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Development and Standardisation of Protein Rich Sorghum Based Cereal Bars

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A B S T R A C T

Sorghum [*Sorghum bicolor* (L). Moench] is the crop for human and animal consumption. Sorghum is produced in areas that are too hot, a minimum average temperature of 25°C is necessary to ensure maximum grain production. Sorghum [*Sorghum bicolor* (L). Moench] is the crop for human and animal consumption. 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. Sorghum (HC 308 and HJ 513) based protein rich cereal bars were not only nutritious but had added advantage of good amount of dietary fibre and high total polyphenols which are known to possess antioxidant properties. Moreover, 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.

Introduction

Sorghum is produced in areas that are too hot, a minimum average temperature of 25°C is necessary to ensure maximum grain production. The morphological characteristics of the culture make it one of the currently cultivated cereals that have the best drought tolerance. During the drought, it rolls its leaves to reduce water loss due to perspiration. If the drought continues, it becomes dormant instead of dying. The leaves are protected by a waxy cuticle to reduce evapo-transpiration. 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). 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).

Nutritionally sorghum was found to possess 13 per cent protein, high amounts of zinc, iron, and dietary fibre, with an additional benefit of presence of significantly high total polyphenols content, which are known to possess antioxidant properties (Anonymous. 2011; Hemalatha *et al.,* 2012). The usage of the product has to be increased by producing novel health food in the form of cereal snack bar as per today's consumer demands.

Sorghum is one of the crops grown in many countries primarily as food crop with less than 5percent of the annual production commercially processed by the industry. Sorghum grain ranks third among the domesticated cereals for human consumption and is a staple food in many African countries, India.

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 objective

To develop protein rich sorghum based cereal bars and to study their proximate composition and nutrient composition of bars.

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, almonds, gingelly seeds, oat flakes, defatted soy flour, water melon seeds, roasted bengal gram, coconut meal, rice flakes and amaranth seeds were 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

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

Protein rich sorghum based cereal bars

Three different types of protein 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 below in Table 1.

Procedure

Sorghum grains were soaked overnight, sun dried and were then popped up using HTST method (240° C for 120 sec.) Popped sorghum grains were powdered coarsely.

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.

Roasted bengal gram and watermelon seeds were powdered coarsely separately.

Peanut butter and cocoa butter were put on a flame and they were melted. To it sorghum flour, cocoa powder, binder and powdered watermelon seeds, bengal gram and defatted soya flour were added and mixed well.

The mixture was cooled and was rolled to a desirable thickness.

This mixture was cut into desirable shapes of cereal bars and was wrapped in aluminium foil.

Nutritional composition of sorghum based cereal bar

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

Results and Discussion

Nutritional evaluation of sorghum based protein rich cereal bars

Proximate composition

The moisture content of sorghum based (40%) protein rich bars was found to be 9.74 percent (HC 308) and 9.80 percent (HJ 513) which did not differ significantly but both had significantly ($p \leq 0.05$) higher moisture content when compared to that of wheat control cereal bars (8.33%).Varietal differences had significant effect on crude protein contents of Type-II sorghum based protein rich cereal bars with the crude protein content being the highest in cereal bar having HJ 513 (25.97%) followed by that having HC 308 (24.69%). The wheat control cereal bar had significantly ($p \leq 0.05$) the lowest amount of crude protein content (16.28%) (Table 2).

Crude fat contents of Type-II (40%) sorghum based protein rich cereal bars incorporating HC 308 and HJ 513 were found to be 20.34 and 20.62 percent, respectively which was almost similar. However, crude fat contents of both the Type-II sorghum based protein rich cereal bars was significantly ($p \leq 0.05$) higher than that of wheat control cereal bar (15.92 %).

Crude fibre and ash contents of Type –II (40%) sorghum based protein rich cereal bars having HC 308 and HJ 513 was found to be 9.62, 2.73; and 9.69, 2.80 per cent, respectively which did not differ significantly from each other. Both of these cereal bars had significantly ($p \leq 0.05$) higher crude fibre contents than that of wheat control cereal bars (6.42%).

Carbohydrate content of wheat control cereal bar (58.95 %) was found to be significantly ($p \leq 0.05$) higher than that of Type-II of sorghum based protein rich cereal bars having HC 308 (43.22%) and HJ 513 (40.92%). Varietal differences in sorghum did not significantly affect the carbohydrate and energy contents sorghum based protein rich cereal bars. Energy contents of sorghum based protein rich cereal bars were almost similar i.e. 452.30 Kcal/100g (HC 308) and 453.34Kcal/100g (HJ 513); however, both of them had significantly ($p \leq 0.05$) higher amount of energy content when compared to that of wheat control cereal bar (444. 20Kcal/100g).

Total dietary fibre

Both of the sorghum based protein rich cereal bars (Table 3) had almost similar total dietary fibre contents (9.07 - 9.11 g/100g) but significantly higher than that of wheat control cereal bar (7.80 g/100gm).

The soluble dietary fibre contents of sorghum based protein rich cereal bars developed with 40 per cent of HC 308 (1.50g/100g) and HJ 513(1.61g/100g) were almost similar to each other as well as to that of wheat control cereal bar (1.73 g/100g). Similar varietal differences did not significantly affect the insoluble dietary fibre contents as they had 7.46 to 7.60g of insoluble dietary fibre per 100g in sorghum based protein cereal bars but both of them had significantly ($p \leq 0.05$) higher insoluble dietary fibre contents than that of wheat control cereal bars (6.07g/100g).

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

Calcium content of Type-II sorghum based protein rich cereal bars having 40 percent of HC 308 (78.27 mg/100g) and HJ 513 (79.03mg/100g) and wheat control cereal bar (78.58mg/100g) did not differ significantly among themselves (Table 4).

Table.1 Ingredients used for making protein rich cereal bars

Ingredients	Protein 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
Defatted soya flour (g)	8	6	4
Roasted bengal gram (g)	8	6	4
Water melon seeds (g)	8	6	4

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

Table.2 Proximate composition of sorghum based protein rich cereal bars (per cent, on dry matter basis)

Proximate nutrients	Sorghum varieties		Wheat (control)	CD($p \leq 0.05$)
	HC308	HJ513		
Moisture (%)	9.74±0.11 a	9.80±0.12 a	8.33±0.11 b	0.07
Crude Protein (%)	24.09±0.11 a	25.97±0.14 b	16.28±0.12c	1.21
Crude Fat (%)	20.34±0.10 a	20.62±0.06 a	15.92±0.11 b	0.13
Crude Fibre (%)	9.62±0.09 a	9.69±0.11 a	6.42±0.07 b	1.07
Ash (%)	2.73±0.10 a	2.80±0.09 a	2.43±0.12 b	0.11
Carbohydrate (%)	43.22±0.12 a	40.92±0.29 a	58.95±0.11 b	6.12
Energy (Kcal/100g)	452.30±0.15 a	453.34±0.08 a	444.20±1.08b	7.03

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

Table.3 Dietary fibre contents of sorghum based protein 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	9.11±0.11 a	9.07±0.11 a	7.80±0.16 b	0.02
Soluble dietary fibre	1.50±0.14 a	1.61±0.11 a	1.73±0.10 a	0.48
Insoluble dietary fibre	7.60±0.03 a	7.46±0.03 a	6.07±0.05 b	0.14

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

Table.4 Total minerals (mg/100g) and available mineral (%) contents of sorghum based protein rich cereal bars (on dry matter basis)

Minerals	Sorghum varieties		Wheat (control)	CD(p ≤0.05)
	HC308	HJ513		
Total calcium	78.27±2.12 a	79.03±3.28 a	78.58±1.28 a	1.32
Available calcium	34.40±1.22 a	34.53±1.01 a	32.59±0.97 b	0.52
Total iron	6.29±0.09 a	6.83±0.04 a	6.62±0.11 a	0.15
Available iron	15.02±0.21 a	15.21±0.15 a	14.08±0.08 b	0.69
Total zinc	3.63±0.10 a	3.73±0.09 a	3.36±0.11 a	1.01

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

Table.5 Phytic acid (mg/100g) and polyphenol contents (mg/100g) of sorghum based protein rich cereal bars (on dry matter basis)

Parameters		Sorghum varieties		Wheat (control)	CD (p≤0.05)
		HC 308	HJ 513		
Antinutrient content	Phytic Acid	465.59±13.51 a	469.67±13.39 a	593.59±13.20 b	**15.07**
	Polyphenols	**578.58±15.83 a**	**579.50±23.43 a**	**686.79±23.18 b**	**1.32**

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

Table.6 *In vitro* protein (%) and starch (mg maltose released/g meal) digestibility of sorghum based protein rich cereal bars (on dry matter basis)

Parameters		Sorghum varieties		Wheat (control)	CD (p≤0.05)
		HC 308	HJ 513		
IVD	Protein	68.10±0.10 a	67.90±0.07 a	61.09±0.55 b	**5.13**
	Starch	**45.55±0.75 a**	**44.38±0.61 a**	**40.58±0.50 b**	**1.17**

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

Table.7 Total phenolic content (mg GAE/g) and DPPH free radical scavenging activity (%) of sorghum based protein rich cereal bars (on dry matter basis)

Antioxidants	Sorghum varieties		Wheat (Control)	CD(p ≤0.05)
	HC308	HJ513		
Total Phenolic content	6.69±2.34 a	7.09±2.26 a	7.15±1.67 a	1.12
DPPH free radical scavenging Activity	126.75±2.48 b	127.26±2.69 b	180.46±2.69 a	10.17

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

However, availability of calcium was significantly higher (p≤ 0.05) in both the sorghum based protein rich cereal bars containing 40 percent of HC 308 (34.40%) and HJ 513 (34.53%) than the wheat control cereal bar (32.59%). Varietal differences did not change the calcium availability of sorghum based protein rich cereal bars.

Total iron and zinc contents of sorghum based protein rich cereal bars having HC 308, HJ 513 and wheat control cereal bar were found to be 6.29, 3.63; 6.83, 3.73; and 6.62, 3.36 mg/100g, respectively which did not differ significantly when compared to each other.

Availability of iron was similar in both the type of sorghum based protein rich cereal bars prepared from HC 308 (15.02%) and HJ 513 (15.21%); both of sorghum based protein rich cereal bars had similar iron availability as to that of wheat control cereal bar.

Antinutrients

Phytic acid contents of protein rich cereal bars (Table 5) having 40 per cent of sorghum i.e. HC308 (465.59mg/100g) and HJ 513 (469.67 mg/100g) were almost similar and both of them had significantly (p≤ 0.05) lower amount of phytic acid than that of wheat control cereal bar (593.59 mg/100g).

Varietal differences had no effect on the polyphenol contents of sorghum based protein rich cereal bars as they had 578.58 (HC 308) and 579.50 (HJ 513) mg polyphenol per 100g. The wheat control cereal bar had significantly (p ≤0.05) higher amount of polyphenols i.e. 686.79 mg/100g when compared to those of sorghum based protein rich cereal bars.

In vitro digestibility

In vitro protein digestibilities of Type-II sorghum based protein rich cereal bars developed from HC 308 and HJ 513 were found to be 68.10 and 67.90 percent, respectively, which varied non-significantly from each other but showed significant (p≤ 0.05) difference when compared to that of wheat control cereal bar (61.09%).

In-vitro starch digestibility of Type-II sorghum based protein rich cereal bars incorporating HC 308 (45.55 mg maltose released/g) and HJ 513 (44.38 mg maltose released/g) was almost similar. However, both types of sorghum based protein rich cereal bars had significantly (p≤ 0.05) higher starch digestibility (in-vitro) than that of wheat control cereal bar (40.58 mg maltose released/g).

Antioxidant activity of sorghum based protein rich bars

Total phenolic content of sorghum based protein rich cereal bars prepared from HC 308 (6.69 mg GAE/g), HJ 513 (7.09 mg GAE/gm) and wheat control cereal bar was (7.15 mg GAE/gm) which did not differ significantly and had almost similar total phenolic content. Protein bars prepared with HC 308 (126.75 %) and HJ 513 (127.26 %) varied non-significantly from each other. However, the wheat control cereal bars had significantly higher i.e. 180.46 percent of DPPH free radical scavenging activity in comparison to sorghum based protein rich cereal bars.

Therefore, it is concluded that all the types of sorghum (HC 308 and HJ 513) based protein rich cereal bars were not only nutritious but had added advantage of good amount of dietary fibre and high total polyphenols which are known to possess antioxidant properties. Moreover, 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.

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