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Development and standardisation of iron rich sorghum based cereal bars and their nutrient composition

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Abstract
Utilization of sorghum alone and in combination with other cereals, legumes, oilseeds etc in development of value added foods may result in their wide spread utilization among non-traditional sorghum consumers. This will also result in improving status of sorghum among cereals in economic upliftment of millet producers and will contribute for the health of the population. Increasing demands from consumers for nutritious snacks providing healthy nutrition and to enhance the utilization of sorghum in daily diets of people, it is desirable to develop novel and value added products from sorghum. Keeping these facts in considerations, present study was planned with the specific objectives to develop iron rich sorghum based cereal bars and to study their and nutrient composition. Results of study showed that the moisture content of sorghum based iron rich cereal bars having sorghum varieties HC 308 and HJ 513 was found to be 9 9.74-9.80 percent, these were slightly higher when compared to 8.33 percent of moisture in wheat control cereal bars. Crude protein content of iron rich cereal bars prepared with HJ 513 and HC-308 was 21.35 and 19.47 per cent, respectively. Crude protein content of wheat control cereal bars (16.28%) was low as compared to all types of sorghum based cereal bars. Iron content of wheat control cereal bar was 6.62 mg/100g which was lower than sorghum based iron rich cereal bars. Availability of iron too showed the similar trend and noticed 19.57 and 19.68 per cent in sorghum based iron rich cereals bars having HC 308 and HJ 513, respectively. They are ready to eat nutritious snacks no mess while eating too, ideal for all age groups, easily transportable and have good shelf life. Hence, it is recommended that sorghum based cereal bars may be included in the supplementary nutrition programme like ICDS and Mid-Day Meal programme for alleviating protein energy malnutrition among malnourished children. Diverse and delicious sorghum based cereal bars will pave the way for entrepreneurship development too and this will indirectly trigger positive inspiration among sorghum growers.

Keywords: sorghum, iron rich cereal bars, nutrient composition

Introduction
Sorghum is the fifth most important cereal crop in the world after rice, wheat, corn and barley. It is the main cereal food for over 750 million people living in semi-arid tropical regions of Africa, Asia and Latin America. It is one of the major cereal crops produced and consumed after rice (*Oryza sativa*) and wheat (*Triticum aestivum*). Sorghum grains are used by these people (especially farmers), who often do not have the means to feed themselves with food sources of energy, rich in protein, vitamins, minerals. Sorghum grains are rich in energy and non-energy nutrients (Ramatoulaye *et al.* 2016) [3]. Sorghum commonly is eaten with the hull (the outer layer of the grain), which retains the majority of the nutrients. Sorghum has excellent chemical and physical properties, which make it a grain of good quality for processing different types of products. The nutrient composition of sorghum grain indicates that it is a good source of carbohydrates, fibre, protein, vitamins and minerals. Sorghum contains about 70 per cent starch, so is a good energy source. Its starch consists of 70 to 80 per cent amylopectin, a branched-chain polymer of glucose, and 20 to 30 per cent amylose, a straight-chain polymer.

It is a gluten-free, high protein and cholesterol-free source of a variety of essential nutrients i.e. iron, zinc, manganese and copper. Sorghum has the potential for high levels of iron (more than 70 ppm) and zinc (more than 50 ppm) in the grain. It is rich in B-complex vitamins like thiamine, riboflavin, niacin, pantothenate, and vitamin B_6 which play key role in energy metabolism. Sorghum's high-energy content and ready supply of B-complex vitamins are a perfect combination for energy utilization.

Depending upon the variety, sorghum provides good to excellent sources of phytochemicals such as phenolic acids, anthocyanins, phytosterols and policosanols etc. and antioxidants which are believed to help lower the risk of cancer, diabetes, heart disease and some

neurological diseases. The wax surrounding the sorghum grain contains compounds, policosanols that may have an impact on human cardiac health.

As with other foodstuffs, certain nutritional inhibitors and toxic substances are associated with sorghum grains as well which lower its nutritional value. The antinutritional effect of tannin and phytate in sorghum has been demonstrated by many researchers. The tannin-protein interaction in sorghum involves hydrogen bonding and hydrophobic interactions. Sorghum prolamins (proline-rich proteins) bind strongly to sorghum tannins and these results in reduced protein digestibility (Abdelhaleem *et al*., 2008). Like all grain species, sorghum contains phytic acid which binds minerals and reduces their availability to the consumer. However, these antinutrients could be eliminated or reduced by processes such as soaking, dehulling, popping, germination and fermentation involved in processing of sorghum during product development (Ugwu and Oranye, 2006) [4]. During the value addition and application of suitable processing methods, the utilization of sorghum, being a cheap protein and mineral source, can be greatly enhanced.

Eaten in a variety of forms depending on the region, sorghum may be consumed as whole grain, flat bread, (unleavened and prepared from fermented or unfermented dough), deep fried preparations, popped as a snack or boiled into porridge, processed into flour for baking, or fermented to produce beer or other baked goods. Sorghum can be puffed, popped, shredded and flaked to produce ready-to-eat breakfast cereals. As, sorghum is genetically more closely related to maize than it is to wheat, rye or barley, hence value added products prepared from it can be considered a safe food for patients with celiac disease (Ciacci *et al*., 2007) [2].

It is quite evident that the utilization of sorghum alone and in combination with other cereals, legumes, oilseeds etc in development of value added foods may result in their wide spread utilization among non-traditional sorghum consumers. This will also result in improving status of sorghum among cereals in economic upliftment of millet producers and will contribute for the health of the population. Since sorghum is drought resistant food security crop, there is great potential for its increased production in our country and hence, diversification of its utilization is highly desired.

Increasing demands from consumers for nutritious snacks providing healthy nutrition and to enhance the utilization of sorghum in daily diets of people, it is desirable to develop novel and value added products from sorghum. Keeping these facts in considerations, present study was planned with the following specific objectives to develop iron rich sorghum based cereal bars and to study their nutrient composition.

Materials and Methods

Procurement of raw material

The locally available varieties of sorghum *i.e* HC 308 and HJ 513 were procured from the Department of Genetics and Plant Breeding, CCSHAU, Hisar. Wheat (C-306), peanut butter, sugar was procured from local market in a single lot. Other ingredients viz. cocoa butter, cocoa powder, corn syrup and glucose syrup were procured from a local market of Chandigarh in a single lot. The grains of sorghum and wheat were cleaned and made free of dust, dirt and foreign material and stored in air tight containers. Other ingredients were cleaned and stored in hygienic conditions till further use. Sorghum and wheat grains were ground in junior mill to pass through 60 mesh sieve size to obtain fine flour for further analysis.

Standardization and development of bars

Three types viz iron rich bars from two different varieties of sorghum HC308 and HJ 513 were standardize and developed as per the methods given below.

Iron rich sorghum based cereal bars

Three different types of iron rich cereal bars (I, II, III) proportions of sorghum (30, 40 and 50%) were prepared from two different varieties of sorghum *viz* HC 308 and HJ 513 each using ingredient as given in Table 1.

Table 1: Ingredients used for making iron rich cereal bars

Ingredients	Iron rich sorghum based cereal bars (amount)		
	I	II	III
Sorghum flour (g)	30	40	50
Peanut butter (g)	25	25	25
Coca butter (g)	5	5	5
Cocoa powder (g)	8	6	4
Binder* (g)	8	6	4
Rice flakes (g)	8	6	4
Coconut meal (g)	8	6	4
Amaranth seeds (g)	8	6	4

*****Binder contained sugar (30 g), honey (50 g), corn syrup (10g), glucose syrup (10g) and water (60 ml)

Procedure

1. Sorghum and amaranth seeds were soaked overnight seperately, sun dried and were then popped up using HTST method (240° C for 120 sec.) Popped seeds were powdered coarsely and mixed well.
2. For preparation of binder, 30 g of sugar was dissolved in 60 ml of water. It was filtered through muslin cloth to remove any impurities. Then 50g of honey, 10g of corn syrup and 10g of glucose syrup were added to have thick consistent syrup.
3. Rice flakes were roasted and powdered coarsely.
4. Peanut butter and cocoa butter were put on a flame and they were melted. To it sorghum flour, cocoa powder, binder, amaranth powder, coconut meal, coarsely ground rice flakes were added and mixed well.
5. The mixture was cooled and rolled to a desirable thickness.
6. The mixture was cut into desirable shapes of cereal bars and wrapped in aluminium foil.

Wheat based cereal bars (control): Wheat based cereal bar which served as the control was prepared by using the following ingredients:

Table 2: Ingredients used for making wheat control cereal bars

Ingredients	Amount
Wheat flour (g)	40
Peanut butter (g)	25
Coca butter (g)	5
Cocoa powder (g)	12
Binder (g)	12
Milk Powder (g)	6

*****Binder contained sugar (30g), honey (50g), corn syrup (10g), glucose syrup (10g) and water (60ml)

Procedure

1. Wheat grains (C 306) were ground into fine flour.
2. For preparation of a binder, 30 g of sugar was dissolved in 60 ml of water. It was filtered through muslin cloth to remove any impurities. Then 50g of honey, 10g of corn

syrup and 10g of glucose syrup were added to have thick consistent syrup.
3. Peanut butter and cocoa butter were put on a flame and they were melted. To it milk powder, cocoa powder, binder and wheat flour were added and mixed well.

This mixture was cooled, rolled into desired thickness and was cut into desirable shapes of cereal bars and was wrapped in aluminium foil.

Nutritional composition of sorghum based cereal bar

The most acceptable iron rich cereal bars were analyzed for proximate composition and different parameters using methods.

Results of the Study

Nutritional evaluation of sorghum based iron rich cereal bars

Proximate composition

The moisture contents of sorghum based iron rich cereal bars were 9.63 (HC 308) and 9.77 percent (HJ 513), respectively and did not differ significantly but both had significantly ($p \leq 0.05$) higher moisture content when compared to that of wheat control cereal bar (8.33%). Crude protein content of sorghum based iron rich cereal bars having HC 308, HJ 513 as well as wheat control cereal bar varied significantly ($p \leq 0.05$) among themselves with the crude protein content being the highest in cereal bar having HJ 513 (21.35%) followed by HC 308 (19.47 %) and wheat control cereal bar (16.28).Crude fat contents of sorghum based iron rich cereal bars prepared with HC 308 and HJ 513 17.46 and 17.74 percent, respectively and both were almost similar. However, crude fat content of both the sorghum varieties had significantly ($p \leq 0.05$) higher crude fat content than that of wheat control cereal bar (15.92%).The sorghum based iron rich cereal bars incorporating 40 per cent level of HC 308 and HJ 513 had 6.15 and 6.22 per cent crude fibre content, respectively which did not differ significantly from each other. However, crude fibre contents of both sorghum based iron rich cereal bars was significantly ($p \leq 0.05$) lower than that of wheat control cereal bar (6.42%). Ash content of both the sorghum based iron rich cereal bars i.e. 2.42 (HC 308) and 2.50 per cent (HJ 513) were almost similar and did not differ significantly ($p \leq 0.05$) from that of wheat control cereal bar (2.43 %) too. The wheat control cereal bar had significantly ($p \leq 0.05$) higher amount of carbohydrates (58.95 %) when compared to that of HC 308 (54.50) and HJ 513 (52.19%) of sorghum based iron rich cereal bars. However, varietal differences had no significant effect on the carbohydrate content of sorghum based iron rich cereal bars. Similar superscripts in the column indicate that they do not differ significantly ($p \leq 0.05$)

Energy contents of sorghum based iron rich cereal bars containing HC 308 and HJ 513 were 453.02 and 453.82 Kcal/100g, respectively which did not differ significantly from each other. However, energy content of wheat control cereal bar (444. 2 Kcal/100g) was significantly ($p \leq 0.05$) lower than that of sorghum based iron rich cereal bars developed from both the varieties.

Table 3: Proximate composition of sorghum based iron rich cereal bars (per cent, on dry matter basis)

Proximate nutrients	Sorghum varieties		Wheat (Control)	CD($p \leq 0.05$)
	HC308	HJ513		
Moisture (%)	9.63±0.14 [a]	9.77±0.10 [a]	8.33±0.11 [b]	0.11
Crude protein (%)	19.47±0.13 [b]	21.48±0.10 [a]	16.28±0.12 [c]	2.01
Crude fat (%)	17.46±0.12 [a]	17.74±0.12 [a]	15.92±0.11 [b]	0.56
Crude fibre (%)	6.15±0.09 [a]	6.22±0.11 [a]	6.42±0.07 [b]	0.07
Ash (%)	2.42±0.11 [a]	2.50±0.08 [a]	2.43±0.12 [c]	0.87
Carbohydrate (%)	54.50±0.14 [a]	52.19±0.15 [a]	58.95±0.11 [b]	3.01
Energy (Kcal/100 g)	453.02±1.10 [a]	453.82±0.99 [a]	444.20±1.08 [b]	6.37

Values are mean ±SE of three independent determinations

Total dietary fibre

Total dietary fibre contents of sorghum based iron rich cereal bars prepared with HC 308 (7.83 g/100g), HJ 513 (7.89 g/100g) were almost similar to that of wheat control cereal bars (7.80 g/100g).

Table 4: Dietary fibre contents of sorghum based iron rich cereal bars (g/100g, on dry matter basis)

Dietary fibre constituents	Sorghum varieties		Wheat (Control)	CD($p \leq 0.05$)
	HC308	HJ513		
Total dietary fibre	7.83±0.10 [a]	7.89±0.09 [a]	7.80±0.16 [a]	0.98
Soluble dietary fibre	1.26±0.07 [c]	1.37±0.09 [b]	1.73±0.10 [a]	0.02
Insoluble dietary fibre	6.57±0.18 [a]	6.52±0.03 [a]	6.07±0.05 [b]	0.04

Values are mean ±SE of three independent determinations

Similar superscripts in the column indicate that they do not differ significantly ($p \leq 0.05$)

The soluble dietary fibre contents of sorghum based iron rich cereal bars having HC 308 (1.26g/100g), HJ 513(1.37g/100g) and wheat control cereal bar (1.73 g/100g) differed significantly ($p \leq 0.05$) from each other. Insoluble dietary fibre contents of cereal bars containing HC 308 (6.57 g/100g) and HJ 513 (6.52 g/100g) did not differ significantly ($p \leq 0.05$) from each other but both of the sorghum based iron rich cereal bars had significantly ($p \leq 0.05$) higher insoluble dietary fibre contents than the wheat control cereal bar (6.07g/100g).

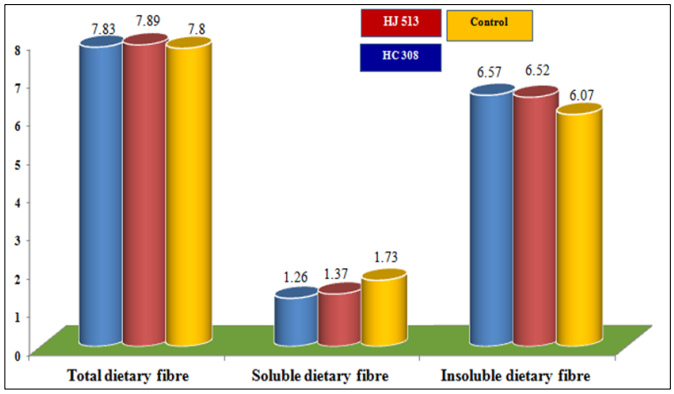

Fig 1: Dietary fibre contents of sorghum based iron rich cereal bars (g/100g, on dry matter basis)

Total and available mineral contents of sorghum based iron rich cereal bars

Varietal differences had no effect on the total calcium contents of sorghum based iron rich cereal bars. But both of the sorghum based iron rich cereal bars had significantly ($p \leq 0.05$) lower amount of total calcium content when compared to that of wheat control cereal bar. The available calcium of sorghum based iron rich cereal bars developed from HC 308 (34.68%) and HJ 513 (34.62 %) did not differ significantly from each other and both of them had significantly ($p \leq 0.05$) higher available calcium than that of wheat control cereal bar (32.59%). Both the sorghum based HC 308 and HJ 513 iron rich cereal bars had similar total iron content 10.37 and 10.67mg/100g, respectively but had significantly ($p \leq 0.05$) higher iron contents than that of wheat control cereal bar (6.62mg/100g).

Table 5: Total minerals (mg/100g) and available minerals (%) content of sorghum based iron rich cereal bars (on dry matter basis)

Minerals	Sorghum varieties		Wheat (Control)	CD(P ≤0.05)
	HC308	HJ513		
Total calcium	70.68±1.57 [c]	74.08±4.5 [b]	78.58±1.28 [a]	0.40
Available calcium	34.68±0.94 [a]	34.62±0.88 [a]	32.59±0.97 [b]	0.18
Total iron	10.37±0.15 [a]	10.67±0.08 [a]	6.62±0.11 [b]	0.45
Available iron	19.57±0.14 [a]	19.68±0.22 [a]	14.08±0.08 [b]	1.01
Total zinc	2.78±0.05 [a]	2.81±0.05 [a]	3.36±0.11 [b]	0.32

Values are mean ±SE of three independent determinations
Similar superscripts in the column indicate that they do not differ significantly ($p \leq 0.05$)

Availability of iron too showed the similar trend i.e. available iron contents from both sorghum based iron rich cereal bars were almost similar but they had significantly ($p \leq 0.05$) higher available iron when compared to that of wheat control cereal bar (14.08 %).

Zinc content of sorghum based iron rich cereal bars developed from HC 308 (2.78 mg/100g) and HJ 513 (2.81 mg/100g) did not differ significantly ($p \leq 0.05$) from each other but had lower zinc content in comparison to wheat control cereal bar (3.36 mg/100g).

Conclusion

The moisture content of sorghum based iron rich cereal bars having sorghum varieties HC 308 and HJ 513 was found to be 99.74 - 9.80 percent, these were slightly higher when compared to 8.33 percent of moisture in wheat control cereal bars. Crude protein content of iron rich cereal bars prepared with HJ 513 and HC-308 was 21.35 and 19.47 per cent, respectively. Crude protein content of wheat control cereal bars (16.28%) was low as compared to all types of sorghum based cereal bars.

Crude fat content of sorghum based iron rich cereal bars prepared with HC 308 and HJ 513 was found to be 17.46 and 17.74 percent, respectively; these values were higher than that of wheat control bars (15.92%). Crude fibre content of sorghum based iron rich cereal bars from HC 308 and HJ 513 was 6.15 and 6.22 per cent, respectively; these contents were higher than that of wheat control cereal bars (6.42%). Carbohydrate content of control cereal bars (58.95 %) was higher than 54.50 and 52.19 percent (sorghum based iron rich cereal bars) having flour of HC 308 and HJ 513, respectively. Energy content of sorghum based iron rich cereal bars having HC 308 and HJ 513 was 453.02 and 453.82 Kcal/100g, respectively. Total dietary fibre contents of sorghum based iron rich cereal bars (7.83-7.89g/100g) were comparable to that of control cereal bars (7.80 g/100g). Iron content of wheat control cereal bar was 6.62 mg/100g which was lower than sorghum based iron rich cereal bars. Availability of iron too showed the similar trend and noticed 19.57 and 19.68 per cent in sorghum based iron rich cereals bars having HC 308 and HJ 513, respectively.

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