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SHORT COMMUNICATION

Development and standardization of sorghum pasta using extrusion technology

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Abstract Extrusion cooking is a unique method for preparing pasta, which is generally produced from durum wheat semolina. However, preparation of pasta from sorghum is not practiced in India. Therefore, the present study was undertaken to develop and standardize pasta from sorghum cultivar, M35-1 and wheat semolina of 0.1 mm particle size. Sorghum and wheat semolina in different proportions (T1;S:W-50:50, T2;S:W-60:40,T3;S:W-70:30,T4; S:W-80:20, T5; S −100) were mixed with lukewarm water (40 °C) in the cold extruder for 30 min and passed through the extruder with a screw speed of 80 rpm and at a temperature of 55° to obtain pasta of diameter (0.6 mm) and length (1.4 mm). The extruded pasta was dried at 70 °C in a tray drier for 8 h, cooled and stored in polyethylene bags at room temperature. The pasta was subjected to physico-chemical analysis such as length, diameter, bulk density, water absorption, cooking time, cooking loss, moisture, water activity, alcoholic acidity, amylase, carbohydrates, fat, protein, fibre and ash using standard methods. Organoleptic characteristics such as color and appearance, texture, taste, flavor and overall acceptability, stickiness, bulkiness and firmness were evaluated at laboratory level by a panel of semi trained judges using 5 point hedonic rating scale. Among the various blends studied, the sorghum and wheat semolina with a combination of 50:50 (T1) and 60:40 (T2) and 70:30 (T3) were more acceptable than others. Well acceptable sorghum pasta can be developed from sorghum and wheat, thereby improving its nutritional composition.

Keywords Millets · Sorghum · Pasta · Extrusion Cooking · Organoleptic evaluation

Introduction

Sorghum [Sorghum bicolor (L.) Moench] is one of the important staple food crops in the semi- arid regions of sub- Saharan Africa and India. With the increasing world population and decreasing water supplies, sorghum is considered as an important future crop. Like other cereals, sorghum is rich in starch–a major storage form for carbohydrates–which makes up about 60–80 % of normal kernels and has excellent potential for industrial applications (Zhang et al. 2003; Elmoneim et al. 2004; Claver et al. 2010). It is a potential source of energy, protein, fibre, vitamins, minerals and phytochemicals (FAO 2005). However, as a food or feed, digestibility of sorghum continues to be a concern because of pronounced starch-protein interactions, and formation of intermolecular disulphide bonds in the proteins upon high-moisture heat treatments, both of which render its starch and protein as less digestible compared to that of other cereals (Ezeogu et al. 2005).

Extrusion cooking is one of the contemporary food processing technologies applied for the preparation of a variety of inexpensive foods and snacks, specialty and supplementary

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Table 1 Formulations used for preparation of sorghum pasta

S.No	Treatment	Ingredients	Formulation (%)	Technology
1	T1	S+W	50:50	Extrusion Cooking
2	T2	S+W	60:40	Extrusion Cooking
3	T3	S+W	70:30	Extrusion Cooking
4	T4	S+W	80:20	Extrusion Cooking
5	T5	S	100	Extrusion Cooking

(Sorghum Semolina, Wheat Semolina: S+W)

foods (Harper and Jansen 1985). It reduces the anti nutritional factors, renders the product microbial safe and enhances the consumer acceptability (Nibedita and Sukumar 2003). It also reduces the destruction of nutrients, improves starch and protein digestibility.

Pasta is a popular convenience food worldwide, prepared from durum wheat or rice using extrusion cooking. Previous research has shown that sorghum may be used to produce noodles (Suherndro et al. 2000; Liu et al. 2012) and pasta with combination of other cereals (Faure 1992). However, minimum amount of sorghum was used for the development of such products. It was therefore felt worthwhile to develop nutrient rich, high quality sorghum pasta in combination with minimum amount of wheat, as sorghum, by itself lacks gluten protein to produce viscoelasticity. Accordingly, the present study deals with the formulation and standardization of sorghum based Ready to Cook (RTC) food with utilization of extrusion technology.

Materials and methods

Procurement of raw material

M35-1, cultivar was used for the preparation of sorghum pasta, procured from solapur market, Maharastra and wheat was procured from local market, Hyderabad.

Processing

Grains were subjected to processing such as sorting, cleaning, grading and finally processed into semolina using Brabender Junior (*Brabender Unit, Italy*), then sieved using a standard sieve (BSS) to produce particle size of 0.1 mm.

Formulations used

The formulations made for the preparation of pasta using sorghum and wheat semolina is given in Table 1.

Extrusion conditions

Low temperature short-time (LTST) extrusion cooking was conducted using a single-screw model (*La Monferrina, Italy*). To optimize the process variables of extrusion cooking for preparation of the pasta extrudates with desirable internal and apparent good texture, the blended samples were tempered by adding a predetermined amount of water (30 %) at 40 °C by spraying and mixed in a mixer thoroughly for 30 min to adjust the feed moisture content to 14 %, for moisture equilibrium. The operating conditions were fixed at 600 RPM shearing forces; 15 kg/h feed rate; 6.5 mm diameter of the die. The temperature profile in the barrel zone towards die was 55 °C. The extrudates were collected when the operation conditions were at constant state, cooled at room temperature, dried overnight in tray drier at 60 °C before packing.

Physical characteristics

Bulk density was determined by filling a 1 L measuring cylinder with the extrudates with less than 12 % moisture slightly above the liter mark. The cylinder was tapped 10 times till the products measured up to the litre mark. The weight of the extrudates was taken and bulk density was calculated with the formulae Bulk density (g/ml) = Weight of the sample/ Volume of the sample after tapping (Okaka and Porter 1977). Length of extrudates was measured using a measuring scale.

Determination of Water Absorption Index (WAI) and Water Solubility Index (WSI)

WAI and WSI were determined in triplicate following the method described by Carine et al. (2010). Each sample (1 g) was suspended in 20 ml of distilled water in a tared 50 ml centrifuge tube and stirred with glass rod, put in water bath for 30 min at 30 °C temperature. Subsequently, the dispersions were centrifuged at 2000 g for 10 min using a centrifuge (Remi Q-8C, India). The supernatants were poured into dry

Table 2 Physical characteristics of extrudates

Characteristics	T1	T2	T3	T4	T5	‘*F*’ value
Length (mm)	1.4±0.04	1.4±0.04	1.3±0.04	1.3±0.04	1.2±0.01	26.92**
Weight (g)	2.5±0.07	2.5±0.07	2.4±0.14	2.5±0.21	2.1±0.07	10.14**
Bulkdensity ((g/ml))	0.45±0.04	0.44±0.02	0.42±0.02	0.41±0.02	0.36±0.03	2.23**

**significant at 1 % level; *N*=10

Table 3 WAI and WAI of extrudates

Sample	WSI (%)	WAI (%)
T1	11.28±0.12	21.27±1.56
T2	9.43±0.01	31.42±1.24
T3	9.32±0.52	31.39±0.27
T4	8.50±0.56	38.79±0.03
T5	8.38±0.45	36.44±0.08
'*F*'Value	42.061*	280.09**

*significant at 5 % level; **significant at 1 % level; *N*=5

test tubes and stored overnight at 110 °C for the process of evaporation.

WAI and WSI were calculated using following equations:

WAI weight of sediment / weight of dry solids
WSI (Weight of dissolved solids in supernatant x100)/ Weight of dry solids

Cooking properties

Cooking quality of pasta was the most important aspect from the consumer's point of view, including optimal cooking time, swelling or water uptake during cooking, texture of the cooked product, stickiness, aroma and taste. These cooking factors of pasta were related to the gelatinization rates and chemical composition of the pasta used. Cooking time, cooking quality, solid loss and water absorption were studied as per the methods described by American Association of Cereal Chemists (AACC 2000).

Nutrient analysis

The moisture content of the samples was determined by following the method of AOAC (1980). Carbohydrate content was estimated by the difference using the formula: Total Carbohydrates (g) =100 - (weight in grams [protein + fat + water + ash + alcohol] in 100 g of food) (FAO 2003). Energy was determined by the formula: Total Calories (kcal) = (g protein x 4) + (g fat x 9) + (g carbs x 4) (FAO 2003). The crude protein content was estimated by Microkjeldhal method AOAC (1990). Fat was determined using soxhlet method of AOAC (1980). The ash and crude fiber content of the sample was estimated by AOAC (1984) method. Amylose content of starch samples were determined by using the method of Williams et al. (1970) with optical density measurement at 620 nm.

Sensory evaluation

Sensory evaluation was carried out by fifteen semi-trained judges using a 5-point Hedonic rating scale (Amerine et al. 1965) for sensory attributes like color, appearance, flavor, taste, texture, firmness, bulkiness, stickiness and overall acceptability.

Statistical analysis

The data was subjected to statistical analysis. Descriptive statistics like mean and standard deviation were computed. One way analysis of variance (ANOVA) was used to know the mean differences between the different treatments.

Results and discussion

Physical characteristics

The mean physical parameters of different extrudates are given in Table 2. The length of the extrudates was significantly lower ($p<0.01$) in sorghum than that of extrudates of sorghum with different combinations. Similarly maximum bulk density was seen in T1, followed by T2, T3, T4 and T5. Bulk density is a very important parameter in the production of expanded and formed food products. It was ranged from 0.45 to 0.36 g, where it was to be found minimum for extruded Sample - T5 (0.36 g) followed by extruded Sample - T4 (0.41), while maximum bulk density was found for extruded Sample - T1 (0.45 g) followed by extruded Sample - T2. The higher bulk density may be due to the presence of high fiber in the blends. More crude fiber in the composite blend samples resulted in higher bulk density (Sawant et al. 2013).

Table 4 Cooking properties of extrudates

Sample	Cooking time (min)	Cooked weight (g/100 g)	Amount of water absorbed (g/100 g)	Solid loss (g/100 g)
T1	6.0±0.53	17.75±0.20	180.48±5.12	7.41±0.52
T2	7.0±0.12	16.25±0.36	199.74±7.15	8.24±0.43
T3	6.0±0.22	16.75±0.23	177.56±4.40	9.36±0.26
T4	8.0±0.29	15.75±0.12	120.35±6.22	8.25±0.22
T5 '*F*' value	9.0±0.40 67.52*	18.25±0.43 63.71*	86.20±3.50 348.01*	10.12±0.14 55.73*

**significant at 1 % level; *N*=5

Table 5 Nutritional composition of extrudates

Sample	Moisture (%)	Protein (g)	Fat (g)	Fiber (mg)	Amylose (%)	CHO (g)	Energy (kcal)
T1	8.25	9.7	0.44	0.90	13.78	74.2	348.4
T2	8.32	9.5	0.73	0.76	13.98	72.5	348.1
T3	9.20	9.3	0.70	0.77	15.33	71.5	347.8
T4	9.41	9.0	0.82	0.77	16.59	71.3	347.5
T5	10.02	9.6	0.84	1.02	18.48	74.7	349.0

N=2

Water Absorption Index (WAI) and Water Solubility Index (WSI)

WAI, an indicator of the ability of extrudates to absorb water, depends on the availability of hydrophilic groups which bind water molecules and on the gel-forming capacity of macromolecules. WSI is used as a measure for starch degradation. The water absorption index was found to be higher for extruded sample - T5 (36.44±0.08) followed by extruded sample - T4 (38.79±0.03). WAI was increased with an increase in sorghum semolina in the blend. The water solubility index was lower for the extrudates, T1 (11.28±0.12) was followed by T2 (9.43±0.01), T3 (9.32±0.52), T4 (8.50±0.56) and T5 (8.38±0.45). WSI of the extrudates was increased with an increase in wheat semolina in the blend (Table 3). The difference in WAI and WSI may be due to the hydrophilic polysaccharides present in their respective flour (Oninawo and Asugo 2004).

Cooking quality

The cooking quality parameters assessed for sorghum pasta were cooking time, cooked weight, amount of water absorbed and solid loss in gruel as shown in the Table 4. The cooking time of different blends was ranged from 6 to 9 min, with significantly ($p<0.05$) high cooking time was observed in T5 (9 min) and lowest cooking time in T1 (6 min). The difference in cooking time could be attributed to the difference in the gelatinization temperature of respective starch or blend of starches. The cooked weight of the pasta samples varied from 16.25 to 18.25 g, with significantly ($p<0.05$) high cooked weight in T5 sorghum than other blends. The amount of water absorption by pasta extrudates indicates the degree of hydration, which may affect the eating quality. The amount of water absorbed by the extrudates was in the range of 86.20 to 180.48/100 g, showing significantly ($p<0.05$) highest amount of water absorption in T5 than other blends. Cooking loss indicates the ability of the pasta to maintain structural integrity during the cooking process. High cooking loss is undesirable because it represents high solubility of starch, resulting in turbid cooking water; low cooking tolerance and sticky mouth feel (Jin et al. 1994). The solid gruel loss was observed in the range of 7.41 to 10.12/100 g and it was the highest for T5 and lowest for T1, with the difference between them being significant, statistically ($p<0.05$). With an increase in cooking time, the amylose networks are degraded in sorghum pasta blends, increasing the cooking losses. The values of cooking loss in almost all samples of pasta were <10/100 g solid loss during cooking.

Nutrient analysis

The results are tabulated in Table 5. The moisture level was the highest in (T5), followed by T4, T3, T2, and T1 extrudates. However, optimum moisture level was seen (<14 %) in all the extrudates. The protein content was highest in T1, followed by T2, T3 and T4 which could be due to addition of wheat as it has more amount of protein than sorghum as reported by Gopalan et al. (2004). The fat and fibre content was highest in T4 and T5 extrudates than the other formulated extrudates. Foods that are rich in fiber slows down the absorption of sugar, which results in lowering of bad cholesterol and improving blood sugar levels in diabetes and may also protect against cancer (Augustin et al. 2001; Satya et al. 2011). The amylose content was highest in T5, followed by T4, T3, T2

Table 6 Sensory characteristics of the extrudates

	T1	T2	T3	T4	T5	*F* value
Color	4.5±0.07	4.4±0.14	4.0±0.07	4.0±0.14	4.4±0.28	21.9**
Flavor	4.4±0.07	4.2±0.07	4.1±0.07	4.2±0.14	4.2±0.14	14.8**
Texture	4.3±0.14	4.2±0.07	4.0±0.07	3.8±0.21	3.0±0.35	38.68**
Taste	4.5±0.07	4.4±0.14	4.2±0.14	4.2±0.14	4.2±0.07	9.63*
Stickiness	3.5±0.14	3.5±0.14	3.8±0.42	4.2±0.21	4.2±0.07	15.8**
Firmness	4.4±0.07	4.2±0.14	4.3±0.07	4.2±0.14	4.2±0.14	25.2**
Bulkiness	4.5±0.07	4.2±0.14	4.2±0.14	4.0±0.35	4.4±0.21	33.6**
Overall acceptability	4.5±0.07	4.2±0.07	4.0±0.07	3.8±0.21	4.0±0.21	16.6**

N=15

*significant at 5 % level

** Significant at 1 % level

and T1. Human studies have shown that consumption of diets containing high amylose starch modulates glycaemic response (Behall et al. 1989; Hoebler et al. 1999). Leeman et al. (2008) suggested that amylose is prone to react with lipids to form amylose-lipid complexes thus reduces the rate of amylolysis and results in lower glycemic responses and GI values. In a recent study by Prasad et al. (2014) sorghum pasta has shown low GI than wheat based pasta. To control diabetes and related diseases consideration of foods which are high in amylose are also important. The carbohydrate content of blends ranged from 71.3 to 74.7/100 g. The energy value of all products was similar ranging from 348 to 349 Kcal. The millet and cereal based extrudates meets the nutritional requirements indiscriminate of age i.e. providing 300 Kcal and nearly 10 g protein/100 g.

Sensory characteristics

Sorghum pasta prepared from different combinations of sorghum and wheat semolina was evaluated for the color, taste, texture, bulkiness, firmness, stickiness, and overall acceptability by sensory evaluation (Table 6). The mean scores of sensory evaluation showed that all the extrudates prepared from different blends were within the acceptable range, while the extruded product prepared from the blend -T1 had significantly ($p<0.01$) scored higher for colour, texture, flavour taste and overall acceptability than other samples. Transparency is also used an indicator in assessing the quality of pasta (Jane et al. 1996). The pasta prepared from T1 blend (S+W:50:50) scored significantly highest than the other blends for transparency ($p<0.05$), followed by T, T3, T4 and T5. Firmness may be defined as the extent to which the product slides across the tongue. Desirable firmness is required to increase the acceptability of pasta and it should be neither too firm nor too soft (Galvez and Resurreccion 1992). Pasta prepared from the blend, T1 was more acceptable with regard to firmness as compared to other blends. The firmness and bulkiness were decreased and stickiness was increased from T1-T5. The pasta prepared from high amylose starch is known to be too firm (Toyokawa et al. 1989). Therefore, an optimum amylose/ amylopectin ratio is desirable for good quality pasta. The pasta quality can be influenced by the characteristics of flour; wheat has a unique property of forming an extensible, elastic and cohesive mass when mixed with water due to its gluten content, as sorghum and millets lack these properties when used alone. These might have influenced higher scores in T1 than other samples. The sorghum pasta formulation produced with T2 and T3 were near to that of the pasta produced from T1 with the exception of the color attribute due to inherited color component of sorghum. From the overall acceptability rating, it can be concluded that the sorghum pasta enriched with 50, 40, 30 %, wheat semolina of 0.1 mm semolina had better acceptance than 20 %.

Conclusion

The results of the study showed that acceptable ready to cook foods of good quality can be developed with extrusion technology by utilizing sorghum and wheat semolina. The composite blends T1, T2 and T3 showed desirable qualities such as high bulk density, WAI, protein, fibre, amylose, low moisture content, solid loss and WSI and acceptable sensory properties that are suitable for commercialization and marketing.

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