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Influence of Quinoa Enrichment on the Formulation, Qualitative Parameters and Consumer Acceptability of Low-Gluten Foods

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Quinoa, is renowned as a grain of the 21st century in lieu of its capacity to withstand any climatic condition, its potential health benefits and exceptional nutritional value. Breakfast is the important meal of the day, which is skipped most often by most of the people. This study is framed with the objective of developing breakfast foods from the highly nutritious food grain like quinoa. As, Chapati and bars are easier to prepare and consume, the study aims at developing high-quality, convenient foods products by incorporating quinoa flour and quinoa flakes. The processed quinoa flour and flakes was substituted into the wheat flour and rice flakes in the proportion of 25, 50 & 75% to prepare chapati and bars of different variations namely variation1 (25Q:75W), variation2 (50Q:50W) and variation3 (75Q:25W). All the variations were analysed for physical characteristics, and organoleptic attributes like colour, appearance, mouth feel, texture, flavour, taste and overall acceptability was assessed by 30 panelist using a 9-point hedonic rating scale. The statistical analysis by Duncan's test and ANOVA showed significant difference ($p<0.05$) in all the developed variations, when compared with control foods. The most accepted variation was subjected to nutrient analysis. The study report concludes that on comparing with control the presence of macronutrients such as protein and dietary fibre, micronutrients such as calcium, iron, phytochemicals like flavonoids (particularly quercetin, kaempferol and epigallocatechin) were found to be higher in variation 3 of the developed products (chapati and bars). Since quinoa is a gluten free food it can be given to celiac people, their high nutritious and dietary quality meets the demands of the food industry and consumers.

Keywords: Breakfast foods; Cereal bars; Gluten free; Pseudo cereals; Quinoa.

Pseudocereals are edible seeds which has similar physical appearance and higher starch content similar to that of true cereals. The difference lies in that the cereals belong to monocotyledons of the Poaceae family, while the pseudocereals belongs to species of dicotyledons[1]. Amaranth, quinoa and buckwheat are the most commonly used pseudocereals worldwide. Quinoa (*Chenopodium quinoa Willd*.) belongs to Amaranthacease family but earlier on it was places in Chenopodiaceae family, it is an annual herbaceous plant that originated in the Pacific slopes of the Andes in South America. Since 5000 B.C it was produced and utilised by the Inca people, it was called as 'mother grain' in the Quechua language, because it held greater importance in the diet of Inca people[2]. Quinoa does not belongs to the class of true grain, it is not similar as the typical monocot cereal grains, due to this reason it has been called as a pseudocereal[3].

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Nutritional composition of quinoa is higher than that of most cereals. Quinoa has protein profile similar to that of casein and it holds the pride of complete and highest source of protein among all other true cereals. Quinoa on comparison with cereals and millets like barley, corn, rice, rye and sorghum, is considered as the only plant source that comprises and provides all the nine essential amino acids which are needed for the body functions[4].

Upon this quinoa is a completely gluten free, which is a suitable food grain to the people who are allergic towards wheat, barley, rye. Such nutritional features of quinoa make it to be unique from other cereal grain which are already in the practice and yields the greater interest universally[5]. The management and treatment of celiac disease consists gluten free diet, on this cases quinoa can be majorly added to the diet of a celiac patient. 65% of Indian population thrive on agriculture, during 1966-1967 green revolution played an important role on the Indian agriculture sector, they were import of several food grains from other countries because it was found hard to feed the tremendous growth in the Indian population with the crops cultivated and yielded in the Indian grounds. Likewise to tackle the health problems faced by the Indian population, the nutritious grain like quinoa was imported from other countries to combat and malnutrition and several other non-communicable diseases like diabetes, cancer, cardiovascular diseases and obesity and also the consequences of those conditions[6]. Consumption of a healthy diet, designing a routine exercise program and maintenance of a healthy BMI have been associated with a better quality of life[7].

The glycaemic score of quinoa is 53, which indicates quinoa is a low glycaemic food which aids in avoiding sudden spikes in the blood glucose levels but also helps in reducing all the subsequent consequences associated with diabetes and several other non-communicable diseases[8]. Versatile properties in accordance with culinary preparation was exhibited by quinoa because it is easy to cook and requires less cooking time. Quinoa can also be used as whole grains whereas the whole seeds of quinoa can also be ground into flour, flakes which can be used in the preparation of some commercial products like breads, cookies, muffins, cereal bars, it was also used in the Indian kitchens which were subjected to the preparation of chapati, laddu, instant food mixes, nutri bars, salads[9]. Thus, the study aims to develop food products using quinoa flour and flakes with different variations, which pave a better way to include nutrient rich pseudo-cereal in our diets regularly.

METHODOLOGY

Purchase and processing of required ingredients

Different ingredients for the development of value-added food products like whole quinoa seeds, quinoa flakes, whole wheat grains, rice flakes, oil, salt, and jaggery were bought from the quality super market and were stored safely until they were used for further processing and analysis. After procurement, whole quinoa seeds were checked for any infestation or damage. Broken or infested seeds were manually graded and removed. Good quality quinoa was cleaned by removing foreign matters and then washed with cold water several times to remove or eliminate bitter taste and toxic saponins. Once the formation of foam from quinoa got reduced (indicates a partial reduction in saponins) while washing, then it was subjected to soaking for 30min- 1 hour. Then the soaked whole quinoa seeds were allowed to shadow dry at room temperature. Once the moisture from soaked quinoa grains completely evaporated, they were milled to make quinoa flour and properly packed in an airtight container until the next use.

Formulation of different variations of food products from quinoa flour and quinoa flakes

Formulation of quinoa flour chapatis

For the formulation of the quinoa flour incorporated chapati, three different proportions of the quinoa flour viz. 25%, 50% and 75% of quinoa flour was mixed with 75g, 50g and 25g of wheat flour to prepare chapati, whereas in control 100% of wheat flour was used as shown in table 1. Mix all the ingredients together. Knead the mixed ingredients into a soft dough and allow to rest for 10 mins. After 10 minutes pinch a small portion (28gms each approx.) of the dough, make a ball out of it, press it gently on polpat. Flatten the dough with a rolling pin. Heat the tawa, place the flattened dough over it, Flip it and cook well on both the sides.

Formulation of quinoa flakes bars

For the formulation of different variations of quinoa bar, the ingredients as shown in table

-2 were used. The quinoa flakes and rice flakes were dry roasted separately. Melted jaggery syrup was added to quinoa flakes and rice flakes mix. A rectangular base was greased with coconut oil. Bar mix was placed on the pan base, and flattened with a spoon. The evenly spread bar mix was cut into small pieces and allowed to set for 30mins. For preparation of control bar the same procedure was adopted without incorporating quinoa flakes.

Sensory evaluation of the developed food products

Quinoa flour and quinoa flakes incorporated value added foods such as chapati and cereal bars showed variable effects on their sensory parameters. The developed foods were served to 30 panel members for the organoleptic evaluation of parameters like colour, appearance, mouth feel, texture, flavour, taste and overall acceptability using a 9-point hedonic rating scale and the results were subjected to statistical analysis. The descriptive statistical analyses were performed and the mean values were subjected to ANOVA with Duncan's multiple range test at 95% confidence interval to determine the significant difference in the developed variations of food products[10].

Nutrient and phytochemical analysis

The proximate composition such as energy, carbohydrate, protein, fat, fibre and micronutrients like zinc, iron, calcium, folate and phytochemicals in the accepted variation of the developed food products namely quinoa chapati and bar were determined according to the standard procedures[11].

RESULTS AND DISCUSSION

Sensory evaluation of the developed food products

The developed products were subjected to organoleptic evaluation and the accepted variation the developed products (i.e., chapati and bar) were subjected to further nutrient ad phytochemical analysis.

Sensory evaluation of the quinoa flour incorporated chapati

Table 3 indicates that there exists a significant difference ($p<0.05$) between the control and all the three variations of chapati on the basis of all organoleptic parameters assessed.

It is observed that on comparison with control, V_1 and V_2, variation 3 got maximum score for all the sensory characteristics signifying that V_3 was highly acceptable. Hence, further analyses were done for variation 3 (V_3), which has 75% incorporation of quinoa flour. From the above table it can be concluded that as the P value is 0.000,

Table 1. Ingredients for preparation of quinoa flour chapatis

Ingredients	Control	Level of incorporation		
		V_1	V_2	V_3
Whole wheat flour (g)	100	75	50	25
Quinoa flour(g)	0	25	50	75
Salt(g)	2	2	2	2
Oil (ml)	2	2	2	2

V_1- Variation 1, V_2- Variation 2, V_3- Variation 3

Table 2. Ingredients for preparation of quinoa flakes bars

Ingredients	Control	Level of incorporation		
		V1	V2	V3
Quinoa flakes (g)	0	25	50	75
Rice flakes (g)	100	75	50	25
Jaggery(g)	20	20	20	20
Cardamom (g)	2	2	2	2
Coconut oil(ml)	2	2	2	2

V_1- Variation 1, V_2- Variation 2, V_3- Variation 3

the mean of all the variations in terms of overall acceptability is significantly different among the groups. Also, overall acceptability was found to be highest for variation 3, which has maximum mean, similar to other sensory attributes.

Sensory evaluation of the quinoa flakes incorporated bar

Table 4 indicates that there exists a significant difference ($p<0.05$) between the control and all the three variations of bar on the basis of all organoleptic parameters assessed.

It is observed that on comparison with control, V_1 and V_2, variation 3 got maximum score for all the sensory characteristics signifying that V_3 was highly acceptable. Hence, further analyses were done for variation 3 (V_3), which has 75% incorporation of quinoa flakes. The results obtained for sensory evaluation were similar to that of quinoa flour chapati.

Overall acceptability of quinoa flakes incorporated bars showed P-value of 0.000 which is less than 0.05, indicating a significant difference

Table 3. Statistical analysis of organoleptic evaluation of developed chapatis

Variations	Colour	Appearance	Texture	Flavour	Mouth feel	Taste	Overall Acceptability
Control	8.7±0.48^{b}	8.7±0.48^{b}	8.6±0.52^{b}	8.2±0.79^{b}	8.7±0.48^{b}	8.5±0.53^{b}	8.4±0.52^{b}
Variation 1	7.3±0.95^{a}	7.3±0.95^{a}	7.5±0.71^{a}	7.5±0.53^{a}	7.8±0.92^{a}	6.8±0.79^{a}	7.1±0.88^{a}
Variation 2	7.3±0.67^{a}	7.3±0.67^{a}	8.1±0.74^{b}	7.5±0.52^{a}	7.6±0.84^{a}	7.3±0.95^{a}	7.5±0.53^{a}
Variation 3	8.3±0.48^{b}	8.3±0.48^{b}	8.6±0.52^{b}	8.7±0.67^{b}	8.6±0.52^{b}	8.8±0.42^{b}	8.5±0.53^{b}
Sig.	0.000*	0.000*	0.001*	0.000*	0.002*	0.000*	0.000*

Values are the mean ± standard deviation. Means with different superscript across the column are significantly different using Duncan's Multiple Range Test ($P < 0.05$).

Table 4. Statistical analysis of organoleptic evaluation of developed bars

Variations	Colour	Appearance	Texture	Flavour	Mouth feel	Taste	Overall Acceptability
Control	8.3±0.48^{bc}	8.3±0.48^{bc}	8.2±0.79^{bc}	8.4±0.52^{b}	8.3±0.48^{b}	8.0±0.67^{b}	8.9±0.32^{b}
Variation 1	7.8±0.79^{b}	7.8±0.79^{b}	7.0±0.82^{a}	7.6±0.69^{a}	7.5±0.71^{a}	7.7±0.48^{b}	7.1±0.74^{a}
Variation 2	7.2±0.63^{a}	7.2±0.63^{a}	7.6±0.97^{ab}	7.4±0.69^{a}	7.4±0.97^{a}	7.1±0.74^{a}	7.1±0.87^{a}
Variation 3	8.5±0.53^{c}	8.5±0.53^{c}	8.4±0.52^{c}	8.6±0.52^{b}	8.5±0.53^{b}	8.6±0.52^{c}	8.8±0.42^{b}
Sig.	0.000*	0.000*	0.01*	0.000*	0.001*	0.000*	0.000*

Values are the mean ± standard deviation. Means with different superscript across the column are significantly different using Duncan's Multiple Range Test ($P < 0.05$).

Table 5. Nutrient content of 75% quinoa flour incorporated chapati

No	Nutrients	Composition (Variation 3)	Composition (Control)
1	Energy(kcals)	344.12	338.25
2	Carbohydrates(g)	59.2	64.17
3	Protein(g)	12.48	10.57
4	Fat(g)	3.5	3.53
5	Dietary fibre(g)	13.84	11.36
6	Zinc(mg)	3.2	2.85
7	Iron(mg)	6.6	4.1
8	Calcium(mg)	156.24	30.94
9	Folate(mg)	0.129	-

Table 6. Nutrient content of 75% quinoa flakes incorporated bar

No	Nutrients	Composition (Variation 3)	Composition (Control)
1	Energy(kcals)	457.87	474.38
2	Carbohydrates(g)	83.94	103.11
3	Protein(g)	7.14	7.66
4	Fat(g)	2.43	3.27
5	Dietary fibre(g)	14.69	4.02
6	Zinc(mg)	0.61	1.64
7	Iron(mg)	6.22	4.75
8	Calcium(mg)	31.39	17.1
9	Folate(mg)	0.005	0.008

between the different variations and the control. Also, the mean value for overall acceptability was highest for variation 3 as indicated in table-4. Hence, variation 3 of quinoa flakes bar was subjected to further analysis.

Nutrient and phytochemical analysis

Nutrient analysis of 75% quinoa flour incorporated chapati

The 75% quinoa flour incorporated chapati samples were analysed for energy, protein, fat, carbohydrates, iron, zinc, folate, calcium and dietary fibre, as per standard methods.

The 75% quinoa flour incorporated chapati was found to be superior than the chapati set as control in terms of energy (344.12 kcals), protein (12.0g), dietary fibre (13.84g), iron(6.6mg), calcium(156.24mg) and zinc (3.2mg). With respect to carbohydrate, the quinoa flour chapati was observed to be lower than the control chapati by 4.97gms. The raw quinoa protein efficiency ratio (PER) is from 78-93%that of casein. After cooking these PER value increase to 102-105% that of casein. The protein content of quinoa is 14-20, 70 % (g/100g dry basis) and provide high-quality protein because quinoa has a very high amount of lysine and methionine amino acids. Quinoa has a Glycemic Index range of 35-53, depending on cooking time; overcooking does not affect quinoa quality[12]. Hence quinoa flour incorporated chapatis can be strongly recommended for diabetics. M. Priyanka et al., 2017 in their study on the standardisation and evaluation of quinoa incorporated breakfast

Table 7. Phytochemical analysis of quinoa flour chapati and quinoa flakes bar

No	Phytochemical analysis	Composition (Chapati)	Composition (Bar)
1	Total polyphenols (mg)	59	26.19
2	Flavonoids (mg)		
	Kaempferol	0.24	0.04
	Epigallocatechin	0.18	-
	Catechin	1.3	-
	Quercetin	0.8	-
3	Phenolic acids (mg)		
	Ferulic acid	0.04	0.02
	Gallic acid	0.7	0.13

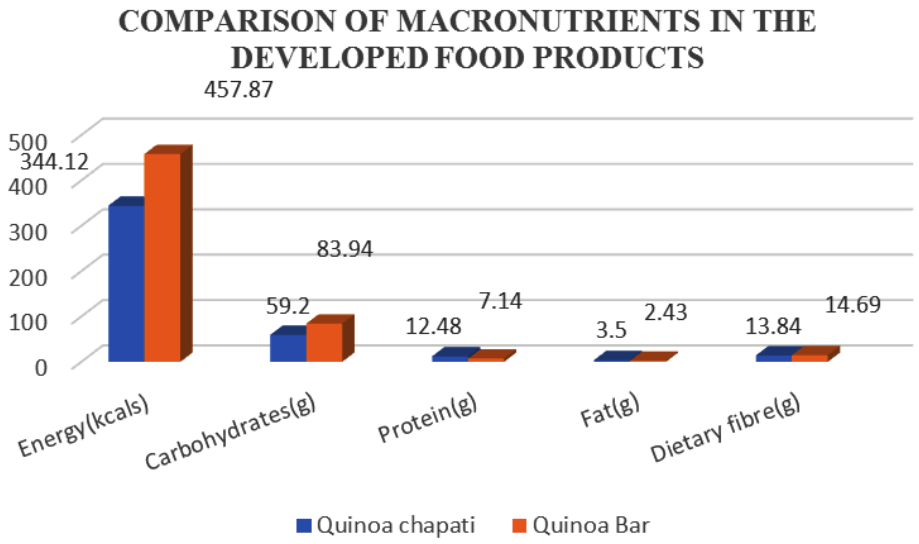

Fig. 1. Comparison of macronutrients in the developed food products

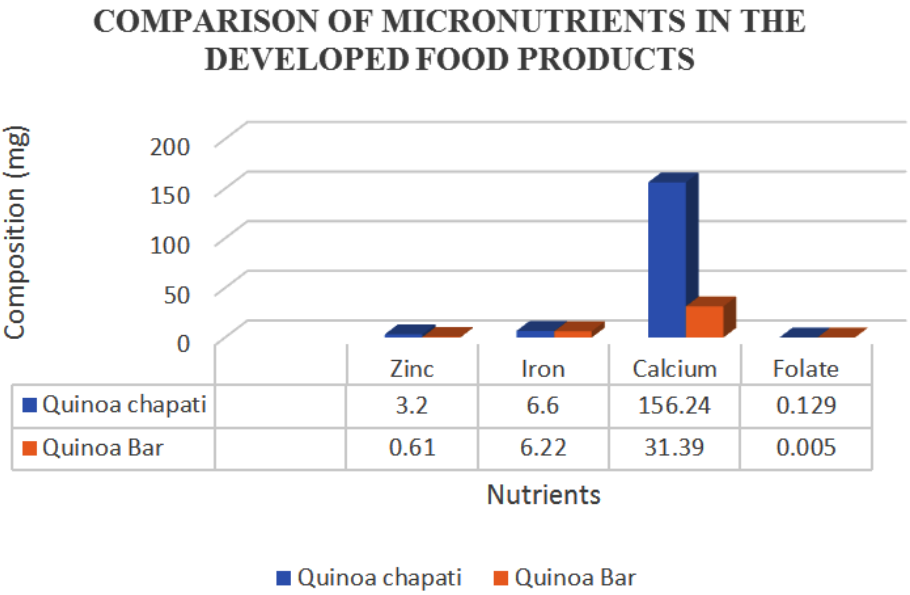

Fig. 2. Comparison of micronutrients in the developed food products

items, has shown that chapati made from quinoa flour had nutritional composition of 383.25 kcals of energy, 9.04g of Protein, 2.81g fat, carbohydrates of 80.45g, 3.47g mineral content and 4.23g crude fiber, which is significant to this study[9].

Nutrient analysis of 75% quinoa flakes incorporated bar

The accepted variation of quinoa flakes incorporated bar samples were analysed for protein, fat, carbohydrates, iron, zinc, folate, calcium and dietary fibre, as per standard methods.

The variation 3, 75% of quinoa flakes incorporated bar was found to contain 457 Kcals, 7 g protein, dietary fibre (14.69gm), iron (6.22mg) and calcium (31.39mg). When compared with the control, variation 3, 75% of the quinoa flakes incorporated bar has highest levels of dietary fibre, calcium, iron, which represents that the developed product is rich in micro nutrients. In children, it was found that 100 g of consumption of quinoa-added baby food twice a day for 15 days significantly increased the plasma insulin-like growth factor (IGF1), provided sufficient protein and other essential nutritional elements, which have a key role in preventing malnutrition among kids. Also, a study carried out on postmenopausal overweight women revealed that consumption of quinoa flakes (25g) daily for four weeks significantly decreased serum triglyceride and Thiobarbituric acid reactive substance (TBARS) levels and decrease total cholesterol and LDL levels as, opposed to increased GSH levels, was observed. The fact reveals the possible benefits of quinoa flakes in reducing blood fat[13]. The developed quinoa flakes bar is completely gluten-free which aids in the management of diabetes by reducing beta-cell stress, preserving the number of islets, reducing insulitis, and ameliorating Type 1 Diabetes. The levels of proinflammatory cytokines and adipokines decreases and the anti-inflammatory adiponectin level increases in the blood, on a gluten free diet. Also, a gluten-free diet reduces obesity by regulating lipid metabolism[14].

Comparison of nutrients in quinoa flour chapati and quinoa flakes bar

From the above figures, it is evident that the energy content of bar is higher than that of chapati. Likewise, the content of protein, fat, zinc, iron and calcium was higher in chapati than in bars. The amount of dietary fibre was higher in bar, which was around 14.69gms in 100gms. Hence, it can be concluded that both chapatti and bars enriched with quinoa can be recommended as breakfast foods.

Phytochemical analysis of quinoa flour chapati and quinoa flakes bar

The above table represents the phytochemicals present in the developed food

products, which reveals bioactive components present in the quinoa seeds prevent oxidative stress and show significant changes in the production of free radicals, that aids in the prevention and management of several degenerative diseases associated with the production of free radicals. Phytonutrients may subdue the proliferation of cancer cells, thwart growth factor signalling pathways and persuade apoptosis[15]. The phytochemicals such as total polyphenols content (59mg), flavonoids such as kaempferol(0.24mg), epigallocatechin (0.18mg), catechin(1.3mg), quercetin(0.8mg), phenolic acids such as ferulic acid(0.04mg), gallic acid(0.7mg) was detected in quinoa flour incorporated chapatti, while total polyphenols(26.19mg), flavonoids such as kaempferol (0.04mg), phenolic acids such as ferulic acid (0.02mg), gallic acid (0.13mg) were present in quinoa flakes incorporated bars. Intelli Arneja et al., (2015) reported that quinoa has exceptionally high flavonoid content varying from 36.2 to 144.3 mg/100 g[16].

The qualitative analysis for antinutrients in composite flour chapati and quinoa flakes bar showed a mild presence of saponins, tannins and phytic acid. The processing techniques adopted have significantly reduced the anti-nutrient contents.

CONCLUSION

Quinoa based foods contain a balanced set of amino acid content as compared to control recipes. Food industries can be recommended to incorporate quinoa flour and quinoa flakes in their food products, to improve the nutritive value. Quinoa flour incorporated chapatis are highly nutritious and can be a better alternative to the regular wheat chapatis, because of highly acceptable taste and low glycemic index for people who are at the risk of diabetes, which subsequently reduces the consequences of other non-communicable diseases. In addition, whole quinoa seeds are completely gluten-free, hence they can also be recommended to celiac patients to enrich their diet and improve the quality of their life. Quinoa flakes bars which are protein-rich acts as a healthy snack, so they can replace the position of junk foods and deep-fried snacks in the individual's diet.

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Conflict of Interest

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