Frederick Herbert-Design 20, Bombay, India) at 35–40^{O}C for 8 hours. The position of trays was interchanged periodically and the pulp was dried till constant weight was attained. In the second lot, the pulp was spread as thin layer on stoppering trays of freeze drier (Freezone freeze dry systems, Labconco, Kansas, USA). The pulp was dried at –30^{O}C temperature and 0.004 mBar pressure for 60 hrs. The conventional hot air dried (CD) and freeze dried (FD) material was grounded finely, packed in aluminium laminates and stored at low temperature for further studies.

2.2 '*Chapatti*' Preparation

Unleavened flat bread or '*chapatti*' was prepared following the procedure described by Austin and Ram[6]. '*Jamun*' powder from both the drying techniques was blended with the whole wheat flour (50g) at the levels of 1, 2, 3, 4 and 5 % and mixed with desired quantity of water. The water required to form viscoelastic dough was reported as water absorption (%). Manual kneading was done for 2.5 minutes for dough development and dough was rested for 30 min. at 30^{O}C and 85% relative humidity. Dough was divided into four equal parts and rounded manually followed by sheeting/rolling on smooth surface to obtain circular '*chapattis*' of 15 cm in diameter. The raw '*chapatti*' was immediately placed on an open hot girdle and baked on one side and then inverted and baked on the other side followed by final baking on the first side. Final product was optimized on the basis of quality and sensory evaluation score for different attributes.

2.3 Quality Evaluation of '*Chapatti*'

Comparative evaluation of cooled '*chapattis*' was done by observing dough handling properties such as stickiness and puffing along with sensory evaluation[7]. '*Jamun*' supplemented '*chapattis*' were evaluated for sensory attributes (appearance, flavour, texture and overall acceptability) using 9-point hedonic scale (Larmond)[8]. Seven semi-trained panellists in the age group of 22–55 years having no medical disorder from the department of Food Science and Technology, PAU, Ludhiana were selected to evaluate the sensory properties of '*chapattis*'.

Color analysis was performed using Hunter Lab Colorimeter, Mini Scan XE Plus (Hunter Lab, Reston, VA). Colour readings were expressed by Hunter values for L^*, a^* and b^*. The a^* value ranges from –100 (greenness) to +100 (redness), b^* value ranges from –100 (blueness) to +100 (yellowness), whereas L^* value, indicating the measure of lightness, ranges from 0 (black) to 100 (white)[9]. Hue angle was calculated using the formula $\tan^{-1} b^*/a^*$.

The texture of '*chapatti*' was analyzed using Texture Analyzer (Stable Micro Systems, Model TA-HDi, UK). Strips measuring 4 cm × 2 cm were cut from each '*chapatti*'.

One strip at a time was placed on the centre of the sample holder and the Warner wratzler blade was allowed to cut the '*chapatti*' strip. The force required to cut '*chapatti*' strip into two pieces was recorded. The speed was maintained at 1.70 mm/s[7].

2.4 Physico-Chemical Analysis

Hot air dried and freeze dried '*jamun*' powder was evaluated for titratable acidity by titrating known volume of aliquots against 0.1 N NaOH and expressed as percent malic acid[10]; aqueous extract of '*jamun*' powder was determined for pH using digital pH meter (MAX electronics, India). Total sugars and reducing sugars of '*jamun*' powder were estimated as per Lane and Eynon method[11]. Crude fibre was estimated by acid-alkali method (Fibertec, FOSS)[12]. Total ash and crude protein content was estimated as per Association of Official Analytical Chemists (AOAC)[11]. Physico-chemical characteristics of supplemented '*chapattis*' such as moisture, ash, crude protein, fat and crude fibre was determined using American Association of Cereal Chemist (AACC)[12] methods.

2.5 Bioactive Components Analysis and Antioxidant Activity

Among the bioactive components hot air dried and freeze dried '*jamun*' powder was evaluated for ascorbic acid, total anthocyanins and total phenols. Ascorbic acid has been determined using direct colorimetric method[10] and expressed as mg/100g. Ascorbic acid from the dried '*jamun*' powder was extracted using 2% metaphosphoric acid and filtered followed by volume make up. Dye solution was prepared by mixing 100mg 2,6-dichlorophenol-indophenol dye with 84 mg $NaHCo_3$ and volume made to 100ml. The dye solution was diluted with water in 1:20 before use. 1 ml aliquot was taken in glass cuvettes alongwith 10ml of dye solution and reading was taken immediately at 518nm (Spectronic 20, Bausch & Lomb, USA). Dried '*jamun*' powder and supplemented '*chapattis*' were analyzed for total anthocyanins content by spectrophotometric method[13] and expressed as mg/100g. Finely ground sample was mixed with ethanolic HCl (85ml 95% ethanol: 15ml 1.5N HCl) followed by volume make up. The contents were allowed to stay overnight at $4^{O}C$ and absorbance was recorded at 530nm. Total phenolic content of methanolic extract of '*jamun*' powder and supplemented '*chapattis*' was determined according to Folin-Ciocalteu spectrophotometric method[14]. Methanolic extract was prepared by refluxing 1 gram of finely ground sample with 80% methanol for one hour in a round bottom flask followed by filtration of the extract and volume make up to 100 ml with 80% methanol. The results were expressed as g Gallic acid Equivalent (GAE)/100g for '*jamun*' powder and as mg GAE/100g for supplemented '*chapattis*' by taking gallic acid (100μg/ml) as reference material to construct standard curve. Antioxidant activity of '*jamun*' powder and supplemented '*chapattis*' was determined by di phenyl picryl hydrazyl (DPPH) method according to Brand-Williams et al.[15] with some modifications. Methanolic extract of samples was taken for antioxidant activity analysis and calculated according to the following formula. The assay contained 2 ml of sample aliquot, 2 ml of tris HCl buffer (pH 7.4) and 4 ml of 0.1mM DPPH. The contents were mixed immediately and the degree of reduction of absorbance was recorded continuously for 30 min. at 517 nm (Spectronic 20, Bausch & Lomb, USA).

$$\text{Radical scavenging activity (\%)} = \frac{\text{Control OD (0 min)} - \text{Sample OD (30 min)} \times 100}{\text{Control OD (0 min)}}$$

2.6 Statistical Analysis

All analyses were carried out using three independent determinations and expressed as mean value ±standard deviation (SD). Students't-test was used to calculate the means and their 95% confidence intervals for hot air dried and freeze dried '*jamun*' powder. Data collected from '*jamun*' powder supplemented '*chapattis*' were subjected to ANOVA (Analysis of variance), comparing averages using Duncan's test at 95% confidence interval using the SPSS software, version 18.0 (Statsoft Inc. USA).

3. Result and Discussion

3.1 Physico-Chemical Properties of '*Jamun*' Powder

Physico-chemical properties of hot air dried and freeze dried '*jamun*' powder has been depicted in Table 1. Titratable acidity was found to be slightly more in freeze dried '*jamun*' powder (4.18%) compared to hot air dried powder (4.12%). Higher total sugars and reducing sugars were found in freeze dried samples (56.52% and 51.59% respectively) than in hot air dried samples (55.08% and 49.78% respectively). Similar results were found by Ali et al.[16] who found 52.48% of total sugar in dried '*jamun*' pulp. Crude fibre was slightly more in freeze dried samples (2.57%) than hot air dried samples (2.47%). Similarly total ash content which represents mineral matter was found to be higher in freeze dried samples (2.97%) than hot air dried samples (2.85%) signifying '*jamun*' fruit as an important source of minerals. Protein content was found to be at par in both the hot air dried and freeze dried samples (1.75 and 1.82% respectively).

3.2 Bioactive Components of '*Jamun*' Powder

'*Jamun*' fruit has been recognized as a nutraceutical fruit due to presence of powerful antioxidant compounds such as ascorbic acid, anthocyanins and total phenols[2]. Ascorbic acid content of hot air dried samples was found to be 25.61 mg/100g and that of freeze dried sample was 36.95 mg/100g (Table 2). Lower ascorbic acid retention in hot air dried '*jamun*' powder is due to oxidation of ascorbic acid in the presence of air and high temperature. Leoni[17] reported that Vitamin C is destroyed mainly due to oxidation reactions and heat applied in the presence of air and Shofian *et al.*[18] revealed that freeze drying process exerted minimal effect on the deterioration of Vitamin C. Anthocyanins one of the potent antioxidant compound was also found to be higher in freeze dried samples (305.47 mg/100g) than in hot air dried samples (259.89 mg/100g) (Table 2). Temperature is one of the factors that affect the stability of anthocyanins and degradation of anthocyanins occurs with increase in temperatures[19]. Total phenols and antioxidant activity of freeze dried '*jamun*' powder was 4.16 g/100g and 88.34% respectively (Table 2). Hot air dried '*jamun*' powder had comparatively low amounts of total phenolics (3.67 g GAE/100g) and lower antioxidant activity (83.53%). A study reports that due to absence of liquid water during freeze drying there was minimal loss of anthocyanins and polyphenols retaining more bioactive components in freeze dried powder[20]. Low antioxidant activity may be due to lowest retention of bioactive compounds in hot air dried '*jamun*' powder. Overall, freeze dried powder was found to better retain bioactive components than hot air drying and can be used to preserve heat labile nutritional components.

3.3 Quality Assessment of '*Jamun*' Powder Supplemented '*Chapatti*'

Qualitative characteristics of '*chapattis*' prepared by supplementing wheat flour with 1 to 5% levels of powder from conventional hot air dried and freeze dried '*jamun*' pulp are tabulated in Table 3. Water absorption was found to increase significantly ($p \leq 0.05$) with increase in supplementation level from 1 to 5 %. The water absorption for dough making was 66.00% for control (C) wheat flour and thereafter with increase in supplementation level water absorption increased to 67.83% and 67.76% at 5% level of conventional hot air dried and freeze dried '*jamun*' powder incorporated whole wheat flour dough, respectively. The increase in water absorption may be due to presence of fibre in '*jamun*' pulp.

Dough handling characteristics of '*jamun*' powder supplemented '*chapatti*' did not show much variation in stickiness with respect to supplementation levels.

Table 1. Physico-chemical properties of hot air dried and freeze dried *jamun* powder

Drying methods	Titratable acidity (%)	pH	Reducing sugar (dextrose, %)	Total sugar (dextrose, %)	Crude fibre (%)	Total ash (%)	Crude protein (%)
Hot air dried	$4.12^a \pm 0.06$	$3.43^a \pm 0.04$	$49.78^a \pm 0.41$	$55.08^a \pm 0.33$	$2.45^a \pm 0.04$	$2.85^a \pm 0.06$	$1.75^a \pm 0.05$
Freeze dried	$4.18^a \pm 0.02$	$3.35^a \pm 0.04$	$51.59^b \pm 0.36$	$56.52^b \pm 0.44$	$2.57^a \pm 0.06$	$2.97^a \pm 0.06$	$1.82^a \pm 0.02$

Means with different letters in the same column are significantly different for $p \leq 0.05$, student's t-test

Table 2. Bioactive components of hot air and freeze dried *jamun* powder

Drying methods	Ascorbic acid (mg/100g)	Anthocyanin (mg/100g)	Total phenols (g GAE/100g)	Antioxidant activity (%)
Hot air dried	$25.61^a \pm 0.29$	$259.89^a \pm 0.48$	$3.67^a \pm 0.49$	$83.53^a \pm 0.34$
Freeze dried	$36.95^b \pm 0.17$	$305.47^b \pm 0.50$	$4.16^b \pm 0.28$	$88.34^b \pm 0.49$

GAE- Gallic acid equivalent; means with different letters in the same column are significantly different for $p \leq 0.05$, student's t-test

However, at 5% and 4% level slight stickiness was observed in hot air dried '*jamun*' powder supplemented '*chapatti*' and freeze dried powder supplemented '*chapatti*', respectively. The puffing characteristics also did not vary much with respect to supplementation levels and drying methods. Full puffing was observed for all '*jamun*' powder supplemented '*chapatti*' except at 5% level that resulted in partial puffing.

Differences were established among the appearance, texture, flavour and overall acceptability scores of conventional hot air dried (CD) and freeze dried (FD) '*jamun*' powder incorporated '*chapatti*' that is depicted in Figure 1a and Figure 1b respectively. Flavour was found to be a prominent factor in determining acceptability of supplemented '*chapattis*' and astringency was found to increase with increase in supplementation levels. Among different supplementation levels, 3% level received maximum overall acceptability scores for CD and FD '*jamun*' powder incorporated '*chapattis*' (8.63 and 8.66 respectively). On the basis of '*chapatti*' making and organoleptic quality supplementation of wheat flour with 3% '*jamun*' powder was selected to prepare '*chapattis*' to carry out further studies.

3.4 Colour Analysis

Colour characteristics of '*jamun*' powder supplemented '*chapattis*' are depicted in Table 4. Lightness (L*), redness (a*), yellowness (b*) and hue angle of whole wheat flour '*chapatti*' (C) were 68.36, 3.43, 19.72 and 80.10

Table 3. Quality evaluation of *jamun* powder supplemented *chapatti*

Supplementation (%)	Water absorption (%)		Dough handling		Puffing	
	CD	FD	CD	FD	CD	FD
Control	$66.0^{dy} \pm 0.20$	$66.0^{dy} \pm 0.20$	NS	NS	FP	FP
1	$66.13^{dy} \pm 0.30$	$66.06^{dy} \pm 0.11$	NS	NS	FP	FP
2	$66.50^{cy} \pm 0.15$	$66.43^{cy} \pm 0.05$	NS	NS	FP	FP
3	$67.53^{by} \pm 0.20$	$67.26^{bz} \pm 0.11$	NS	NS	FP	FP
4	$67.56^{aby} \pm 0.11$	$67.33^{by} \pm 0.11$	NS	SS	FP	FP
5	$67.83^{ay} \pm 0.11$	$67.76^{ay} \pm 0.15$	SS	SS	PP	PP

Means with a-d superscripts are significantly ($p \leq 0.05$) different column wise while y and z (row wise) superscripts show significant ($p \leq 0.05$) effect of drying within a *chapatti*

NS- Non- sticky SS- Slightly sticky FP- Full puffing PP- Partial puffing

CD- Conventional hot air drying FD- Freeze drying

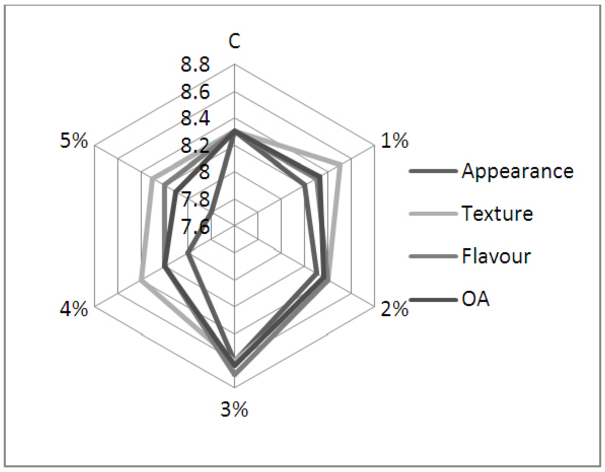


Figure 1(a). Cobweb diagram showing sensory score of different supplementation level of hot air dried *jamun* powder supplemented *chapatti*.

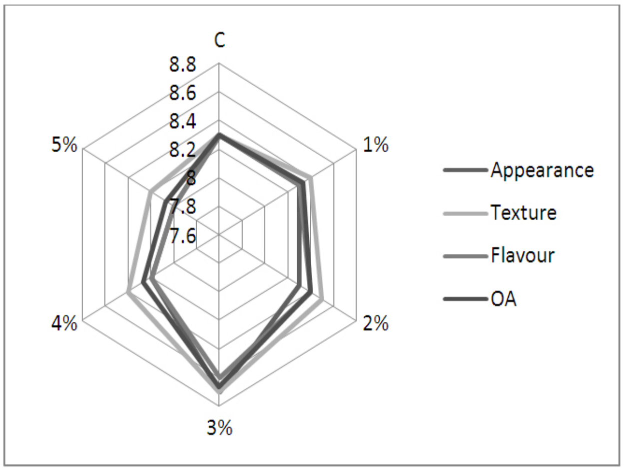


Figure 1(b). Cobweb diagram showing sensory score of different supplementation level of freeze dried *jamun* powder supplemented *chapatti*.

Table 4. Colour analysis of *jamun* powder supplemented *chapatti*

Supplementation (%)	L^*		a^*		b^*		Hue angle (°)	
	CD	FD	CD	FD	CD	FD	CD	FD
Control	$68.36^{ay} \pm 0.46$	$68.36^{ay} \pm 0.46$	$3.43^{by} \pm 0.33$	$3.43^{cy} \pm 0.33$	$19.72^{ay} \pm 0.30$	$19.72^{ay} \pm 0.30$	$80.10^{ay} \pm 1.10$	$80.10^{ay} \pm 1.10$
1	$60.74^{by} \pm 0.55$	$59.50^{bz} \pm 0.41$	$4.71^{ay} \pm 0.36$	$5.24^{by} \pm 0.56$	$17.57^{by} \pm 0.34$	$16.69^{by} \pm 0.45$	$74.97^{by} \pm 1.16$	$72.58^{by} \pm 1.32$
2	$57.51^{cy} \pm 0.63$	$57.62^{cy} \pm 0.44$	$4.48^{ay} \pm 0.25$	$5.33^{bz} \pm 0.42$	$16.50^{cy} \pm 0.38$	$14.56^{cz} \pm 0.41$	$74.80^{by} \pm 0.51$	$69.91^{cz} \pm 1.19$
3	$53.42^{dy} \pm 0.50$	$51.60^{dz} \pm 0.35$	$4.59^{ay} \pm 0.47$	$6.12^{az} \pm 0.39$	$14.54^{dy} \pm 0.28$	$13.37^{dz} \pm 0.50$	$72.46^{cy} \pm 1.82$	$65.42^{dz} \pm 0.58$
4	$50.82^{ey} \pm 0.63$	$50.08^{ey} \pm 0.55$	$4.65^{ay} \pm 0.46$	$6.39^{az} \pm 0.39$	$13.49^{ey} \pm 0.44$	$12.25^{ez} \pm 0.53$	$70.99^{cy} \pm 1.32$	$62.45^{ez} \pm 0.48$
5	$50.84^{ey} \pm 0.42$	$48.44^{fz} \pm 0.47$	$5.13^{ay} \pm 0.05$	$6.83^{az} \pm 0.35$	$12.49^{fy} \pm 0.45$	$10.90^{fz} \pm 0.34$	$67.65^{dy} \pm 0.90$	$57.91^{fz} \pm 2.10$

Means with a-f superscripts are significantly ($p \le 0.05$) different column wise while y and z (row wise) superscripts show significant ($p \le 0.05$) effect of drying within a *chapatti*

CD- Conventional hot air drying FD- Freeze drying

respectively. Incorporation of hot air dried and freeze dried '*jamun*' powder lowered L^* value significantly ($p \le 0.05$) with increased supplementation level. Significant ($p \le 0.05$) differences were also observed among the drying techniques at 1, 3 and 5 % supplementation level. L^* values of supplemented '*chapattis*' were in the range of 60.74 to 50.82 and 59.50 to 48.44 for hot air dried and freeze dried powder supplemented '*chapattis*', respectively at 1–5 % supplementation level. Lower L^* values were noted for freeze dried samples compared to hot air dried samples. Lower L^* values has been reported for deeply coloured red wines whereas lightly coloured wines transmit more light and have higher L^* values[21] which explains the differences between L^* values of hot air dried and freeze dried samples in the present study as anthocyanins responsible for the deep blue coloration may have been degraded more during hot air drying[19] compared to freeze drying.

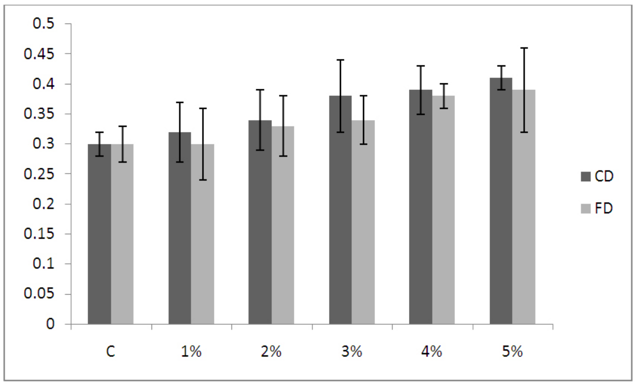
The redness values (a^*) were found to increase significantly ($p \le 0.05$) with increasing supplementation levels and increase was found to be more in freeze dried samples than hot air dried samples. The a^* value increased from 4.71 at 1% supplementation level to 5.13 at 5% supplementation level in case of hot air dried samples and from 5.24 at 1% level to 6.83 at 5% level for freeze dried samples. Hot air dried samples were significantly ($p \le 0.05$) less red than freeze dried samples from 2–5 % supplementation level. Altan et al.[22] stated that an increase in tomato pomace level decreased the L^* value of the sample and increased the a^* value of samples. The b^* values that indicates yellowness/blueness depicted linear decrease with increasing supplementation levels. Among the drying treatments, b^* value was found to be lower for freeze dried samples and minimum b^* value was recorded at 5% supplementation levels (10.90) and maximum for hot air dried samples at 1% supplementation level (17.57). Reduction in b^* values signifies increasing blueness of the samples, thus, freeze dried samples were found to be more blue compared to hot air dried samples that may be due to good retention of anthocyanins in freeze dried powder. '*Jamun*' powder supplemented '*chapattis*' had lower hue angle compared to control samples. Hot air dried samples had hue angle in the range of 74.97 to 67.65 at 1–5 % supplementation and freeze dried samples had hue angle in the range of 72.58 to 57.91 at 1–5 % supplementation level. Hue angle and L^* values are well correlated[21] depicting sample darkness with progression in supplementation levels.

3.5 Texture Analysis

Textural results of the '*chapatti*' supplemented with different levels of '*jamun*' powder are depicted in Figure 2. The hardness of the '*chapatti*' was found to increase slightly with increase in supplementation level due to increase in fibre content. Cutting force of control '*chapatti*' was found to be 0.30 kg which increased to 0.41 kg at 5% supplementation level in case of hot air dried '*jamun*' powder supplemented '*chapattis*' and 0.39 kg in case of freeze dried '*jamun*' powder supplemented '*chapattis*'. Texture of '*chapattis*' supplemented with freeze dried '*jamun*' powder was at par with control *chapatti* at lower supplementation levels. Freeze dried powder supplemented '*chapattis*' were softer than '*chapattis*' supplemented with hot air dried '*jamun*' powder may be due to high hygroscopicity and higher adsorption capacity of freeze dried powder[23].

3.6 Physico-chemical Properties of '*Jamun*' Powder Supplemented '*Chapatti*'

On the basis of quality characteristics and sensory evaluation, 3% supplementation level of both hot air dried and freeze dried '*jamun*' powder was chosen to be best and incorporated in whole wheat flour '*chapattis*' for further studies. Supplemented '*chapattis*' exhibited marginal but significant ($p \leq 0.05$) effect on moisture content (Figure 3). Control '*chapatti*' had 31.58% of moisture content and that of freeze dried and hot air dried '*jamun*' powder supplemented '*chapatti*' was 32.83% and 32.74%, respectively. Fruit fibres contain more pectin and have higher water binding capacity compared to cereal and legume fibres[24] that may have resulted in more moisture content of '*jamun*' powder supplemented *chapattis*. '*Chapattis*' were found to have improved ash and fibre content. Control '*chapatti*' had 1.39 and 0.97 % of ash and fibre content, respectively and after supplementation with '*jamun*' powder, ash content increased by 4.31% and fibre content increased by 5.82% in '*chapattis*'. There was negligible effect of supplementation on protein and fat content of '*chapattis*'. Control '*chapatti*' had 11.87% of protein content and 0.73% of fat content. Protein and fat content of supplemented '*chapattis*' was in the range of 1.70–1.72 % and 0.69–0.70 %, respectively. Non-significant effect of drying methods was found on protein, fat, crude fibre and ash content of supplemented '*chapattis*'.



CD- Conventional hot air dried FD- Freeze dried

Figure 2. Effect of *jamun* powder supplementation on hardness of *chapattis*.

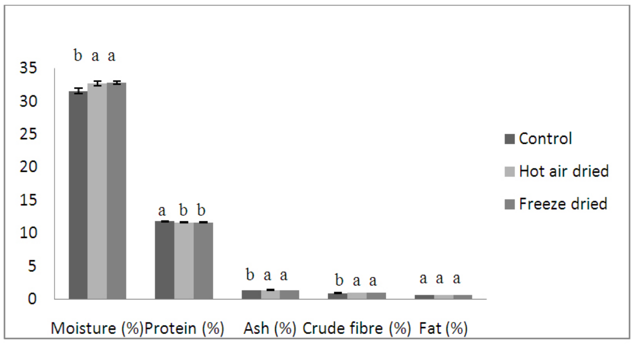


Figure 3. Effect of incorporation of *jamun* powder on physico-chemical properties of whole wheat flour *chapattis*. a, b superscripts show significant ($p<0.05$) difference among the control and supplemented *chapattis*.

3.7 Bioactive Components of '*Jamun*' Powder Supplemented '*Chapatti*'

The bioactive components of supplemented '*chapattis*' is depicted in Table 5. Anthocyanins were not detected in control *chapatti* and in supplemented '*chapattis*' (hot air dried and freeze dried) it was found to be 3.41 and 4.18 mg/100g, respectively. Significant ($p \leq 0.05$) variations were observed with respect to drying methods on anthocyanin content of *chapattis* as freeze dried '*jamun*' powder supplemented *chapatti* had higher value than hot air dried '*jamun*' powder supplemented '*chapatti*'. Total phenols were found to be lowest in control '*chapatti*' (87.59 mg GAE/100g) followed by hot air dried and freeze dried '*jamun*' powder supplemented '*chapatti*'. Similarly, antioxidant activity was found to be minimum for control '*chapatti*' (63.05%) and maximum for freeze dried powder supplemented *chapatti* (83.99%). Correlation

Table 5. Bioactive components of *jamun* powder supplemented *chapatti*

Treatments	Anthocyanins (mg/100g)	Total phenols (mg GAE/100g)	Antioxidant activity (%)
Control	nd	$87.59^{c} \pm 0.43$	$63.05^{c} \pm 0.43$
CD	$3.41^{b} \pm 0.34$	$102.84^{b} \pm 0.40$	$82.57^{b} \pm 0.50$
FD	$4.18^{a} \pm 0.26$	$108.79^{a} \pm 0.51$	$83.99^{a} \pm 0.30$

GAE- Gallic acid equivalent; means with different letters in the same column are significantly different for $p \leq 0.05$; nd: not detected

CD- Conventional hot air drying FD- Freeze drying coefficient has been found to be positive for anthocyanins and antioxidant activity (Figure 4a) and between total phenols and antioxidant activity (Figure 4b). Correlation coefficient above 0.9 confirms that anthocyanins and total phenols are primary bioactive compounds in '*jamun*' powder responsible for antioxidant activity of supplemented '*chapattis*'.

4. Conclusion

Addition of '*jamun*' fruit powder in whole wheat flour, help improved antioxidant activity, total phenolic content and anthocyanin content in '*chapattis*'. Among the drying techniques, freeze drying was found to better retain bioactive components than hot air drying. Slight stickiness and partial puffing behaviour was observed at higher supplementation levels. Supplemented '*chapatti*' received highest sensory scores at 3% level and '*chapattis*' at other supplementation levels was also found to be acceptable. Colour characteristics were also affected by both supplementation levels and type of powder (freeze dried and hot air dried) incorporated in '*chapattis*'. '*Jamun*' fruit powder incorporation in '*chapattis*' slightly improved fibre and ash content. Bioactive components were found to be higher in '*chapattis*' supplemented with freeze dried '*jamun*' powder than in hot air dried powder. Anthocyanins and total phenols were thought to be responsible for antioxidant activity as depicted by correlation studies. Thus, '*jamun*' fruit powder can be used as a potential source to improve antioxidant status of '*chapattis*'.

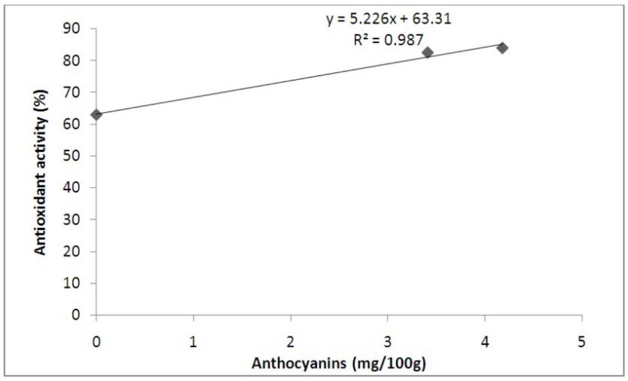


Figure 4(a). Correlation plots between total anthocyanins (mg/100g) and antioxidant activity (%) of *jamun* powder supplemented *chapattis.*

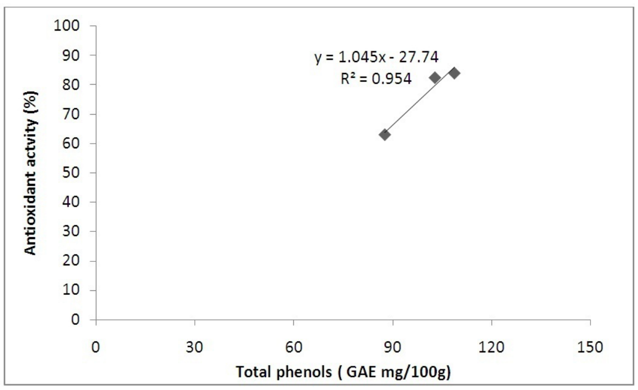


Figure 4(b). Correlation plots between total phenols (mg/100g) and antioxidant activity (%) of *jamun* powder supplemented *chapattis.*

5. Acknowledgement

One of the authors acknowledge Government of India, Ministry of Science and Technology (Department of Science and Technology), New Delhi for rendering the financial support under INSPIRE Programme to carry out the present work.

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