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Original Research Article

Studies on Traditional Indian Fermented food: Characterization and Development of *Jowar papad*

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Keywords

Phytic acid, Jowar papad, Minerals, Textural, Gel properties and functional properties

A B S T R A C T

Traditional fermented food products prepared in varied parts of India, have been well studied and recognized. However, there is no detailed study reported for foods like *jowar papad, a* indigenous food item prepared largely in India. Hence, present work was undertaken to develop a scientifically sound and commercially viable cereal based traditional fermented food products. Traditional fermented food products like *jowar papad* are prepared from the naturally fermented flours of sorghum without addition of any chemical additives. Efforts were made to find out the effect of indigenous fermentation at varied time and temperatures on minerals, phytic acid content and the nutritional characterization of *jowar papad* prepared from fermented flours of sorghum. Study also deals with textural, gel properties and functional properties. Hence, this study provides an option to improve the process of making and more nutritious, a popularly consumed traditional fermented foods like *jowar papad*. In such situations there will be scope for introduction of such indigenous fermentation technology as functional diet and alternative to black gram dhal *papads*.

Introduction

Sorghum (*Sorghum bicolor* (L.) Moench) is an important food crop in arid and semi-arid tropics, where it is grown in drought areas with a high yield (Anglani, 1998). Sorghum is the fifth most important cereal crop in the world, after wheat, rice, maize, and barley.

Sorghum supplies important minerals, vitamins, protein, and micronutrients essential for optimal health, growth, and development (Chan *et al.,* 2007; Salgueiro *et al.,* 2002). Sorghum contains adequate nutritional values with 75% carbohydrate, 10% protein and 3.5% fat, however, sorghum also contains anti-nutrients such as tannin and phytic acid which affects human digestive system (Elefatio *et al.,* 2005). The mineral composition of sorghum grains is highly variable. Sorghum is a rich source of B-complex vitamins. Other fat-soluble vitamins, namely D, E, and K, have also been found in sorghum grain. The concentrations of thiamine, riboflavin, and niacin in sorghum were comparable to those in maize. It is a gluten-free cereal, which bears impact in the present day scenario where the incidence of Celiac Disease (CD), an immunological response to gluten intolerance is on go up. Grain sorghum contains phenolic compounds like flavonoids, (Shahidi *et al.,* 1995) which have been found to inhibit tumour development (Huang *et al.,* 1992). The average energetic value of whole sorghum grain flour is 356 kcal/100g (BSTID-NRC, 1996). However, some varieties of this cereal contain antinutritional factors, that may form stable complexes with proteins and minerals which decreases digestibility and nutritional value. Reduction or elimination of these undesirable components is essential for improving the nutritional quality of sorghum and effectively utilizing their full potential as human food. Several methods have been employed to improve the nutritional quality of sorghum. Numerous workers have proposed fermentation as a way to improve sorghum nutritional value. Fermentation is known to mobilize nutrients and reduce the antinutritonal content in cereal. Chavan *et al.,* (1988) reported that fermentation of sorghum increased protein content, soluble protein and free amino acids. Similarly, Kazanas and Fields (1981) found an increase in essential amino acids and nutritive value of sorghum during natural fermentation. Soaking is one of the methods used to improve the nutritional value of sorghum as raw material, in the manufacturing of food products. During soaking or fermentation the organisms like *Lactobacillus plantarum, Candida crusei* and *Lactobacillus delbruecki* (Ohenhen and Ikenbomeh, 2007) may involve. Soaking also leads to the breakdown of several complex components into simpler, which alters the texture, flavor, aroma and taste (Parveen, 2003).

Papad is a thin circular sheet made from fermented batter or dough of cereals and millets containing black gram (*Phaseolus mungo*), common salt, an additive and spices (with or without) in various proportions. The circular sheets are made either by spreading the fermented batter into thin circular disc shape in an oil smeared plate or by pressing fermented dough into the spherical-shaped dough balls. *Papads* are made commercially at different levels of production, viz., cottage scale, small scale or medium scale. The papad making industry is one of the home based processing units which has provided ample opportunity of employment to the women of low socio-economic status. *Shri Mahila Griha Udyog Lijjat papad* is a well-known *papad* making medium scale industry of India (Bhatnagar and Dixit, 1993). There are different methods of making *papad* sheets; using a wooden roller pin, thumb pressing or by mechanical pressing are some important methods. The method of pressing the dough affects the cellular structure and diametrical expansion of *papads* during deep fat frying, which is desirable and most important quality parameters (Shurpalekar *et al.,* 1970; Govindarajan *et al.,* 1971; Velu *et al.,* 2004) for the *papad.* Before consumption, *papads* are either fat-fried or roasted on a hot plate or on open flame. *Papads* prepared from other suitable raw material will add variety to the diet (Arya, 1992). Analysis of commercial *papad/* black gram dhal *papad* samples indicated wide variation in quality attributes and only 34.2 per cent samples fell within ISI limits (Kulkarni *et al.,* 1996). Efforts were made to increase mass production of the *papad* for domestic consumption and export has necessitated standardization and quality evaluation of the finished product.

Materials and Methods

Materials

Matured grains of variety SPV-1411(Moti) and SPV-1595 (Jyoti) of sorghum (*Sorghum bicolor* (L.) Moench) were procured from Sorghum Research Station, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani.

The grains were sorted by removing broken grains and other unwanted matter.

Chemicals

The culture media and chemicals used were obtained from Hi-Media laboratories Pvt. Ltd., Mumbai, India. Ethanol, Dinitrosalicylic acid reagent and potassium sodium tartarate (Rochelle salt) were procured from S.D. Fine Chem. Pvt. Ltd., Mumbai, India. Some chemicals obtained from Sigma Chemical Co. s (St. Louis, MO) and chemicals and solvents used were of analytical grade.

Preparation of sample

The sorghum grains were soaked in water (1:5 w/v) for a period of 10, 15, and 20 hr at fermentation temperature of 30.0, 37.5 and 45.0^{0}C. The soaked water was changed twice.

At the end of soaking period, the soaked water was discarded. The grains were rinsed twice with water and dried in shade for 12 hr at 30±5°C.

The dried soaked grains were ground in electrical grinder (make Anjali, Mumbai). The ground samples were stored at -20°C in polythene pouches with proper labelling and used for further experiments.

Estimation of total minerals

Preparation of sample

Defatted cereal grains were dried in oven at 70^{o}C for 12 hr. The oven dried samples were ground in electrically operated grinder with stainless steel blades. The ground samples were stored in polythene pouches with proper labelling and used for further determination.

Estimation of minerals

To 1g of ground moisture-free sample (unfermented and fermented) was added 25ml of di acid mixture (HNO_3: $HCLO_4$:: 5:1 v/v), and the mixture was kept overnight. The next day it was digested by heating until clear white precipitates settled at the bottom. The large crystals were dissolved by diluting in double-distilled water, and the contents were filtered through Whatman No. 42 filter paper. The filtrate was made up to 50ml with double-distilled water and was used for the determination of total iron, copper, zinc, and manganese by atomic absorption spectrophotometry (Perkin Elmer Model 3300, USA) according to the method of Lindsey and Norwell (1969).

Determination of phytic acid content

Phytic acid content was determined according to AOAC (2004).

Characterization of fermented sorghum flour

Preparation of sample

Fermented sorghum flour was dried in oven at 70^{o}C for 12 hr. The oven dried samples were ground in electrically operated grinder with stainless steel blades. The ground samples were stored in polythene pouches with proper labelling and used for further investigation.

Thermal properties (Differential scanning calorimetry)

A TA-60WS DSC (Shimadzu Analytical Pvt. Ltd., Singapore) was utilized to measure the gelatinization properties of the sample. 20 mg fermented sorghum flour sample and control sample was transferred in to a DSC pan. The pan was hermetically sealed and inserted in the calorimeter. Thermal curves included onset temperature (T_o), peak temperature (T_p) and end set temperature (T_e). Heating rate was maintained at 10°C/min from 20 to 250°C. DSC-60 software, supplied by the instrument manufacturer, was used to determine the mentioned temperatures and peak area.

The software drew a tangent line at the steepest point of the DSC curve and a baseline connecting the starting and the ending points of the peak. The intersections of the baseline with the DSC curve determined the onset and ending temperatures. Gelatinization energy was calculated by drawing a straight line between onset temperatures and ending temperature and was recorded as endothermic heat (J/g). The enthalpy (ΔH) was estimated by integrating the area between the thermo gram and a base line under the peak and was expressed in terms of calories per unit weight of dry starch (cal g^{-1}). All DSC experiments were replicated at least three times.

Gel hydration (functional) properties

Water absorption index (WAI), water solubility index (WSI) and swelling power of different fermented and unfermented wheat flour sample were determined following the method of Toyokawa *et al.,* (1989), with slight modification as reported Rosell *et al.,* (2011).

Briefly, flour (50.0 ± 0.1 mg) sample was dispersed in 1.0 ml of distilled water in an eppendorf tube using a micropipette and cooked at 90^0C for 10 min in a water bath. The cooked paste was cooled in an ice water bath for 10 min, and then centrifuged at 3000 rpm at 4^0C for 10 min. The supernatant was decanted into an evaporating dish and the weight of dry solids was recovered by evaporating the supernatant at 105^0C till constant weight. Three replicates were made for each sample. Residues (Wr) and dried supernatants (Ws) were weighed and water absorption index (WAI), water solubility index (WSI) and swelling power (SP) were calculated as follows:

WAI (g/g) = Wr/Wi (1)
WSI (g/100 g) = Ws/Wi × 100 (2)
SP (g/g) = Wr/Wi – Ws (3)

Where,

Wi was the initial sample weight (g, db)
Wr was the residual sample weight (g, db)
Ws was the supernatant weight (g, db)

Degree of gelatinization

The degree of gelatinization was measured according to the method reported by (Birch and Priestley, 1973). The cooked (fermented) sample was dried in oven at 58°C, ground and pass through the sieve (80mesh).

The sample (0.2g) was prepared in 125 ml Erlenmeyer flasks; 98 ml of distilled water was added and KOH 10 M 2.0 ml and then mixed for 5 minutes prior to centrifugation at 3000 rpm for 15 min. The supernatant (1.0 ml) was pipetted and added with hydrochloric acid 0.5M 0.4 ml followed by 10 ml of distilled water and 0.1 ml of iodine solution. The mixture was homogenized and measured the absorbance at 600 nm.

The estimation was repeated using 95 ml water and 5 ml 10M-KOH solution, and 1.0 ml 0.5 M-HC1 for neutralization. The ratio of the two absorbance obtained from each sample enabled degree of gelatinization to be obtained.

Nutritional profile and frying characteristics of *papad*

Physical parameters

The diameter of the *papad* was measured at two diametrical positions to an accuracy of 0.02 mm using a Vernier caliper (Mitutoyo, Kawasaki, Japan). Each *papad* was weighed in a monopan analytical balance (AEG-220, Shimadzu, Tokyo, Japan) to an accuracy of 0.0001 gm.

Moisture content

Moisture was determined by hot air oven method by drying the sample in hot air oven at 105 ^{o}C temperature until a constant weight (AOAC, 2010).

The moisture content of sample was estimated by the formula:

Moisture content (%) = Initial weight − Final weight /Initial weight ×100

Frying characteristics of papad

Frying

Jowar papad stored at ambient temperature were deep fat fried in a frying pan containing fresh refined peanut oil at 174± 5 ^{o}C for 6–9 sec.

Oil Uptake

Jowar papad from each selection were weighed before and after deep frying in an electronic balance. Before measuring the weight after frying, the *jowar papad* were wiped with tissue paper to remove the adhering surface oil.

The difference in weight was worked out and expressed as oil uptake in percentage.

Expansion

Jowar papad from each selection were observed for diameter in two directions at a right angle before and after frying. The difference in diameter was worked out and expressed as expansion in percentage. The percent expansion of *jowar papad* was calculated by using the following formula:

Expansion (%) = (DF- DR/ DR) ×100

Where,

DF is the diameter of fried *jowar papad* and DR is the diameter of raw *jowar papad*

Colour measurement

The colour of *jowar papad* was measured using Hunter Lab colourimeter (Model DP-9000 D25A), (Hunter associates laboratory, Reston, VA, USA) in terms of Hunter ‘L’ value (lightness, ranging 0-100 indicating black to white), ‘a’ value (+ ‘a’ value indicates redness and – ‘a’ value indicates greenness) and ‘b’ value (+ ‘b’ value indicates yellowness and – ‘b’ value indicates blueness) (Chaovanalikit *et al.*, 2002).

Textural characteristic of extruded product

The texture of prepared samples before and after frying treatment was analyzed using the TA-XT2i, Texture analyzer from Stable Microsystems (Surrey, England). The software used was the Texture expert exceeds software. A cylindrical probe 2mm R was used for measuring the texture. The force was measured in terms of compression (g). The instrument was calibrated with a 50 kg load cell. The test speed was 1 mm/s and the probe was allowed to compress 0.5 mm into the sample. Five replicate samples were tested on each sample and the recorded values from the resulting one compression cycle for each test were used for texture profile analysis, which includes attributes of hardness, crispiness and fracturability.

Statistical analysis

The results were statistically analyzed by one-way ANOVA using SPSS (IBM statistical analysis, Version 19). Duncan's new multiple-range test was used to determine significant differences. Statistical significance was declared at $p \leq 0.05$ post-hoc comparisons, SPSS 19 version (Duncan, 1955).

Results and Discussion

Total minerals

The soaked and shade dried flour of two sorghum cultivars were fermented at different temperatures, i.e., 30, 37.5**,** and 45^{o}C for varying periods, viz. 10, 15 and 20 hr. Defatted cereal grain was dried in oven at 70^{o}C for 12 hr.

The oven dried samples were ground in electrically operated grinder (Anjalis grinder, Mumbai, India) with stainless steel blades. The ground samples were stored in polythene pouches with proper labelling and used for further determination.

Table 3.1 and Table 3.2 shows the micro elements contents *i.e*. iron (Fe), manganese (Mn), copper (Cu) and zinc (Zn) of sorghum before and after treatments. Apparent changes in the concentrations of Fe, Mn, Cu, and Zn were observed during the fermentations of sorghum millet blends. From Table 3.1 and Table 3.2, it could be noticed that the Fe, Mn, Cu and Zn contents were higher in cultivar SPV-1595 than in cultivar SPV-1411 of unprocessed sorghum.

Iron

Fermentation significantly ($P< 0.05$) reduced the Fe content of the two cultivars sequentially from 71.40 to 37.24 µg/g for SPV-1411 and from 75.30 to 35.60 µg/g for SPV-1595. Longer the fermentation period and higher the temperature of fermentation, the greater was the decrease in HC1 extractability of the minerals in both the varieties of sorghum millet. Same results were reported earlier by Jambunathan (1980). Hamad (2007) found that raw sorghum contains 3.43 to 4.58 mg/100 g iron and micro-elements content were decreased after treatments. Lestienne *et al.*, (2005) reported that up to 40% of Fe content of sorghum grain may be lost as a result of soaking. Kumar and Chauhan (1993) stated that natural fermentation insignificantly affected Fe content.

Manganese

Results indicated that unprocessed SPV-1595 was the highest variety in Mn content (17.31µg / g). Fermented sorghum flour had initial manganese (Mn) content15.23 µg/g for SPV-1595 cultivar and 14.83 µg/g for SPV-1411 cultivar. Moreover, the fermentation period was increased from 10 to 20 hr, a significant decrease was observed in Mn content during fermentation in both the varieties. However, Ahmed (1999) confirmed that natural fermentation had no effect on Mn content of pearl millet.

Copper

It is revealed from Table 3.1 and Table 3.2 that the Cu content ranged from 7.12 to 7.32 µg/g for unfermented sorghum. Fermentation significantly ($P< 0.05$) reduced Cu content of SPV-1411from 5.32 to 4.02 µg/g. Non- significant reduction was observed from 5.34 to 4.21 µg/g in SPV-

1595 cultivar, which in line with results of Abdalla *et al.*, (1998).

Zinc

The effect of fermentation temperature and period on Zn content is shown in Table 3.1 and 3.2. A significant decrease ($P \leq 0.05$) in Zn content was first observed at 30^oC temperature for 20 hr of fermentation period and further significant decrease at 37.5^oC and 45^oC temperature of SPV-1411 cultivar. The significant reduction was observed from 55.51 to 31.64 μg/g in SPV-1595 cultivar. Reduction after soaking may be attributed to leaching of iron and zinc ions into the soaking medium (Saharan *et al.*, 2001). Alemu (2009) reported that sorghum iron and zinc content were decreased after fermentation.

Phytic acid content of sorghum

The data on the effect of soaking for a period of 10, 15, and 20 hr and soaking temperature of 30.0, 37.5 and 45.0^0C on phytic acid content of two cultivars of sorghum, SPV-1411 and SPV-1595 are presented in Table 3.3.

Table 3.3 shows that phytic acid content of both the cultivars was decreased significantly at all soaking periods on increase in the temperature from 30.0 to 45.0^0C. The reduction was from 895.45 to 525.60 mg/100 g (41.3 % reduction) for SPV-1411 cultivar and from 992.45 to 653.10 mg/100 g (34.3% reduction) for SPV-1595 cultivar. Natural fermentation at 30.0, 37.5 and 45.0°C for 20 hr brought about a significant reduction in phytic acid content of sorghum. The SPV-1411 cultivar showed higher levels of phytic acid than the SPV-1595 cultivar. These results were similar to those observed for sorghum by Mahgoub and El-Hag (1998).

Generally, fermentation (soaking in water) is known to cause a greater reduction in phytic acid than other anti-nutrients and this could be due to the low pH of fermented batter, which is considered to be optimum for phytase activity. The reduction in phytic acid during fermentation was attributed to the action of the microbial enzyme phytase. This reduction in phytic acid may be useful in improving nutritional quality of sorghum with respect to mineral bioavailability (Daniels and Fisher, 1981; Lopez *et al.*, 1983). Fermentation is found to decrease antinutrients of pearl millet by decreasing the phytic acid (Monawar, 1983). Results obtained in this study were similar to those obtained by Marfo *et al.*, (1991). Kheterpaul and Chauhan (1989) reported that mixed fermentation for 72 hr at 30°C reduced phytic acid by 56%.

Characterization of fermented sorghum flour

Thermal properties (Differential scanning calorimetry)

The thermal properties of unfermented and fermented (20 hr) flour of two cultivars of sorghum were investigated by differential scanning calorimetry (Fig. 1). Unfermented sorghum starch displayed a major peak of starch gelatinization and minor peak of fermented sorghum starch of both cultivars; due to the melting of an amylose-lipid complex during heating. Gelatinization properties of starches like peak temperature (T_p), and gelatinization enthalpies (ΔH) before and after fermentation of two sorghum cultivars are summarized in Table 3.4.

The gelatinization peak temperature of unfermented sorghum starches was about 19-21 °C higher than that of fermented sorghum starch.

Table.1 Effect of temperature and period of fermentation on mineral content of sorghum var. SPV – 1411*

SPV - 1411					
Fer. Temp. (^{0}C)	**Fer.Time (h)**	**Fe (µg / g)**	**Mn (µg / g)**	**Cu (µg / g)**	**Zn (µg / g)**
Control	0.0	71.40 h ± 0.14	16.82 i ± 0.03	7.12 j ± 0.01	45.31 i ± 0.01
30.0	10.0	45.30 g ± 0.14	14.83 h ± 0.03	5.32 i ± 0.01	35.12 g ± 0.03
	15.0	43.70 f ± 0.14	13.24 g ± 0.06	5.19 h ± 0.01	35.42 h ± 0.03
	20.0	40.60 d ± 0.14	11.85 e ± 0.01	4.92 e ± 0.01	34.62 d ± 0.01
37.5	10.0	43.10 e ± 0.14	12.42 f ± 0.01	5.14 g ± 0.00	35.32 f ± 0.01
	15.0	40.40 d ± 0.14	11.56 d ± 0.03	4.98 f ± 0.02	34.84 e ± 0.04
	20.0	38.30 b ± 0.14	9.92 b ± 0.01	4.72 c ± 0.01	33.62 a ± 0.03
45.0	10.0	39.85 c ± 0.04	10.22 c ± 0.03	4.88 d ± 0.01	34.65 d ± 0.05
	15.0	38.44 b ± 0.03	9.93 b ± 0.02	4.62 b ± 0.01	33.96 c ± 0.03
	20.0	37.24 a ± 0.06	9.83 a ± 0.03	4.02 a ± 0.01	33.74 b ± 0.03

*Values are means ± (S.D.).Means not sharing a common letter in a column are significantly different at P ≤ 0.05, as assessed by Duncan's multiple range test.

Table.2 Effect of temperature and period of fermentation on mineral content of sorghum var. SPV – 1595*

SPV – 1595					
Fer. Temp(^{0}C)	**Fer. Time (h)**	**Fe (µg / g)**	**Mn (µg / g)**	**Cu (µg / g)**	**Zn (µg / g)**
Control	0.0	75.30 h ± 0.03	17.31 i ± 0.01	7.32 b ± 0.01	51.55 i ± 0.07
30.0	10.0	46.60 g ± 0.28	15.23 h ± 0.04	5.34 a ± 0.03	36.41 g ± 0.01
	15.0	43.60 f ± 0.28	13.82 f ± 0.03	5.28 a ± 0.01	35.70 f ± 0.14
	20.0	40.20 d ± 0.14	11.62 d ± 0.01	5.12 a ± 0.01	34.82 e ± 0.03
37.5	10.0	41.50 e ± 0.28	14.33 g ± 0.03	3.76 a ± 2.11	36.54 h ± 0.04
	15.0	39.40 c ± 0.14	12.53 e ± 0.02	5.10 a ± 0.01	34.63 d ± 0.01
	20.0	37.20 b ± 0.14	10.82 c ± 0.03	4.81 a ± 0.01	33.45 c ± 0.04
45.0	10.0	39.80 cd ± 0.14	11.66 d ± 0.03	4.98 a ± 0.01	34.93 e ± 0.02
	15.0	37.40 b ± 0.14	10.44 b ± 0.03	4.82 a ± 0.00	32.83 b ± 0.02
	20.0	35.60 a ± 0.14	9.94 a ± 0.04	4.21 a ± 0.01	31.64 a ± 0.02

*Values are means ± (S.D.).Means not sharing a common letter in a column are significantly different at P ≤ 0.05, as assessed by Duncan's multiple range test.

Table.3 Effect of temperature and period of fermentation on phytic acid content of sorghum*

Fermentation Period(hr)	Fermentation Temperature (^{0}C)	Phytic Acid (mg/100 gm)	
		Variety SPV-1411	Variety SPV-1595
0	Control	895.45 j ± 1.91	992.45 j ± 1.34
10	30.0	848.45 i ± 0.92	950.20 i ± 1.13
	37.5	805.80 h ± 0.57	912.25 h ± 0.64
	45.0	763.95 g ± 0.78	873.55 g ± 1.48
15	30.0	727.10 f ± 0.99	836.10 f ± 1.84
	37.5	684.80 e ± 1.27	802.65 e ± 1.77
	45.0	647.75 d ± 0.92	764.15 d ± 1.34
20	30.0	609.05 c ± 0.78	725.50 c ± 1.84
	37.5	563.50 b ± 1.56	684.85 b ± 0.35
	45.0	525.60 a ± 1.13	653.10 a ± 1.41

*Values are means ± (S.D.).Means not sharing a common letter in a column are significantly different at $P \leq 0.05$, as assessed by Duncan's multiple range test.

Table.4 Thermal Properties of sorghum

Variety		Endothermic Heat (J/g)	Peak Temperature (^{o}C)
SPV-1411	Unfermented	12.9	111.40
	Fermented	10.3	90.89
SPV-1595	Unfermented	12.8	111.22
	Fermented	10.8	91.32

Table.5 Functional parameters of sorghum

Cereals	Variety	Water Absorption Index (g/g)	Water Solubility Index (g/100g)	Swelling Power (g/g)
Sorghum unfermented	SPV-1411	0.836	4.4	0.874
	SPV-1595	0.844	3.6	0.875
Sorghum fermented	SPV-1411	0.825	4.0	0.857
	SPV-1595	0.824	2.8	0.847

Table.6 Effect of cooking time on degree of gelatinization at 99.5 ^{0}C Temperature (on dry wt. basis)*

Treatment Time (min)	Degree of gelatinization (%)	
	Variety SPV - 1411	Variety SPV - 1595
0	69.15 ± 0.04	68.30 ± 0.14
15	87.20 ± 0.03	86.03 ± 0.01
18	96.30 ± 0.03	95.15 ± 0.07
21	98.91 ± 0.04	98.73 ± 0.01

*Values are means ± (S.D.).

Table.7 Color properties of *Jowar papad**

Jowar papad	L*	a*	b*
Raw (SPV-1411)	29.02 ± 0.02	0.10 ± 0.03	0.66 ± 0.04
Fried (SPV-1411)	29.04± 0.3	0.06 ± 0.01	0.65 ± 0.03
Raw (SPV-1595)	28.67 ± 0.02	0.13 ± 0.04	0.34 ± 0.04
Fried (SPV-1595)	28.87 ± 0.4	0.24 ± 0.06	0.65 ± 0.06

L, lightness; a: +a, redness and -a, greenness; b: +b, yellowness and-b, blueness.
*Values are mean and standard deviations for n = 3.

Table.8 Textural properties of *jowar papad*

Samples	Variety	Hardness (Force) g	Crispiness (Linear distance) gs	Fracturability (distance) mm
Jowar papad	SPV-1411	704.8	11.37	1.70
		666.9	17.56	1.12
		775.9	21.98	0.71
	SPV- 1595	782.2	8.88	0.91
		785.6	15.32	1.42
		838.1	8.24	1.20

Fig.1 Preparation and optimization of *Jowar papad* (Flow sheet)

Sorghum
↓
Sorted and removal of broken grains
↓
Soaked in water (1:5 w/v)
↓
Discarded excess water
↓
Dried in shade (12 hr at 30±5°C)
↓
Ground
↓
Water (10:9 w/v) and salt (2.5%).
↓
Spread the batter (thin circular disc shape) on an edible oil smeared perforated plate
↓
Steamed
↓
Dried (at 50^{o}C for 8 hr)
↓
Jowar Papad

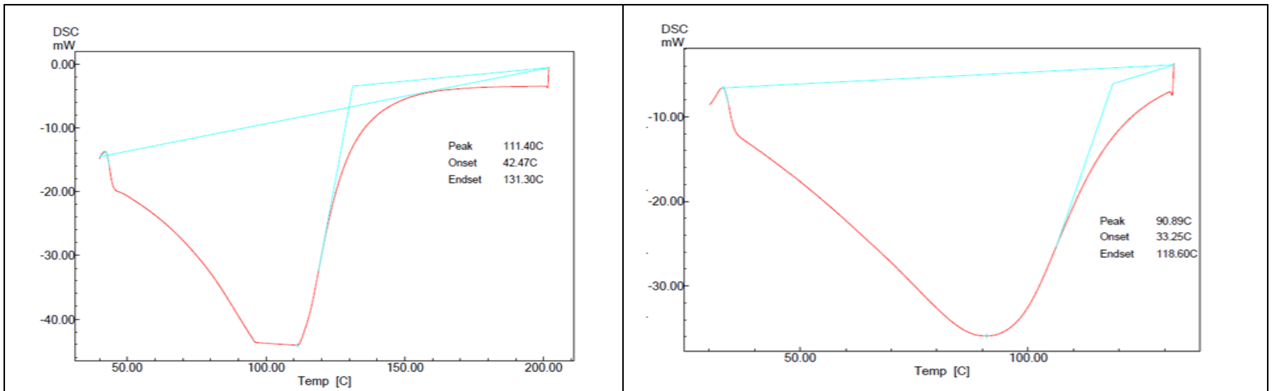

Fig.1 DSC analysis of unfermented and fermented sorghum SPV-1411

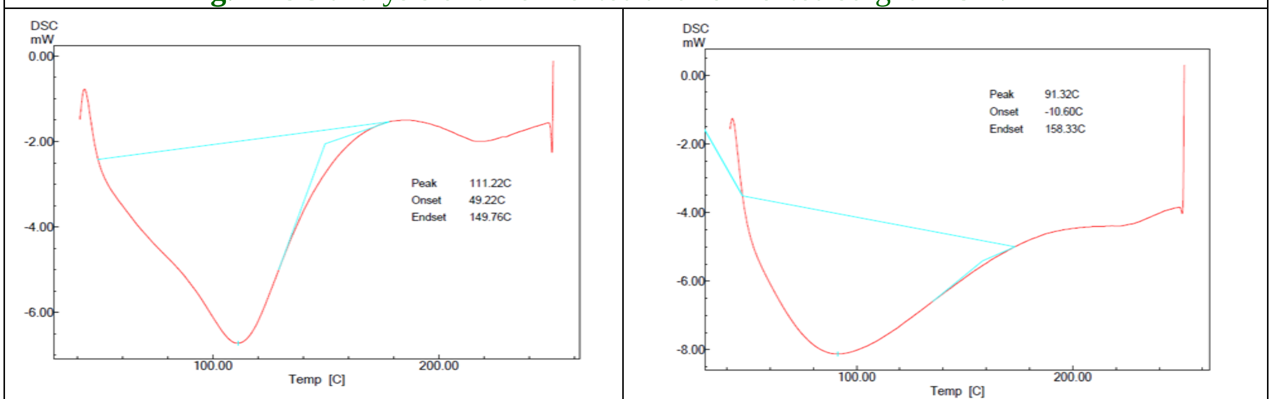

Fig.2 DSC analysis of unfermented and fermented sorghum SPV-1595

Fig.3 *Jowar papad* prepared from variety SPV-1411 and SPV 1595

This study showed that the starches from the two sorghum cultivars differed generally in gelatinization transition temperatures (T_o, T_P and T_c) and enthalpy of gelatinization (ΔH). These differences are probably influenced by differences in the amount of lipid-complexed amylose molecules, the magnitude of interaction between starch chains within the native granule, and the chain lengths of amylose and amylopectin

(Biliaderis *et al.,* 1986). The peak gelatinization temperature is believed to be an indicator of crystallite quality, which is related to double helix length, whereas the gelatinization enthalpy (ΔH) is a measure of the loss of molecular order (Cooke and Gidley, 1992; Singh *et al.*, 2007). Akingbala *et al.,* (1988), elucidated the gelatinization temperature of starches isolated from 24 non waxy varieties of sorghum using a differential scanning calorimeter and have reported the gelatinization energies to be in the range of 2.51 to 3.96 cal/g.

Gel hydration (functional) properties

Water uptake during thermal processing involves starch gelatinization and protein denaturation, was assessed by determining the water absorption index (WAI), water solubility index (WSI) and swelling power (SP). The WAI, WSI and SP values of processed and unprocessed sorghum flour of both cultivars were presented in Table 3.5.

The WAI, WSI and SP values for unprocessed sorghum flour of cultivar SPV-1411 were 0.844 g/g, 3.6 g/100g and 0.875 g/g, respectively whereas, 0.824 g/g,2.8 g/100g and 0.847 g/g respectively for cultivar SPV-1595. There was no significant effect of variety on these parameters. In fermented sorghum flour, the WAI, WSI and SP values were decreased from 0.836 to 0.825 g/g, 4.4 to 4.2 g/100g and 0.874 to 0.857 g/g in cultivar SPV-1411. A similar decrease in the WAI, WSI and SP values were also observed in case of cultivar SPV-1595. Most probably, this might be attributed due to more intensity of starch damage and further the interactions with proteins and cell walls matrices affected the water uptake ability. In addition, the level of amylose has been linked with swelling power of rice (Andrade-Mahecha *et al.,* 2012; Chung *et al.,* 2011). Swelling was main property of amylopectin, but the amylose inhibited amylopectin to swell (Tester and Morrison, 1990). It also seems that the presence of other non-starch components affects the swelling pattern of amylopectin. A high WAI is a desirable property in ready to eat products of sorghum (Pelembe *et al.,* 2002). At high temperatures the starch is degraded or dextrinized to smaller soluble molecules, thus increasing WSI, and the WAI decreases (Ding *et al.,* 2005).

Degree of gelatinization (Pasting properties)

The pasting properties of fermented sorghum starches are presented in Table 3.6. A quantitative measure of phenomena like gelatinization is provided based on the heat flow. The fermented sorghum starches showed identical pasting temperatures (95±5^{0}C), which were higher than those of wheat (86°C) and corn (81^{0}C) starches (Hoover and Vasanthan, 1994a; Hoover *et al.,* 1991). The effect of cooking time on degree of gelatinization at 99.5 ^{0}C of sorghum was shown in Table 3.6. The degree of gelatinization of cooked fermented sorghum from different cooking time was ranged from 68.30% to 98.73%. The degree of gelatinization of cooked fermented sorghum starch of both cultivars tended to increase with increasing the cooking time. The gelatinization of cooked fermented sorghum starch is depends on cooking time and sorghum variety (Belitz *et al.,* 2004).

Color properties of *Jowar papad*

The colour values of *jowar papads* (Hunter L, a and b) were shown in Table 3.7. The L, a and b values for *jowar papad* prepared from the fermented (20 hr) sorghum batter were 29.02, 0.10 and 0.66 respectively for cultivar SPV-1411; 28.67, 0.13 and 0.34

respectively for cultivar SPV-1595 and were taken as the control readings. In the fried *jowar papad*, the L value was increased from 29.02 to 29.04 in cultivar SPV-1411. A similar increase in the L value was also observed in case of cultivar SPV-1595, which indicated an improvement in the whiteness of fried *jowar papad*. Similarly, the Hunter b value, which indicates the yellowness increased during frying of *jowar papad* prepared from cultivar SPV-1595, whereas in fried *jowar papad* from cultivar SPV-1411 slight increase in the blueness was observed. It was observed that Hunter a value of *jowar papad* made from SPV-1411 cultivar showed more value (0.10) compared to that of fried *jowar papad* (0.06) indicated a slight greenness of the finished product.

It was also observed that Hunter a value of *jowar papad* made from SPV-1595 cultivar showed less value (0.13) compared to that of fried *jowar papad* (0.24) indicate that redness was more prominent of the finished product.

Texture measurement of *jowar papad*

Viscosity and elasticity are very important for handling of dough. Good understanding of relationship between composition and structure is essential for the development of optimum processing regimes. In food processing industry, elastic and viscous properties of dough are usually considered as functions of time and tension applied. Continuous operations such as sheeting and rolling knead the dough at proper consistency. Various techniques have been used to narrate sensory texture measurements to dough behaviour during processing**.** The rheological properties of hardness, crispiness and fracturabilily (distance mm) were analyzed using the TA-XT2i, texture analyzer from Stable Microsystems (Surrey, England).

The results of texture analyzer are shown in Table 3.8. Force (peak) applied was found higher values in *Jowar papad* prepared from cultivar SPV- 1595 than *jowar papad* of cultivar SPV-1411. However, the values were higher in *jowar papad* prepared from cultivar SPV-1595 indicating probable development of starch-associated networks at higher temperatures of cooking. It indicates that hardness values were higher in *jowar papad* prepared from cultivar SPV-1595 than *Jowar papad* of cultivar SPV-1411. On the other hand, linear distance (gs) was found higher values in *jowar papad* prepared from cultivar SPV-1411 than *jowar papad* of cultivar SPV-1595. It indicates that crispiness values were higher in *jowar papad* prepared from cultivar SPV-1411 than *jowar papad* of cultivar SPV- 1595. Moreover, not much difference was observed in the distance (mm) among *jowar papad* prepared from two cultivars of sorghum i. e. SPV-1411 and SPV- 1595.

It means fracturability showed not much difference among *jowar papad* prepared from both cultivars of sorghum. It is interesting to note that those cereals which contain roughly twice the amount of fat found in the standard cereals like wheat, corn etc. The presence of fat and its variation with temperature could significantly alter the viscoelastic qualities of that cereal dough (Hibberd and Parker, 1975; Dreese *et al.*, 1988).

The unprocessed sorghum variety SPV-1595 recorded highest content of Fe (75.3μg/g), Mn (17.31μg/g), Cu (7.32μg/g) and Zn (51.55μg/g) whereas SPV-1411 recorded lowest content Fe (71.40μg/g), Mn (16.82μg/g), Cu (7.12μg/g) and Zn (45.31μg/g). Soaking at 45°C for 20 hr in both the varieties, significantly ($P \leq 0.05$) decreased the minerals content *i.e.*, Fe, Mn, Cu and Zn. The soaking treatment can decrease several nutritional components of sorghum as most components were soluble in water.This study has demonstrated that the traditional fermentation of these local sorghum varieties resulted in a significant reduction in phytic acid contents. Natural fermentation at 45°C had the most pronounced effect on lowering phytate followed by 37.5 and 30°C; the higher the temperature, the greater the loss of phytic acid during fermentation. This was accompanied by significant improvement in protein digestibility (*in vitro*). These results clearly indicate that fermentation may be useful for improving the nutritional quality of the sorghum with respect to protein and carbohydrate utilization, but mineral contents of the two cultivars were markedly reduced during the processing methods used. Fermentation and soaking could be regarded as viable means for improvement of the nutritional quality of sorghum. Fermentation offers unique nutritional advantages for making the starch and protein of coarse-grained sorghum more digestible, possibly by drastically reducing its phytate content. It may be concluded that by indigenous fermentation with natural organism of indigenously developed food mixtures is a potential process for developing food products of improved nutritional quality. This type of fermented food product not only offers unique nutritional value but also has therapeutic value.

Traditional methods of preparation of *jowar papad* thus, seem to have certain nutritional advantages. Reduction in the phytic acid and polyphenol content of sorghum through *jowar papad* fermentation may imply improved digestibility of proteins and carbohydrates and enhanced bioavailability of minerals in the fermented product. Hence, this study provides an option to improve the process of making and more nutritious, a popularly consumed traditional fermented food, *jowar papad*. *Indigenous jowar papad* is prepared from the naturally fermented batter without addition of any chemical additives to improve the textural quality of *jowar papad*. The instrumental analysis showed that *jowar papad* made from fermented batter of SPV-1411 has ‘very good’ quality attributes within a very short period of fermentation than the one made from traditional method.

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