Development of gluten-free cereal bar for gluten intolerant population by using quinoa as major ingredient

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Abstract The present study was carried out to develop gluten free cereal bars for gluten intolerant population. The cereal bar was formulated using dry raw materials (quinoa, brown rice, flaxseed and dry fruits) and binding agents (honey). Honey was added as a sweetener and binding agent. The raw materials were assessed for physico-chemical parameters such as moisture, ash, crude protein and fat content and the functional parameters such as antioxidant activity, total phenolic content and β -carotene. Dry heat treatment (80–100 °C for 8–12 min) was given to grains (quinoa, brown rice and flaxseed) prior to use in preparation of cereal bar. Significant variation was found after treatment of grains among all the physico-chemical and functional parameters of grains except ash content which showed a non-significant variation. Four formulations (F1, F2, F3 and F4) were developed using different combination of grains at different honey levels (40, 50 and 60%). On the basis of sensory evaluation, formulation- 4 at 50% honey level was found to be best. Selected cereal bar was assessed for physico-chemical and functional parameters. Selected cereal bar had 8.53% moisture content, 1.34% ash content, 10.50% protein content, 2.89% fat content, 0.51 mg GAE/g total phenolic content, 33.87% antioxidant activity and 0.384 μ g/g β -carotene.

Keywords Quinoa · Brown rice · Flaxseed · Cereal bar · Heat treatment

Introduction

Celiac disease (CD) is a genetically linked autoimmune disorder that's triggered by consuming protein gluten, which is present in several cereals like wheat, rye, barley. When people with celiac disease eat foods containing gluten, their immune system responds by damaging the finger-like villi of the small intestine, resulting in malabsorption of nutrients due to an immunological reaction to gluten. Gluten-free diet is only lifelong treatment for celiac patients. So quinoa, amaranth, arrowroot, millets and rice are the best option to develop gluten-free diet (Green et al. 2005).

In recent years, food consumption habits and preferences have changed to a great extent. Consumers demand for wholesome, natural and convenient foods. Cereals play an important role in today's lifestyles for their various uses as ready-to-eat products, instant products, cereal bars and energy bars. Cereal bar is chosen as an alternative source of snacks being high in protein, bioactive compounds and is a major supplier of energy to every day. The consumption of cereals bars has been elaborated from the breakfast table to any time of the day and these products have become an integral part of consumer's diet (Dutcosky et al. 2006).

Selected grains like quinoa, rice and flaxseed are combined with nuts and honey to prepare a nutritious healthy bar. As we know, cereals are not good source of protein as they are deficient in lysine whereas quinoa in diet improves overall quality of protein as it is rich in essential fatty acid lysine. Quinoa is marvellous food due to its multi-functional characteristics and nutritional profile. Quinoa is

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ample in minerals and vitamins as a good source of calcium, iron, magnesium, potassium, phosphorus, copper, zinc & B vitamins. It is also pre-eminent for people with lactose intolerance and celiac disease. Similarly, brown rice is highly nutritious, gluten-free and has antioxidants and phytonutrients that boosts the immune system, lowers the cholesterol level and blood pressure, reduces risk of heart diseases and prevents stroke and colon cancer (Vetha varshini et al. 2013). The use of flaxseed in various functional and designer foods as a dietary supplement is growing. Flaxseed contains functional components such as dietary fibre, oil, protein and phenolic compounds, which has valuable effect on health. Flaxseed is rich in polyunsaturated fatty acids (ALA and linoleic acid) which is beneficial in infant brain development and reduces blood lipids and cardiovascular diseases (Gutte et al. 2015). It is also a rich source of lignin which has ability to bind estrogen receptors in the body and acts as anti-carcinogenic agent (Chan et al. 1993). Nuts are also a good source of protein, fibre, vitamins and provide a good taste to food product.

Previous studies found that gluten-free products are deprived sources of minerals, vitamins and fibre; therefore there is necessity to develop the highly nutritious gluten-free products for celiac patients. Lee et al. (2009) studied that the addition of three servings of gluten-free alternative grains, like oats and quinoa, increase the nutritive value of the gluten-free diet. Minor cereals and pseudo-cereals are significant sources of proteins, carbohydrates and fibre and delivered the wide choice of foods for celiac patients.

Therefore, the main objective of this study was to develop a nutritious, gluten-free cereal bar from quinoa, brown rice and flaxseed with honey as a binding agent as well as evaluate the physico-chemical characteristic of raw material and gluten-free bar.

Materials and methods

Materials

Good quality quinoa of Organic India Company, brown rice of Daawat Company, flaxseed, almonds, raisins and dried figs were acquired from local market of Ludhiana. Honey was acquired from Dabur India Ltd. New Delhi. All chemicals used were of analytical reagent grade and procured from reputed companies.

Preparation of material

Quinoa, brown rice and flaxseed were subjected to dry heat treatment at temperature of 85, 100, 80 °C respectively for 8–12 min prior to use in preparation of bar. After this,

quinoa, brown rice, flaxseed and almonds were ground into coarse particles in mortar and pestle. Raisins and dried figs were diced into small pieces with stainless steel knife. The temperature of heat treatment was selected on the basis of trials. Heat treatment improves taste, texture, flavor and color of the grains as well as increases the bioactive component of grains (Mridula et al. 2013).

Preparation of cereal bar

The cereal bar was composed of dry ingredients (quinoa, brown rice, flaxseed & nuts) and binder (honey). Honey was used as a sweetener and binding agent. The binding agent (honey) was poured into the bowl that contained the dry ingredients and the mass was kept under constant stirring until completely mixed. Stainless steel spoon was used for stirring. The mass was poured into non-sticked stainless steel mould having dimension $10 \times 3 \times 1$ cm. Then the bar was heated in oven at 120 °C for 20 min. After heating in the oven, bar was cooled and packed. The four formulations (Table 3) were tried for the preparation of cereal bar. On the basis of sensory scores, final product was selected.

Physico-chemical and functional properties

The bars were evaluated for their physico-chemical parameters, in triplicates ($n = 3$). Moisture, crude fat, crude protein and ash content of raw materials before and after heat treatment and cereal bar were estimated using standard method AACC (2000) and results expressed on wet-matter basis. Total phenolic content and antioxidant activity of raw materials before and after heat treatment and cereal bar were also estimated using standard method reported by Yu et al. (2004) and Liang Yu (2008) respectively. β -carotene was estimated using AOAC (2000) method.

To study the total phenolic content 1 g of the tested samples were dissolved in 50 ml of 80% methanol. After that, refluxed it for 2 h at 30 °C and process was repeated for 2 h. Then extract was collected and make up volume to 100 ml with 80% methanol and then 0.2 ml filtrate was taken and mixed with 5 ml Folin–Ciocalteu reagent. It was kept for 5 min and 4 ml of sodium carbonate was added. Then absorbance was measured at 765 nm. Gallic acid was used as a standard and the results were calculated as mg gallic acid equivalents of the sample (mg GAE/g).

To study the anti-oxidant activity free radical scavenging activity was measured using 1, 1-diphenyl-2-picrylhydrazil (DPPH). 1 ml of refluxed sample was mixed with 1 ml of tris buffer and 2 ml of DPPH and incubated for 30 min in dark at room temperature. Methanol was used as control. The absorbance was measured at 517 nm.

Texture analysis

Textural quality of cereal bar samples was examined for compression (CF) by applying a TA-XT2i Texture analyzer. HDP/BSK blade set, with knife probe, cross head space 0.5 mm/s, distance 15 mm, force 0.05 N was applied to measure compression force required for sample breakage which indicate hardness, cohesiveness, springiness and chewiness (Piga et al. 2005). Hardness is the peak force that occurs during first compression. Cohesiveness is ratio of positive force during the second to that of the first compression cycle (downward strokes only). Springiness (mm) is the ability of sample to recover its original form after the deforming force removed. The work needed to chew a solid sample to a steady state of swallowing (springiness $\times$ hardness $\times$ cohesiveness) is considered as chewiness.

Sensory analysis

Cereal bar was evaluated for different sensory attributes by a group of ten panellists. Sensory attributes like appearance, taste, texture and overall-acceptability for all samples were assessed using nine point hedonic scale and grading 9 for excellent, 5 for moderately liked and 1 for highly disliked sample.

Statistical analysis

Data obtained were analysed using CPCS-1 software. The statistical analyses were conducted using one way ANOVA procedure in triplicates. Statistical difference was tested at $p \leq 0.05$ (Singh et al. 1998).

Results and discussion

Physico-chemical properties of raw materials

The physico-chemical parameters such as moisture, ash, crude protein and fat content of selected raw materials were determined. The results regarding moisture, ash, crude protein and fat content are tabulated in Table 1. From the table it was observed that the physico-chemical analysis varied with the types of raw materials and showed significant difference ($p < 0.05$). The moisture content which plays significant role in determining the shelf life was ranged from 4.91 ± 0.09 to $14.57 \pm 0.06\%$. The dried figs followed by raisins, brown rice, quinoa, flaxseed and almonds showed the highest amount of moisture content. The moisture content of dried figs was $14.57 \pm 0.06\%$ which was in consonance with those obtained by Ghrairi et al. (2013). Similarly $9.90 \pm 0.09\%$ moisture content was

found in brown rice and this result was on par with Islam et al. (2012) who reported the moisture content of brown rice as 9.61%. The percentage moisture of quinoa ($7.25 \pm 0.06\%$) and almonds ($4.91 \pm 0.09\%$) in the current study was also found closely related to those obtained by Miranda et al. (2011) and Barbera et al. (1994) respectively. A wide range of values (1.13 ± 0.11 to $3.93 \pm 0.12\%$) were observed for ash content among the different raw materials, it was found lowest in brown rice ($1.13 \pm 0.11\%$) and highest in almonds ($3.93 \pm 0.12\%$). The ash content obtained was in agreement with the results of Islam et al. (2012) for brown rice and Saura-Calixto et al. (1981) for almonds. Ash is an inorganic residue remaining after water and organic matter have been removed by heating in the presence of oxidizing agent. Apart from this, it is true that the minerals are not destroyed even at very high temperatures and comprises of low volatility as compared to other food components. The ash content in this study was higher for raisins and dried figs than values observed by Ghrairi et al. (2013). The little difference in the ash content could be attributed to the difference in the varieties. The crude protein content of raw material ranged from $2.27 \pm 0.08\%$ to $23.63 \pm 0.09\%$. Flaxseed showed the highest crude protein content ($23.63 \pm 0.09\%$) while raisins showed the lowest value of crude protein content ($2.27 \pm 0.08\%$). The major proteins in flaxseed are albumin and globulin and relatively high in arginine, aspartic acid and glutamic acid (Madusudhan and Singh 1983). Likewise, almonds are also filled with good quality of protein and $20.68 \pm 0.05\%$ of crude protein was found in this study. This finding was similar to Saura-Calixto et al. (1981). Fat content was found higher in almond ($48.33 \pm 0.06\%$) as well as in flaxseed ($32.57 \pm 0.11\%$) as compared to other materials. The results for fat content of raw materials were in conformity with the result of Miranda et al. (2011) and Ghrairi et al. (2013). However, the lowest amount of protein and fat were observed in raisins and dried figs. As we know, fruits are generally low in fats and proteins.

Functional properties of raw materials

Total phenolic content, antioxidant activity and β -carotene content were assessed in the different grains (quinoa, brown rice & flaxseed) and nuts (almonds, raisins & dried figs). The analysis of functional parameters of raw materials is depicted in Table 1. The total phenolic content, antioxidant activity and β -carotene of raw materials were ranged from 1.80 ± 0.06 to 3.80 ± 0.06 mg GAE/g, 48.02 ± 0.09 to $78.23 \pm 0.07\%$, and 0.11 ± 0.09 to 8.52 ± 0.08 $\mu\text{g/g}$ respectively in different materials. Sharma et al. (2012) found 1.9–59.1 $\mu\text{g/g}$ β -carotene of different chenopodium varieties. Similarly, Lamberts and

Table 1 Physico-chemical analysis and functional parameters of raw material

Materials	Moisture content (%)	Ash (%)	Protein (%)	Fat (%)	Total phenolic content (mg GAE/g)	Antioxidant (% inhibition)	β -carotene ($\mu\text{g/g}$)
Quinoa	7.25 ± 0.06	3.13 ± 0.12	12.63 ± 0.07	4.94 ± 0.02	3.00 ± 0.09	56.19 ± 0.10	1.60 ± 0.06
Brown rice	9.90 ± 0.09	1.13 ± 0.11	7.23 ± 0.07	2.06 ± 0.06	1.80 ± 0.06	58.97 ± 0.04	0.11 ± 0.09
Flax seed	5.90 ± 0.06	3.43 ± 0.06	23.63 ± 0.09	32.57 ± 0.11	3.80 ± 0.06	78.23 ± 0.07	8.52 ± 0.08
Almond	4.91 ± 0.09	3.93 ± 0.12	20.68 ± 0.05	48.33 ± 0.06	2.70 ± 0.05	48.02 ± 0.09	0.17 ± 0.07
Raisins	13.6 ± 0.06	2.47 ± 0.06	2.27 ± 0.08	1.32 ± 0.01	1.85 ± 0.06	62.30 ± 0.08	0.32 ± 0.08
Dried figs	14.57 ± 0.06	3.87 ± 0.06	3.93 ± 0.02	1.02 ± 0.01	1.90 ± 0.07	74.10 ± 0.07	0.20 ± 0.05
CD (0.05)	0.17	0.17	0.31	0.22	0.24	0.16	NS

Delcour (2008) obtained 0.066 to 0.150 $\mu\text{g/g}$ β -carotene in brown rice. The phytochemical content of grains is influenced considerably by genetics and agro-climatic factors. Phenolic compounds have antioxidant properties which can lower the risk of cardiovascular diseases in which reactive oxygen species are involved (Harborne and Williams 2000). Flaxseed contained highest concentration of total phenolic content (3.80 ± 0.06 mg GAE/g), Antioxidant activity ($78.23 \pm 0.07\%$) as well as β -carotene (8.52 ± 0.08 $\mu\text{g/g}$) whereas the lowest amount of total phenolic content (1.80 ± 0.06 mg GAE/g) and β -carotene (0.11 ± 0.09 $\mu\text{g/g}$) was found in brown rice. The lowest value of antioxidant activity was observed in almonds ($48.02 \pm 0.09\%$). Our results for total phenolic content and antioxidant activity were in compliance with the Abderahim et al. (2015).

Effect of heat treatment on physico-chemical and functional properties of quinoa, brown rice and flaxseed

Table 2 shows the effect of dry heat treatment on the physico-chemical properties of quinoa, brown rice and flaxseed. From the results, it was apparent, dry heat treatment had a significant impact on the overall quality of grains. Moisture content of grains was assessed to determine stability of the product. Dry heat treatment resulted in reduced moisture content of grains (quinoa, brown rice and flaxseed). This moisture reduction was probably due to dehydration of samples. These findings are consistent with the results obtained by Msheliza et al. (2018) who reported that roasting treatment resulted in decreased moisture content. Statistically significant variation ($p < 0.05$) was found in the mean value for moisture content of quinoa (7.25 ± 0.06 – $2.10 \pm 0.08\%$), brown rice (9.90 ± 0.09 – $2.20 \pm 0.06\%$) and flaxseed (5.90 ± 0.06 – $5.35 \pm 0.08\%$) after treatment. The results for the ash content of the untreated

and treated material showed that no statistically significant difference ($p < 0.05$) was found in ash content after heat treatment as depicted in Table 2. There was no change in ash content of raw material after dry heat treatment and this result perhaps due to fact that low temperature and time combination used for dry heat treatment (80 – 100 $^{\circ}\text{C}$ for 8 – 12 min). The values obtained for crude protein and fat content of treated samples were different from untreated samples for all the grains (quinoa, brown rice & flaxseed). The results of the untreated and treated samples showed significantly ($p < 0.05$) reduction in crude protein and fat content after dry heat treatment. The crude protein content of quinoa was $12.63 \pm 0.07\%$ and it decreased to $12.55 \pm 0.09\%$ after dry heat treatment. Similar results were observed in brown rice and flaxseed. The consequences for decreased crude protein content owing to fact that dry heat treatment had destroyed some of non-protein content and caused denaturation of protein. The fat content was also found to be lower in treated materials (2.01 ± 0.06 – $32.50 \pm 0.07\%$). This result was similar with other study done by Hecimovic et al. (2011). He found that fat content is decreased during dry heat treatment due to the breakdown of some fat content and oxidation of fat.

Dry heat treatment on one hand leads to the formation of maillard reaction products, on the other to the decomposition of bioactive compounds and consequently may change total phenolic content, antioxidant activity and β -carotene. Therefore, it was essential to study the influence of dry heat treatment on the bioactive compounds of quinoa, brown rice and flaxseed. Dry heat treatment considerably affected bioactive compounds of grains. So, statistically significant difference ($p < 0.05$) was found in total phenolic content, antioxidant activity as well as in β -carotene after dry heat treatment as depicted in Table 2. Treated grains had the highest amount of total phenolics, followed by untreated grains. The total phenolics for treated samples varied from 2.04 ± 0.08 to $4.00 \pm 0.09\%$.

Table 2 Physico-chemical and functional parameters of dry heat treated raw materials

Parameters	Quinoa		Brown rice		Flaxseed		CD ($p \leq 0.05$)
	UT	HT	UT	HT	UT	HT	
Moisture (%)	7.25 $\pm$ 0.06	2.10 $\pm$ 0.08	9.90 $\pm$ 0.09	2.20 $\pm$ 0.06	5.90 $\pm$ 0.06	5.35 $\pm$ 0.08	UT = 0.5 HT = 0.4 UT $\times$ HT = 0.7
Ash (%)	3.13 $\pm$ 0.12	3.13 $\pm$ 0.07	1.13 $\pm$ 0.11	1.13 $\pm$ 0.07	3.43 $\pm$ 0.06	3.43 $\pm$ 0.09	UT = 0.7 HT = NS UT $\times$ HT = NS
Crude protein (%)	12.63 $\pm$ 0.07	12.55 $\pm$ 0.09	7.23 $\pm$ 0.07	7.01 $\pm$ 0.04	23.63 $\pm$ 0.09	23.56 $\pm$ 0.06	UT = 0.6 HT = 0.5 UT $\times$ HT = 0.9
Fat (%)	4.94 $\pm$ 0.02	4.91 $\pm$ 0.07	2.06 $\pm$ 0.09	2.01 $\pm$ 0.06	32.57 $\pm$ 0.11	32.50 $\pm$ 0.07	UT = 0.5 HT = 0.4 UT $\times$ HT = 0.8
Total phenolic content (mg GAE/g)	3.00 $\pm$ 0.09	3.70 $\pm$ 0.10	1.80 $\pm$ 0.09	2.04 $\pm$ 0.09	3.80 $\pm$ 0.06	4.00 $\pm$ 0.09	UT = 0.6 HT = 0.5 UT $\times$ HT = 0.8
Antioxidant (% inhibition)	56.19 $\pm$ 0.10	56.32 $\pm$ 0.09	58.97 $\pm$ 0.06	60.07 $\pm$ 0.08	78.23 $\pm$ 0.07	78.31 $\pm$ 0.04	UT = 0.4 HT = 0.3 UT $\times$ HT = 0.6
β -carotene (μ g/g)	1.60 $\pm$ 0.06	1.55 $\pm$ 0.07	0.11 $\pm$ 0.04	0.08 $\pm$ 0.07	8.52 $\pm$ 0.08	8.44 $\pm$ 0.09	UT = 0.7 HT = 0.6 UT $\times$ HT = 0.1

Data are represented as mean $\pm$ SD ($n = 3$)

UT Untreated, HT heat treated

The increase in total phenolic content may be due to the increase in the extractability of bound phenolics by the thermal degradation of cellular constituents. The dry heated grains (56.32 ± 0.09 – $78.31 \pm 0.04\%$) showed highest antioxidant content as compared to raw grains (56.19 ± 0.10 – $78.23 \pm 0.07\%$). The antioxidant properties of grains, which are mainly due to the polyphenols, can be increased by formation of Maillard reaction products during the roasting process. Similar observations of increased TPC and antioxidant activity with increased roasting temperature and duration have been found as result reported by Durmaz and Alpaslan (2007). β -carotene of different grains were significantly ($p < 0.05$) degraded after the dry heat treatment. Since the oxidation and trans-cis isomerization of β -carotene occurred during dry heat treatment (Inocent et al. 2011).

Optimization of levels of honey and flaxseed for the preparation of cereal bar

Blends of quinoa, brown rice and flaxseed were taken in four proportions (F1, F2, F3 and F4) with different levels of honey (40, 50 and 60%) for the preparation of cereal bar

(Table 3). Hedonic scores for product attributes and overall-acceptability are presented in Table 4. Statistically significant variations were observed regarding overall-acceptability of cereal bar while carrying out the sensory analysis by semi trained panel of judges on nine point hedonic scale. Higher percentage of flaxseed was affect too much to the taste of cereal bar. Flaxseed has a natural bitter taste. Therefore, the Hedonic scores for taste were lowest for 25% flaxseed (F1). However, the substitution for flaxseed up to 15% to quinoa and brown rice were the best

Table 3 Formulation of cereal bar

Constituents	Formulations			
	F1	F2	F3	F4
Quinoa (%)	35	35	40	40
Brown rice (%)	25	30	30	35
Flaxseed (%)	25	20	15	10
Almonds (%)	5	5	5	5
Raisins (%)	5	5	5	5
Dried figs (%)	5	5	5	5

Table 4 Effect of different levels of honey on the mean panel scores (max 9) for sensory evaluation of cereal bar

Honey level	Formulation	Appearance	Taste	Texture	Overall acceptability
40%	F1	6.60 ± 0.06	5.10 ± 0.09	5.10 ± 0.06	5.90 ± 0.07
	F2	6.60 ± 0.09	5.55 ± 0.10	5.95 ± 0.04	5.97 ± 0.04
	F3	6.85 ± 0.03	6.05 ± 0.07	5.60 ± 0.09	6.06 ± 0.03
	F4	6.85 ± 0.06	7.55 ± 0.08	7.05 ± 0.11	7.15 ± 0.06
	CD (p ≤ 0.05)	NS	0.26	0.31	0.31
50%	F1	8.10 ± 0.05	6.60 ± 0.10	7.10 ± 0.04	7.27 ± 0.06
	F2	8.10 ± 0.08	7.05 ± 0.07	7.55 ± 0.03	7.56 ± 0.07
	F3	8.75 ± 0.05	8.20 ± 0.06	8.35 ± 0.05	8.42 ± 0.09
	F4	8.75 ± 0.07	8.95 ± 0.05	8.55 ± 0.04	8.75 ± 0.02
	CD (p ≤ 0.05)	NS	0.23	0.31	0.26
60%	F1	7.05 ± 0.10	7.05 ± 0.04	7.05 ± 0.07	7.05 ± 0.06
	F2	7.05 ± 0.09	7.35 ± 0.08	7.15 ± 0.04	7.20 ± 0.07
	F3	7.00 ± 0.10	7.45 ± 0.06	7.10 ± 0.06	7.20 ± 0.04
	F4	7.02 ± 0.06	7.60 ± 0.05	7.55 ± 0.08	7.45 ± 0.04
	CD (p ≤ 0.05)	NS	0.26	0.26	0.14
F = Formulation		F = 0.04	F = 0.13	F = 0.11	F = 0.09
H = Honey		H = 0.03	H = 0.07	H = 0.07	H = 0.07
CD (p ≤ 0.05)		F × H = NS	F × H = 0.09	F × H = 0.05	F × H = 0.06

Data are represented as mean ± SD (n = 3)

overall acceptable composition for a gluten free cereal bars (F4). Mridula et al. (2013) produced oat cereal bar containing 0–20% flaxseed and 45–55% sweetener and observed significant interaction between flaxseed and sweetener.

Qualities of the cereal bars were greatly influenced by their appearance due to its Texture. There was significant change of texture (Table 4) of cereal bars due to different levels of honey (40, 50 and 60%). Cereal bars at honey level 40% were very brittle, hedonic scores were ranged from 5.90 to 7.15, might be because of at this honey level the binding of ingredients were not proper. Increasing levels of honey showed increase in sensory scores. Honey level of 50% was showed best result for overall acceptability (7.27–8.75) of cereal bars. All the parameters evaluated, did not significantly affect the acceptability and preference of the samples, except taste and texture which showed a significant difference among the samples. At the honey level 60% cereal bars were very soft, sticky and sweeter in taste. This could have been because of more amount of honey in the cereal bar. On the basis of sensory analysis, F4 formulation at honey level 50% was chosen to be best. It was in agreement with results reported by Mridula et al. (2013) who observed that the sensory scores of oat bar with flaxseed enrichment with 55% sweetener content had higher acceptability.

Physico-chemical and functional parameters of final product

Sensory scores revealed that composite cereal bar made by using 40% quinoa, 35% brown rice, 10% flaxseed, 5% of almonds, raisins & dried figs and 50% honey received an overall acceptability score of 8.75 and highly accepted by the taste panel members. Results of the physico-chemical analysis of cereal bar are presented in Table 5. The mean moisture content of cereal bar was 8.53 ± 0.07%. The lower moisture content ensures the prevention of microbial growth and elongates the shelf stability of the product, hence is an important factor in food preservation. Souza et al. (2014) reported 7.19–8.24% moisture content that

Table 5 Physico-chemical and functional parameters of cereal bar

Parameter	Value
Moisture (%)	8.53 ± 0.07
Ash (%)	1.34 ± 0.04
Protein (%)	10.50 ± 0.04
Fat (%)	2.89 ± 0.07
Total phenolic content (mg GAE/g)	0.51 ± 0.06
Antioxidant (% inhibition)	33.87 ± 0.06
β-carotene (μg/g)	0.384 ± 0.09

Data are represented as mean ± SD (n = 3)

made cereal bar with whole flour of pseudo-cereals new cultivars. The amount of ash present in a food product plays a significant role while determining the levels of essential minerals. Ash content of cereal bar was found $1.34 \pm 0.04\%$, the results were in conformity with the results of Mendes et al. (2013). Protein content of cereal bar was good ($10.50 \pm 0.04\%$). Quinoa and brown rice which were the main ingredients of the bar, generally have high protein content. This was in line with the work of Mridula et al. (2013). The fat result obtained in this study was $2.89 \pm 0.07\%$. This was closer to result obtained by Shaheen et al. (2013) who reported 2.16–8.07% fat content of date based fibre enriched fruit bar. The cereal bar was also assayed for the total phenolic content as well as for antioxidant activity and β -carotene (Table 5). The total phenolic content of the bar was expressed as mg gallic acid per gram of dry weight. Total phenolic content, antioxidant activity and β -carotene of cereal bar were found 0.51 ± 0.06 mg GAE/g, $33.87 \pm 0.06\%$ and 0.384 ± 0.09 μ g/g respectively in this study. The content of phenolic compounds in the designed bar was 0.51 mg GAE/g and higher than as reported by Alvarez-Jubete et al. (2010). The high phenolics content may be related to high DPPH scavenging activity of the cereal bar. Free radical scavenging is one of the most important function of antioxidant, since free radicals induce oxidation of lipids and proteins. The antioxidant activity of the cereal bar measured as % of DPPH radical scavenging, which was found 33.87% in bar.

Textural properties of cereal bar

Texture analysis of cereal bar was measured in terms of hardness (N), cohesiveness (dimensionless), springiness (mm) and chewiness (N/mm). Mean values of hardness, cohesiveness, springiness and chewiness were 27.73 N, 0.249, 0.359 mm and 254 2.48 (N/mm) respectively.

Conclusion

Based on the results obtained, it was concluded that good quality cereal bar with high acceptability can be made from combination of quinoa, flaxseed and brown rice along with nuts and honey. Nuts provide extra nutritional value to the cereal bar. The findings revealed that gluten-free cereal bar provided substantial amount of protein, fat and bioactive compounds. For celiac patient, gluten-free diet is only life long treatment so, this can be a good option for consuming as a snack for those patients.

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