Original Research Article

Different Heat Processing methods on Flour yield, Nutritional composition and Acceptability of Jack Seed flour-based Low-fat functional Breadsticks

ABSTRACT

Jackfruit (Artocarpus heterophyllus Lam.) popular tropical fruit of Moraceae family, the ripe bulbs are sweet delicious to eat besides variety of preparations. The seeds are discarded as waste. The study was conducted with different heat processing methods like blanching (BL), roasting (RO) and pressure-cooking (PC) to know the flour yield, nutritional composition and acceptable level. On milling maximum flour recovery of 98.76% in RO, 96% in BL and 93.30% in PC treatments were observed. Among the minerals, highest potassium content of 9245.90 mg/kg, 7382.24mg/kg, 8232.31mg/kg in BL, RO) and PC seed flours were reported. Magnesium content of 942.84 mg/kg, 775.32 mg/kg and 886.14mg/kg observed in BL, RO and PC flours, highest sodium content of 243.69 mg/kg in PC, followed by 193.23 mg/kg and 46.44 mg/kg in RO and BL samples. Calcium content of 82.01 mg/kg, 60.48 mg/kg, 83.33 mg/kg was observed in BL, RO, PC flour samples were noticed. Iron (43.36 mg/100g BL, 20.10 mg/kg RO, 16.20 mg/kg PC), Aluminium (31.36 mg/kg BL, 16.69 mg/kg RO, 5.50 PC). Zinc (12.46 mg/kg BL, 10.18 mg/kg RO, 16.48 mg/kg PC), Manganese (4.80 mg/kg BL, 2.61 mg/kg RO, 3.81 mg/kg PC), Boron(6.25 mg/kg BL, 2.29 mg/kg RO, 3.46 mg/kg PC), Barium(2.37 mg/kg BL, 1.12 mg/kg RO, 1.88 mg/kg PC), Chromium (0.84 mg/kg BL, 0.51 mg/kg RO, PC 0.42 mg/kg), Nickle (0.81 mg/kg BL, 0.42 mg/kg RO, 0.82 mg/kg PC), Copper(4.86 mg/kg BL, 2.78mg/kg RO, 3.52mg/kg PC) etc., other trace elements observed were Strontium(1.08 mg/kg, 0.71 mg/kg, 1.38 mg/kg), Lead(0.28 mg/kg ,0.13 mg/kg , 0.11 mg/kg) Gallium(0.32 mg/kg, 0.15 mg/kg , 0.24 mg/kg) and Cobalt(0.18 mg/kg, 0.02 mg/kg ,0.06 mg/kg). Maximum of 20% of BL- seed flour 30% RO-seed flour and 50% PC-seed flour was found to be acceptable for commercial production of functional bread sticks or as a functional food ingredient.

Keywords: **Jackfruit seed flour, Functional breadsticks, Functional ingredients, Jack seed processing**.

Introduction

Jackfruit (*Artocarpus heterophyllus Lam.*) is a tropical fruit extensively grown in India, others neighbouring countries. The ripe fruit bulbs flakes consumed in fresh or processed into several products like juice, natural ice creams and halva and freeze-dried fruit flakes and the matured raw bulbs are utilised in the production of a snack food called chips. The seed is rich in carbohydrates and protein. Seed yield is about 10-15% of total fruit weight and a good source of carbohydrate, protein, dietary fibre, vitamins, minerals and phytonutrients (Abraham and Jayamuthunagai, 2014). Jack fruit seeds are discarded as waste, sometimes boiled or roasted and eaten (Rani *et al.*, 2019). Lectins are known as jacalin, used as a tool to gauge the immune system of an HIV infected person. It has antifungal properties. Jack seeds contain a high amount of resistant undigestible starch, escape digestion in the small intestine, passes into the colon and is reported to act like dietary fibre. This resistant starch is heat stable in most normal cooking operations and permits its use as an ingredient in a wide variety of conventional foods (Hettiaratchi *et al.*, 2011). Seed flour has much potential in the food industry. Seeds are rich in fibre, and carbohydrates could be used as a thickener and foods binding agent (Ocloo *et al.*, 2010). It has a physically protected form of resistant starch that could be incorporated in various baked goods as texture modifiers, imparting a favourable tenderness to the crumb (Sajilata *et al*., 2006). Jackfruit seed helps maintain bone health, is rich in magnesium, an essential nutrient necessary to absorb calcium and works along with calcium to strengthen the bones and protect the body from various bone-related disorders like Osteoporosis (Epainassist, 2016). Jack seed in the diet makes a genius way of nutritious food (Jessica, 2015), could be used as an alternative source of protein to tackle malnutrition (Chowdhury *et al.*, 2012), due to their rich source of several high-value compounds they serve as vital food for good health (Sreeletha *et al*. 2017). The heat-treated (60-80°C water for 30 to 60 mins) jackfruit seed flour showed enhanced amino acid levels, besides the highest protein (24.94%) and vitamin-C content (78.78mg/100g) in geminated jack seed flour (Zuwariah *et al.,* 2018). Despite having lots of medicinal, nutritional and physiological benefits, the jackfruit seeds are underutilised. Jack fruit seeds are seasonal and with shorter shelf life and are wasted during the season(Soma and Santa, 2015). Seeds are also a rich source of starch (22%) and dietary fibre (3.9%), lignans, isoflavones, saponins, and phytonutrients with anti-cancer, anti-hypertensive, antioxidant, anti-ulcer and anti-ageing properties. High potassium levels in the seed help lower blood pressure (Ethnichealth, 2013). By keeping the above benefits in view, the present investigation was undertaken to know the local jack seeds nutritional status and find simple ways to utilise the valuable seed as a functional food ingredient using affordable heat processing methods.

Materials and Methods

Jackfruit seeds were procured from the fully ripened fruits fresh cut of local varieties in and around Gandhi Krishi Vijayan Kendra, University of Agricultural Sciences Bangalore. The seeds were separated from the seed sacks and graded for broken, damaged, spoiled, with roots, green colour ones and washed for 3-4 times in running tap water, air-dried packed in HDPE bags and preserved in the refrigerator at 4°C for further study.

Treatment of samples (Treatment details)

The following treatments were given to the seeds collected from the ripened fruit bulbs

Treatment T1-Blanched, oven-dried, hammer milled and sieved called blanched jack seed flour (BLJSF or BL). Treatment T2-open pan-roasted, oven-dried, hammer milled and sieved as roasted jack seed flour (ROJSF or RO). Treatment T3-Pressure cooked, dried hammer milled, sieved called pressure cooked jack seed flour (PCJSF or PC).

Blanching process

The ripened jack fruit was procured from the University of Agricultural Sciences, Bangalore. The fruits were cut into two halves longitudinally; the central core was cut removed using stainless steel knife, and the seeds with seed sacks were separated. The seed sacks were separated manually from the seeds, and the seeds were soaked in cold water for 20-25min and washed twice using running tap water. The washed seeds were blanched for 5 minutes in boiling water and oven drying at 60°C for 24 hours (Ocloo *et al.*, 2010) for <10 % moisture content. After cooling the loosened primary seed coat (white arils) and part of the thin secondary seed coat, thin brown spermoderm covered the cotyledons (Rani *et al.*, 2019) was separated by hand rubbing and preserved airtight HDPE bags for further studies.

Pressure cooking process

The collected ripened jack fruit seeds were soaked in cold water for 20-25min and washed using tap water. Washed whole seeds were pressure cooked with 300 ml water for 10-12 minutes in a 10litre capacity stainless steel pressure cooker on a medium flame for two pressure release ($1kg/cm^2$). The cooked seeds were separated from the water and tray dried at 60°C (Vinod *et al.*,

2015) for 15-16 hours (<12 % moisture content), followed by removal of loosened primary seed coat and part of the thin secondary seed coat and preserved airtightly.

Roasting process

The fresh washed and air-dried ripened jack fruit seeds without seed sack were halved into two pieces using stainless steel knives. About 250 gm halved seeds per batch were open-plan roasted in an aluminium pan for about 16-17 min on a medium flame. The roasted seeds were oven-dried at 60°C for 15-16 hours and cooled and dried; the loosened primary seed coat and part of the secondary seed coat were separated by hand rubbing and preserved for further studies.

Production of heat-processed Jackfruit seed flours

The above heat-treated seed samples weighing one kilogram for each treatment was hammer milled separately, milling duration in minutes, per cent flour recovery, and flour loss was computed. The milled flours were sieved separately using 80-100 sieve mesh (Vinod *et al.,* 2015; Meethal *et al*., 2017), and the sieved flours were preserved in airtight sealed HDPE Polythene bags and preserved in stainless steel food storage containers in the refrigerator at 4^{0}C(Ocloo *et al*., 2010) for further studies.

Proximate composition of Jackfruit seed flours

Standard procedures assessed the proximate analysis of the different heat-treated jackfruit seed flours for their proximate composition. Moisture: IS4333 2002 (RA:2012). Ash IS 1155 1968(2010). Fat: AOAC.06,20^{th} Edition, 2016. Fibre: AOAC 962.09, 20^{th} Edition, 2016. Protein: AOAC 948.13, 20^{th} Edition, 2016. Carbohydrate: IS 1656;2007(RA:2009).

Mineral or Elemental Analysis

The study of the elemental or mineral composition in foods is of significant scientific interest. Since some of these elements are toxic at low concentrations (e.g., Cd and Pb), some are essential and required for everyday functions. Hence different heat-treated Jack seed flours were subjected to 23 mineral or elemental analysis using Inductively Coupled Plasma Mass Spectrometry (ICP-MS) Make- PerkinElmer, USA. (Model NexION 350 X) and with microwave sample digestion (Model- Titan M.P.S.) with standard protocols (AOAC 2013.)

Colour Measurement

Food colour is the noble gauge for successful quality evaluation (Markovic *et al*.,). The colour of the Different heat-treated and milled Jack seed flours was measured using Konica Minolta Spectrophotometer CM-5. The instrument was calibrated using the standard black cup and white plate supplied by the manufacturer. The values of *L, a*, b* were recorded, the *L scale indicates light to dark colour, low number *L(0-50) indicates dark, and a high number L (51-100) indicates light grey to white colour *L(100). The scale a* indicates red to green, where positive +a* indicates red and negative -a* indicates green. The scale b* indicates yellow to blue, positive +b* number indicates yellow and negative -b* indicates the blue colour

Sensory Evaluation

Sensory evaluation of the different heat-treated jack seed flour incorporated. Breadsticks were assessed with 21 semi-trained judges for appearance, mouthfeel/texture, colour, flavour, taste, and overall acceptability using a nine-point hedonic scale 1=dislike extremely to 9=like extremely. The judges were provided with glasses of water to rinse their mouths in between the sample.

Statistical analysis

The data obtained from different sensory attributes were pooled and subjected to analysis of variance (ANOVA) using the IBM statistical package (IBM-SPSS) version 23. Means are computed using Duncan's Multiple Range Tests (Duncan, 1955) at a 95% confidence level ($p \leq 0.05$).

Product formulation

The heat processed, dried, milled, and sieved jack seed flours such as Blanched Jack Fruit Seed Raw Flour (BLJSF), *Roasted Jack Fruit Seed Flour* (ROJSF) and pressure-cooked, dried, milled and sieved flour (PCJSF) were used at different levels(10 to 100%)to standardise the low-fat Breadsticks by incorporating different levels of all-purpose flours (bread flour). All-purpose flour, bakery fat, powdered salt and sugar was procured from the local supermarket.

The following levels of all-purpose flour and heat-treated jack seed flours were tried separately in ten different ratios to prepare low-fat Breadsticks (Table 1).

The treatments formulations were, all-purpose flour (APF): Blanched jackfruit seed flours(BLJSF)ie.,90g:10g(T1),80:20g(T2),70:30g(T3),60:40g(T4),50:50g(T5),40:60g(T6),30:70g(T7),20:80g(T8), 10:90g(T9), 0:100g(T10).The control(C)had 100 per cent all-purpose flour. For all the treatment formulations, 10% fat, 10%skim milk powder (SMP), 2% salt, 2% ajwain seeds and 2% powdered east dissolved in little lukewarm water and used to prepare the dough. The dough was rolled to a thickness of 10-12mm and arranged on a greased baking tray and cut into 10±1cm length using a rolling knife followed by proofing for about 20-25min, and baking in a preheated tabletop kitchen baking oven at 180°C for 38 ±1 min, and oven-drying for 5±1 hours at 60°C. The procedure was repeated for all the heat-processed seed flours. The cooled breadsticks were packed in HDPE bags airtight and preserved for further studies.

Table 1. Different heat-processed jack seed flour blended Breadstick formulation.

Ingredients (%)	C	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
All-purpose flour (APF)	100	90	80	70	60	50	40	30	20	10	0
Fat	10	10	10	10	10	10	10	10	10	10	10
Yeast	2	2	2	2	2	2	2	2	2	2	2
Salt	2	2	2	2	2	2	2	2	2	2	2
SMP	10	10	10	10	10	10	10	10	10	10	10
Ajwan seeds	2	2	2	2	2	2	2	2	2	2	2
T1-BLJSF	0	10	20	30	40	50	60	70	80	90	100
T2- ROJSF	0	10	20	30	40	50	60	70	80	90	100
T3- PCJCF	0	10	20	30	40	50	60	70	80	90	100

Chart 1 : BLJF-Blanched, ROJSF-Roasted and PCJSFPressure-Cooked Jack Fruit Seed Flour, C-Control.

Weighing & sieving of the ingredients

⇩

Mixing of ingredients with fat

⇩

Addition of water, yeast & dough preparation

⇩

Rolling of dough into Soft raw dough breadsticks

⇩

Arrangement of raw dough sticks on a greased baking tray & cutting for the required length

⇩

Proofing for 20-25 min

⇩

Baking at a pre-set oven temperature of 180℃ for 38-40 min

⇩

Cooling for 20 min.

⇩

Drying for six hours at 59±1℃

⇩

Cooling & Packing

Results and Discussion

The different heat treatments on flour recovery, colour, nutritional and proximate composition, Jack seed flours-based product, and acceptability studies were discussed and summarised below.

The flour recovery, milling duration, per cent flour recovery, per cent flour loss was documented (Table 1). It was evident from the results that the highest flour recovery of 98.76% (987.65mg/1000g) was noticed in the treatment of roasted seeds (T2) with a flour loss of 1.23%, followed by blanched seed flour recovery (T1) 96% (960mg/1000 g) with 4% flour loss on milling. The lowest flour recovery of 93.30% (933.00mg/1000g) was recorded in the treatment(T3) pressure-cooked, dried and milled seeds with 6.4% flour loss (Table 2).

Table 2 Jackfruit seed flour recovery and colour on different heat processing and milling

Treat ments	Initial Seed wt. (g)	Milling time (Min.)	Flour Recover y (g)	Flour recov ery (%)	Flour loss (%)	Flour colour			
						L*	a*	b*	Comparative colour
T1	1000	3.02	960.00	96.00	4.00	79.50	5.97	33.14	Light biscuit
T2	1000	1.33	987.65	98.76	1.23	84.33	2.25	15.09	Light ivory
T3	1000	1.00	933.00	93.30	6.70	82.81	2.94	16.95	Light ivory

T1: Blanched (BL), T2: Roasted (RO), T3: Pressure cooked (PC.)

The highest flour loss in (6.7%) in the treatment T3(PC) might be due to substantial leaching loss in the pressure cooking process. However, the milling duration was low(1.00 minutes), compared to 1.23 per cent flour loss in the treatment T2(1.23%)roasted seeds with a slightly higher milling duration of 1.33minutes might be due to the hardness of the sliced (whole seed damage) seeds on roasting and drying with less flour loss (1.23%) and higher flour recovery (98.76%). Blanched seeds reported higher flour loss (4%) during milling with violent milling noise due to the rugged nature of blanched seed took 3.02 min milling time besides flour loss in the form of fine dust reported 96% recovery. The result confirms the findings of other workers where lye peeled dried seeds were reported to be 75% flour recovery (Islam et al., 2015).

Raw seeds BLJSF ROJSF PCJSF

Fig.1 Different heat-treated seed flours

Flour colour

With respect to flour colour, blanched seed flour reported slightly lesser *L value (79.50) with lower a*(5.97) and b*(33.14) might be due to insufficient blanching time caused enzymatic browning on drying and strong odour on milling (biscuit or light straw colour) as compared to increased *L (lightness) and decreased a*, b* values contributed light (ivory) colour in roasted seed flour (*L=84.33, a*=2.25, b*=15.09) and pressure cooked seed flour(*L=82.81, a*=2.94, b*=16.95) seed flours (Table 2).

Proximate or Nutrient composition of heat-treated jackfruit seed flours

The proximate composition of three different heat-treated, jack seed flours are furnished in the table-2 and fig-2 below

Table 3 Proximate composition of different Heat-processed Jackfruit Seed Flours

Sl. No.	Parameter	Seed flours		
		BLJSF(BL)	ROJSF(RO)	PCJSF(PC)
1	Moisture (%)	7.58	6.70	8.92
2	Ash (%)	3.13	2.78	3.01
3	Fat (%)	1.13	0.98	0.62
4	Fibre (%)	3.46	3.08	3.33
5	Protein (%)	12.79	11.28	11.46
6	Carbohydrate (%)	71.91	72.78	75.06

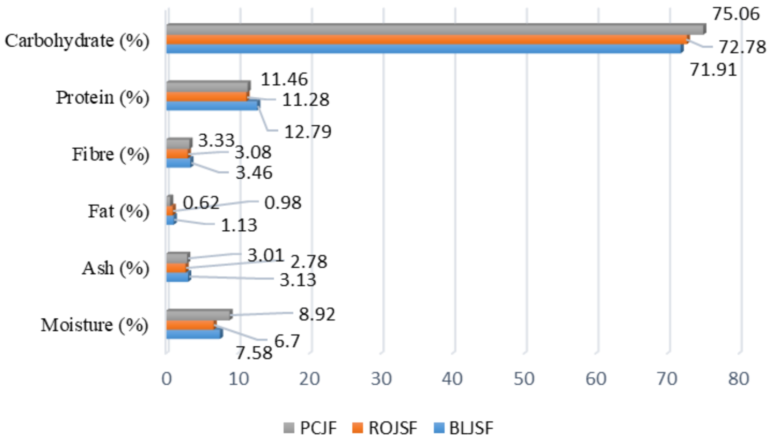

Fig. 2 Proximate composition of Different heat-treated Jack Seed Flours

The moisture content of jack seed flour varied from 7.58%(BLJSF),6.70%(ROJSF) and 8.92%(PCJSF). The ash content ranged from 2.78% in ROJSF to 3.13 % in BL-seed flour in between 3.01% in PCJSF. Similar results were reported by many workers (Ocloo *et al*., 2010). The variation in ash content might be due to the variety and locality. The fat content significantly reduced from 1.13%(BLJSF) to 0.98% (ROJSF) and 0.62%(PCJSF). The higher crude fibre content of 3.46%(BL) was observed due to 5 minutes blanching against lower fibre content of 3.08% (RO) due to degradation in higher conductive heat transfer for16-17min open-pan roasting and 3.33%(PCJSF)loss in pressure cooking. Crude protein content decreased from 12.79%(BL) to 11.46% (PCJSF), and 11.28%(ROJSF) may be due to the leaching of nutrients during heating and pressure cooking; similar findings were reported in 60 minutes boiling of jack seeds (Akinmutini, 2006). The carbohydrate content was reported to be low in BL seed flour (71.91%); a similar result was documented in lye peeled jack seed flour (Islam *et al.,* 2015)compared to ROJSF (72.78) and PCJSF (75.06%) seed flours (Table 3)

Mineral composition of different heat-treated jack seed flours

Results of the mineral or elemental composition of different heat-processed jackfruit seed flours (table 3.) revealed that the highest potassium content of 9245.90 mg/kg, 7382.24mg/kg, 8232.31mg/kg documented in blanched (BLJSF), roasted (ROJSF) and pressure cooked (PCJSF) seed flours. Highest magnesium content of 942.84 mg/kg, 775.32 mg/kg and 886.14mg/kg observed in blanched (BLJSF), roasted (ROJSF) and pressure cooked (PCJSF) samples. The highest sodium content of 243.69 mg/kg reported in pressure cooked against 193.23 mg/kg and 46.44 mg/kg in roasted and blanched seed flour samples. Calcium content of 82.01 mg/kg, 60.48 mg/kg, 83.33 mg/kg was observed in BLJSF, ROJSF and in PCJSF flour samples. Other elements reported were Iron (43.36 mg/100g in BLJSF, 20.10 mg/kg in ROJSF, 16.20 mg/kg in PCJSF), Aluminium (31.36 mg/kg in BLJSF, 16.69 mg/kg in ROJSF, 5.50 in PCJSF). Zinc (12.46 mg/kg in BLJSF, 10.18 mg/kg in ROJSF, 16.48 mg/kg PCJSF), Manganese (4.80 mg/kg BLJSF, 2.61 mg/kg ROJSF, 3.81 mg/kg PCJSF), Boron (6.25 mg/kg in BLJSF, 2.29 mg/kg in ROJSF, 3.46 mg/kg in PCJSF), Barium (2.37 mg/kg in BLJSF, 1.12 mg/kg in ROJSF, 1.88 mg/kg in PCJSF), Chromium (0.84 mg/kg in BLJSF, 0.51 mg/kg in ROJSF, and 0.42 mg/kg in PCJSF samples), Nickle (0.81 mg/kg in BLJSF, 0.42 mg/kg in ROJSF, 0.82 mg/kg in PCJSF seed flours). Copper (4.86 mg/kg in BLJSF, 2.78mg/kg in ROJSF and 3.52mg/kg in PCJSF samples). The other trace elements observed significantly in lowered level were Strontium (1.08 mg/kg, 0.71 mg/kg, 1.38 mg/kg), Lead (0.28 mg/kg ,0.13 mg/kg, 0.11 mg/kg) Gallium (0.32 mg/kg, 0.15 mg/kg, 0.24 mg/kg) and Cobalt (0.18 mg/kg, 0.02 mg/kg ,0.06 mg/kg). This might be due to heat and leaching loss during roasting, water blanching and in pressure-cooking process (Table 4). Different workers reported the above facts (Swamy *et al.* 2012) hence the seeds could be consumed as a right source of naturally available nutrients and a potential source for value addition and nutraceutical developments (Sreeletha *et al*., 2017).

Table 4 Mineral composition (Mg/kg) of different Heat-Treated Jack Seed Flours

Elements	BLJSF	ROJSF	PCJSF	**Elements**	BLJSF	ROJSF	PCJSF
Aluminium	31.36	16.69	5.50	Potassium	9245.90	7382.24	8232.31
Boron	6.25	2.29	3.46	Magnesium	942.84	775.32	886.14
Barium	2.37	1.12	1.88	Manganese	4.80	2.61	3.81
Calcium	82.01	60.48	83.33	Sodium	46.44	193.23	243.69
Cobalt	0.18	0.02	0.06	Nickle	0.81	0.42	0.82
Chromium	0.84	0.51	0.42	Lead	0.28	0.13	0.11

Copper	4.86	2.78	3.52	Strontium	1.08	0.71	1.38
Iron	43.36	20.10	16.20	Zink	12.46	10.18	16.48
Gallium	0.32	0.15	0.24				

AOAC 2013.06,20th Edition 2016, ICM-MS

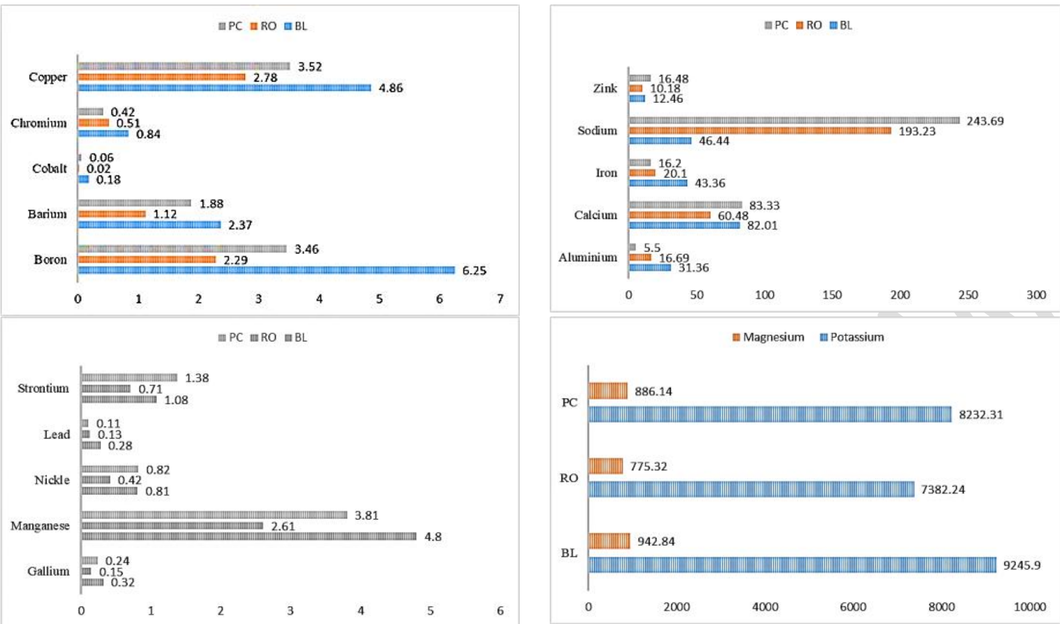

Fig 3 Elemental or Mineral composition(mg/kg) of three different heat-processed Jack Seed Flours

Yield and Acceptability of Low-Fat functional Breadsticks

Different heat-treated jack seed flours at 10 to 100 per cent level was incorporated with all-purpose flours in the preparation of Functional Breadsticks to know the level of acceptance in the treatment T9(10:90) and T10(i.e., all-purpose flour: Blanched Jack seed flour) the dough was unable to roll due to weak dough rolling properties with lower to zero percentage of all-purpose flour.

The yield of Breadsticks varied significantly among the treatments ranging from 100.9g(T1) to 128.06g(T9). The weight difference was mainly due to variation in the diameter along the length of the individual hand rolled raw-unbaked product and slow moisture escape from the interior part of the breadstick having variations in the diameter; hence the shelf life and acceptability was also low during the preliminary trails. This problem was solved by oven drying of the baked breadsticks at 60±1℃ for 6±1 hr for crunchy texture with moisture content 5±1 per cent before packing.

Table 5 Product yield from different heat-processed Jack seed flour blended Breadsticks formulations

Treatment Combination	Product yield (g)										
	C	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
*APF + BLJSF	115.03	126.7	121.36	119.93	111.86	119.63	123.56	118.70	120.20	-	-
*APF+ ROJSF	112.57	116.33	115.10	123.97	123.93	116.60	122.33	124.73	116.13	128.06	123.57
*APF+ PCJSF	116.43	100.90	112.50	114.46	106.83	120.36	116.00	117.23	119.33	116.73	115.56

*The above values are the average of three observations

The data obtained from the results of different sensory attributes for the product, blended with different heat-processed jack seed flours such as BLJSF, ROJSF and PCJSF with different levels of all-purpose flour (BF), are significantly differed ($p<0.05$) in texture, flavour and overall acceptability respectively (Tables 6, 7 and 8).

The acceptability of Blanched Jack seed flour (BLJSF) blended breadsticks (Table.4) reported significantly like-very-much scores in overall-acceptability in the treatment T1(8.33) (10:90%, BLJSF: All-purpose flour) liked very much followed moderate likeness in the treatment T2 (7.80) (20:80%) and, significantly reduced scores in other treatments due to higher levels of (> 20% BLJSF) blanched seed flours raw-unacceptable flavour and mildly bitter taste. Similar findings were reported with lye-peeled 20% jack seed flour incorporated biscuits (Butool and Butool, 2015); this was mainly due to a reduction in anti-nutritional factors in seeds(Akinmutini, 2006). (Table 6).

In another study, severe growth retardation in experimental animals was reported in the group fed with a diet containing 65% dry heat-treated jack seed flour, compared to 22.5% flour-based diet imparted comparable growth without any adverse effects on liver weight and liver function test and recommended that a small to moderate quantity of dry heat-treated jackfruit seed flour can be used to develop food products (Banerjee and Datta, 2015), *hence higher levels of BLJSF flour may not be suitable for value-added products.*

Table 6 Acceptability of BLJSF incorporated Breadsticks

Variation	Appearance	Texture	Colour	Flavour	Taste	OA
T1	8.47±0.51	8.33±0.65	8.23±0.70	7.14±1.38	8.14±0.79	8.33±0.75
T2	8.38± 0.66	7.92±0.50	8.09±0.62	5.47±1.74	6.22±0.72	6.73±0.46
T3	7.14±0.72	6.40±1.15	7.19±0.69	5.33±1.79	6.35±1.19	6.51±1.02
T4	6.64±0.76	6.16±0.89	6.52±0.74	5.20±1.54	5.52±1.56	5.07±1.38
T5	5.54±1.38	5.71±0.84	5.85±1.38	4.80±1.20	3.00±1.76	3.02±1.70
T6	5.40±1.22	4.03±1.27	7±0.35	4.90±1.13	2.76±1.54	2.52±1.24
T7	6.61±0.66	4.33±1.28	6.90±0.83	4.14±1.73	2.81±1.99	2.52±1.36
T8	6.35±0.52	3.57±0.97	6.90±0.30	3.85±2.03	2.85±1.06	2.38±0.80
T9	6.35±0.52	3.57±0.97	6.90±0.30	3.23±1.41	2.38±0.86	2.00±0.54
T10	6.35±0.52	3.57±0.97	6.90±0.30	3.85±2.03	2.04±1.07	1.66±0.65
TC	8.04±0.38	7.95±0.49	8.00±0.44	7.88±0.54	8.03±0.39	8.11±0.44
F value	*	*	*	*	*	*
SE(m)	0.169	0.208	0.149	0.341	0.277	0.222
CD@5%	0.471	0.579	0.416	0.952	0.771	0.62

CD >0.05% Non-significant, CD<0.05% Significant, CD<0.01% Highly significant

Concerning roasted jack seed flour (ROJSF) based Breadsticks (Table 7), all the sensory scores were significantly good in the treatments T1 to T3. The overall acceptability score for the treatments T1(8.61)(90:10%), T2(8.91)(80:20%) and T3(8.81)(70:30%) were liked extremely, compared to other combinations scored moderate likeness in the treatment T4(7.31)(60:40%), T5(7.33)(50:50%), T6 and T7(6.92 and 6.91)(40:60% & 30:70%) followed by slightly liked in T8(6.31)(20:80%), T9(6.38)(10:90%), T10(5.64)(0:100%) which is hundred per cent ROJSF flour. The control product was liked very much with a score of 8.02(TC) (100:0%) due to one hundred per cent all purpose-flour without seed flour. This confirms that up to 30% roasted jack seed flour was acceptable in all the sensory attributes. Other workers made similar remarks (Eke-Ejiofor *et al*., 2014), hence roasting of jack seeds before flour production contributes best results compared to autoclave and boiling and suggested that the flour could be utilised in baking and confectionary preparations along with refined flours (Table 7). This conforms with the findings of other workers where 30-40% jack seed flour (JSF) based noodles are highly acceptable when blended with 10-20% jack bulb flour and 50% refined flour (Kuamr et al., 2015).In another study, 30% seed flour-based instant vermicelli sweet-mix (Ajisha *et al*., 2018) and 30 % JSF-based pasta were best accepted compared to 10% (Malathi Devi, 2015). This is contrary, with 10% JSF substituted pasta having the maximum consumer acceptability, as Abraham and Jayamuthunagai (2014) reported. This might be due to varietal variations, soil-water types in which they grow and the masking effect of sugar and other ingredients incorporated during value addition**.**

Table 7 Acceptability ROJSF incorporated Bread Sticks

ROJF Variation	Appearance	Texture	Colour	Flavour	Taste	OA
T1	8.04±0.66	8.92±0.32	8.00±0.59	8.04±0.46	8.86±0.31	8.61±0.49
T2	8.00±0.54	8.00±0.63	8.25±0.63	7.90±0.59	8.35±0.57	8.90±0.30
T3	8.07±0.50	8.23±0.49	8.15±0.37	8.07±0.50	8.15±0.43	8.81±0.40
T4	8.04±0.49	8.07±0.59	8.01±0.50	7.26±0.53	7.11±0.53	7.31±0.33
T5	7.65±0.45	7.64±0.46	7.76±0.43	7.19±0.40	7.54±0.56	7.33±0.50
T6	7.35±0.57	7.02±0.58	7.45±0.58	7.07±0.61	7.09±0.58	6.92±0.39
T7	7.06±1.44	7.11±1.46	7.11±1.46	7.11±1.46	7.09±1.44	6.91±1.63
T8	7.14±0.55	6.14±0.79	6.21±0.71	6.14±0.79	5.76±1.44	6.31±1.63
T9	6.97±0.43	6.78±0.83	6.44±0.68	6.76±0.73	6.53±0.75	6.38±0.72
T10	7.09±0.30	5.52±1.24	5.61±1.24	6.21±1.30	5.14±1.46	5.64±1.17
TC	8.00±0.31	7.67±0.53	8.03±0.50	7.95±0.38	8.52±0.67	8.02±0.57
F value	*	*	*	*	*	*
CD	0.392	10.778	0.46	0.474	0.548	0.523
SE(m)	0.14	0.174	0.165	0.17	0.197	0.188

The Pressure-cooked seed flour (PCJSF) incorporated breadsticks exhibited a significantly higher level of acceptability, with a liked-very-much score ranging from 8.80 (T1)(90:10%),8.9(T2)(80:20%),8.45(T3)(70:30%) to 8.04(T5)(50:50%). Up to 50% pressure cooked jack seed flour (PCJF)blended breadsticks liked very much compared to moderate likeness in the treatments T6(6.95), T7(6.78) (30:70%), T8(6.54) (20:80%), T9(6.66) (10:90%) and T10(6.73) (0:100%) which is hundred per cent PCJF seed flour (Table 8). This may be due to reduced anti-nutritional factors in the quicker pressure cooking process. This conforms with the findings where jack seeds boiled for 60 min., reported 50 % reduction oxalates, phytin, 44 % reduction in saponin and 32% reduction in tannin (Akinmutini, 2006) due to leaching. Hence pressure cooking saves energy than longer boiling treatments.

Table 8 Acceptability of PCJSF incorporated Breadsticks

PCJF Variation	Appearance	Texture	Colour	Flavour	Taste	OA
T1	8.38±0.49	8.04±0.38	8.09±0.70	8.14±0.72	8.33±0.61	8.8±0.40
T2	8.33±0.48	8.28±0.46	8.14±0.72	8.09±0.70	8.28±0.56	8.9±0.30
T3	8.07±0.55	8.07±0.63	8.09±0.53	7.95±0.74	7.880.63	8.45±0.61
T4	8.19±0.98	7.61±0.72	8.02±0.92	7.19±0.74	7.58±0.64	8.04±0.26
T5	8.02±0.60	7.38±0.56	7.50±0.59	7.31±0.46	7.69±0.43	8.04±0.26
T6	7.81±0.74	7.9±0.40	7.90±0.43	7.28±0.46	6.83±0.57	6.95±0.58
T7	7.97±0.64	7.04±0.41	7.52±0.67	7.04±0.38	6.69±0.66	6.78±0.62
T8	7.81±0.51	6.98±0.66	8.09±0.53	6.90±0.60	6.42±1.04	6.54±1.01
T9	7.69±0.46	6.9±0.51	7.81±0.40	7.26±0.73	6.52±0.98	6.66±0.81

T10	6.88±0.56	7.11±0.63	7.26±0.53	6.95±0.38	6.52±0.41	6.73±0.49
TC	8.42±0.53	8.11±0.49	8.166±0.65	7.66±0.45	6.52±0.32	8.50±0.74
F value	*	*	*	*	*	*
SEM	0.131	0.12	0.137	0.131	0.144	0.126
CD@5%	0.365	0.334	0.383	0.365	0.402	0.351

PCJF-Pressure cooked jack seed flour, OA=Overall acceptability

The treatment T6 to T10 showed “moderate” to “like slightly”, i.e., T6(6.95)40:60%, T8(6.54)20:80%, T9(6.66)10:90%, T10(7.78) (0:100%) due to reduced taste might be due to the thermostability of the tannins in the seed bulk during pressure cooking led to mild bitterness (D’mello, 1995; Okwu, 2002). The mild bitterness could be overcome by incorporating elevated levels of sugar and salt in the recipe. Similar observations were reported (Joy *et al*., 2019) in the fermented (48 hours and dried at 60°C) jack seed flour blended wheat flour cookies (30% wheat flour and 70% jack seed flour) had similar sensory scores for flavour (6.86), colour (6.70), taste (6.88), crispness (6.48) with overall acceptability (7.06). Others documented that up to 60% jack seed flour was best accepted in jack seed flour-based burfi (Dey and Amin., 2017) and 70% in Cookies(Joy *et al*., 2019). This higher level of acceptance might be due to masking effect of added khova and sugar. Other researchers reported that 25% seed flour is preferred (Hossain, 2014) in bread and biscuits. Bread made with less than 30% jack seed flour showed good overall acceptability (Butool and Butool, 2015)and suggested for baked products which are lacking in dietary fibre (Islam *et al*., 2015). Incorporating jack seed flour enhances crude fibre content besides other nutrients as a functional food ingredient.

Among the treatment’s combinations (APF: PCJSF), from T1(8.80) (90:10%) to T5(8.90), 50:50% were liked very much in overall acceptability. This confirms that up to 10% to 50% PCJSF incorporated breadsticks were best rated due to the detoxification of trypsin inhibitors (Akinmutini, 2006) compared to blanching and roasting, and the PCJSC based products could be commercialised as functional low-fat breadsticks

Scale-up studies

Based on the acceptability of the three heat-treated jack seed flours, the scale-up study was conducted by incorporating a maximum level of (50%) jack-seed flour with all-purpose flour. The following recipe was optimised for commercial production (Table. 6 and 7). The nutritional composition of pressure-cooked jack seed flour (PCJSF) based low-fat breadsticks showed a moisture content of 4.33g/100g, protein 9.78g/100g, fat 7.03g/100g, total ash 3.09g/100g, Carbohydrates 75.55g/100g and energy 405 K.cal/100g (Table.8). It can be preserved like other breadsticks.

Table 9 Jack seed flour (PCJSF)-based Breadsticks for Commercialization

Sl No	Ingredients	Percentage
1	PC-Jack seed flour	50
2	All-purpose flour	50
3	Fat	10
4	Powdered sugar	10
5	Ajwan seeds	2
6	yeast	2
7	Salt	2
8	Milk powder	10
9	Water to mix	70

	Total (g) ingredients	206
	Baked product (g)	123.44

.

Table 10 Proximate composition of best-accepted PCJSF incorporated Breadsticks

Parameter	Result
Moisture(g/100g)	4.33
Protein(g/100g)	9.78
Fat(g/100g)	7.03
Total ash(g/100g)	3.09
Carbohydrates(g/100g)	75.55
Energy (K.cal/100g)	405.00

Fig 4. Jack seed flour (PCJF)-based functional Breadsticks

Conclusion

Jack fruit seeds are rich in proteins, carbohydrates, and minerals, an excellent ingredient for developing functional foods. Seeds have a poor shelf life, wasted during the seasonal glut. By using simple heat processing methods, acceptable seed flour could be produced as a functional food ingredient. The study revealed that the pressure-cooking process helps smooth milling and acceptable flour recovery compared to other methods. Pressure cooking of whole seeds or the size reduction of fresh seeds before open pan-roasting followed by drying and milling is advantageous in getting bitter free acceptable light colour flour. In the preparation of value-added functional products maximum of 10-20% of blanched jack seed flour (BJSF), 30% roasted jack-seed flours (ROJSF), about 50 % pressure-cooked seed flour (PCJSF) could be replaced as a functional food ingredient with all-purpose flour for commercial production of functional breadsticks. The study also observed that different heat processing methods significantly contributed to the milling yield or flour recovery of about 93 to 98% in pressure cooking and roasting methods. To conclude 15-16min, short pressure cooking is the best heat processing method to remove anti-nutritional factors and unacceptable raw flavour in the jack seeds for a higher level of blending as a functional product instead of wastage

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

References

1) Ajisha K.H., Sharon C.L., Aneena E.R. and Panjikkaran S.T., 2018, Development and Evaluation of Raw Jackfruit and Jackfruit Seed Based Instant Payasam Mix. *Indian J.Sci.Res*. 19(1): 10-15

2) Akinmutini A.H., 2006, Nutritive value of raw and processed jack fruit seeds (Artocarpus heterophyllus): Chemical Analysis. *Agri. J.*, 1(4):266-271,
3) Albi Abraham and Jayamuthunagai, J., 2014, An Analytical Study on Jackfruit Seed Flour and its Incorporation in Pasta. Research Journal of Pharmaceutical, Biological and Chemical Sciences. 5(2): 1597- 1610.
4) Amadi Joy A.C, Ezenwa, Chinyere., 2019, Nutrient Evaluation and Acceptability of Cookies Produced from Wheat Flour, Tiger Nut Milk and Fermented Jack Fruit Seeds (Artocarpus Heterophyllus). *Elixir Food Sci*., 127, 52710-52715,
5) AOAC, 2013.06,20th Edition.2016. http://members.aoac.org/ Changes.pdf
6) Butool S, Butool, M., 2015, Nutritional quality on value addition to jack fruit seed flour. *Int. J. Sci. Res*., 4, 2406-2411.
7) Dmello J.P.F., DEVENDRA, 1995, Tropical Legumes in Animal Nutrition: United Kingdom, pp: 96-133.
8) Duncan P.B.,1955, New Multiple Range and Multiple F-tests *Biometrics*,11:1-42.
9) Eke- Ejiofor J., Beleya E.A., Onyenorah N.I., 2014, The Effect of Processing Methods on the Functional and Compositional Properties of Jackfruit Seed Flour. *Int.J. Nutri. and Food Sci.,* 3(3): 166-173.
10) Epainassist, 2016, Health Benefits of Jackfruit and Jackfruit Seeds. http://www.epainassist. com/articles/healthbenefitsofjackfruitandjackfruitsee.
11) Ethnichealth, 2013, Health Benefits of Jack fruit seeds. Cited from ethnichealthcourt.com/2013/01/ 30/health-benefits-of-jack-fruit-seeds
12) Hettiaratchi, U.P. K., Ekanayake S, Welihinda, J., 2011, Nutritional Assessment of a jackfruit (Artocarpus heterophyllus) meal. *Cey.Medi. J*., 56: 54-58.
13) Hossain, M.T., 2014, Development and quality evaluation of bread supplemented with jackfruit seed flour. *Int. J. Nutri. and Food Sci*., 3(5): 484.
14) IVANA MARKOVIC, JELENA ILIC, DRAGAN MARKOVIC, VOJISLAV SIMONOVIC, NENAD KOSANIC. J.Hyg. Eng.Desi. Original scientific paper UDC 613.2-026.613:614.31.
15) JESSICA, B., 2015, Nutrition in Boiled Jackfruit Seeds.http://www.livestrong.com/article/ 546837-nutrition-in-boiled-jackfruit-seeds/ retrieve on 28/09/15
16) KUMARI, VEENA AND DIVAKAR, SUMA, 2016, Nutrient and chemical profile of raw jackfruit based noodles. Food Sci. Res. J Vol.7(2) p:156-164
17) Malathi Devi, T., 2015, Development of Extruded product using jackfruit bulbs and seed flours., MTech thesis submitted to the university of Agricultural Sciences, GKVK, Bangalore

18) MD. SHARIFUL ISLAM, ROKEYA BEGUM, MORSHADA KHATUN, KAMALESH CHANDRA DEY, 2015, A Study on Nutritional and Functional Properties Analysis of Jackfruit Seed Flour and Value Addition to Biscuits. *Int. J. Eng. Res & Tech.,* 4(12):139-147.
19) NILANJANA NANDLAL DEY AND BIJAL KEYUR AMIN, 2017. Effect of Nutritional,Sensory and Texture Properties of Jackfruit Seed (ArtocarpusHeterophyllus Lam.) Flour Burfi. International Journal of Science and Qualitative Analysis, 3(4): 42-48

20) OCLOO FCK, BANSA D., BOATIN R., ADOM T., AGBEMAVOR, W.S., 2010, Physico-Chemical, Functional and Pasting Characteristics of Flour produced from Jackfruits (Artocarpus heterophyllus) seeds. *Agric. Biol. J. N. Am*.,1(5): 903-908.
21) OKWU N.D.E., 2002, The effect of cooked Mucuna utilis meal as a substitute for soya bean meal in broiler finisher. Diet.B.Sc., Project. Michael Okpara University of Agric.Umudike, pp:1-5.

22) ROY CHOWDHURY A., BHATTACHARYYA, A.K., CHATTOPADHYAY, 2012, Study of Functional Properties of Raw and Blended Jackfruit Seed Flours (A non-conventional source) for food application, https://www.researchgate.net/publication/285983474
23) SAJILATA, M., SINGHAL, S., KULKARNI, P., 2006, Resistant starch -A comprehensive Reviews in Food Food Sci. and Safety 5: 1-17.
24) SAYOOJ MAMMALY MEETHAL, NARINDER KAUR, JYOTI SINGH AND YOGESH GAT, 2017, Effect of Addition of Jackfruit Seed Flour on Nutrimental, Phytochemical and Sensory Properties of Snack Bar. *Curr. Res. Nutri and Fd Sci*., 05(2):154-158, seed flour. 2015. *Int. J.Sci.Res*, 4(4):2319-7064,
25) SELVA RANI, N., RAJA M., SURESH, M.,2019, Quality evaluation of musk melon seeds flour and jackfruit seeds flour for bakery products development. The Pharma Innovation Journal. 8(6):703-706.
26) SHADAB BUTOOL, MASRATH BUTOOL, 2015, Nutritional Quality on Value Addition to Jack Fruit seed flour. *Int. J. Sci.Res*.4(4)2319-7064.
27) SOMA BANERJEE, SANTA DATTA D.E, 2015, effect of dry heat treated jackfruit seed powder on growth of experimental animals. Journal of Pharmacy and Biological Sciences, Vol.10(6)p:42-46
28) SOMA, B., SANTA, D., 2015, Effect of dry heat-treated jackfruit seed flour on the growth of experimental animals., *IOSR J. Phar.Bio. Sci*.,10:42-46.
29) SREELETHA, A.S., LINI J.J, DHANYALEKSHMI C.S., SABU KR, PRATAP, C R., 2017, Phytochemical, Proximate, Antimicrobial, Antioxidant and FTIR Analyses of Seeds of Artocarpus heterophyllus Lam. Adv. Biotech & Micro. 5(1) p:001-009
30) SWAMI S.B., THAKOR N.J., HALDANKAR P.M. AND KALSE S.B., SWAMI S.B., THAKOR N.J., HALDANKAR P.M AND KALSE S.B., 2012, International Journal of Processing and Post-Harvest Technology. 3(1) p:142-146
31) VINOD, D., NANDKULE, DORCUS MASIH, CHITRA SONKAR, DEVENDRASING, D., PATIL, 2015, Development and Quality Evaluation of Jackfruit Seed and Soy Flour Noodles. *Int. J. Sci, Eng and Tech*., 3(3) p:802-806
32) ZUWARIAH, I., NOOR FADILAH M.B., HADIJAH H., RODHIAH, R., 2018, Comparing amino acid and chemical composition of jackfruit seed flour treatment. *Fd. Res*.,2(6): 539-545.

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