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Effect of cooking on nutritional and antinutritional components of quinoa incorporated products

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Abstract
Present study was undertaken with an objective to evaluate traditional products prepared by incorporating quinoa under different cooking methods such as boiling (quinoa upma and quinoa kesaribath) roasting (quinoa laddu and quinoa chikki) and frying (quinoa chakli and nippattu). In case of boiling (60% quinoa and 40% wheat semolina) and in roasting the ratio consisting of 60% quinoa along with other ingredients (40% besan flour for laddu and 40% groundnut for chikki) were found to be acceptable in sensory quality. While in case of frying, the ratio consisting of 50% quinoa flour+50% rice flour was found to be acceptable. Results showed that protein and fat content were significantly more (P>0.05) in roasted products (quinoaladdu and quinoachikki) followed by fried products (quinoachakli and quinoanippattu) when compared to boiled products (quinoa upma and quinoa kesaribath). Even the minerals such as calcium (100.6, 110.9%) and iron (6.46, 8.23%) were significantly more in roasted products such as quinoaladdu (6.46%) and quinoachikki (8.23%) respectively as compared to other methods of cooking. While, the antinutritional factors such as phytic acid (2.32and2.08%), tannin (1.32 and 1.65%) and saponin (0.41and 0.4%) content were significantly reducedin upma and kesari bath respectively when compared to other method of cooking. Among quinoa incorporated products quinoa upma and quinoa kesaribath were highly acceptable (82-84% and 83-85%) followed by roasted (77-81% and 76-79%) and fried products (60-70 and 60-66%).

Keywords: Quinoa, saponin, phytic acid, roasting, frying and boiling

1. Introduction

Quinoa is a pseudo cereal plant native to South America with 5000 to 7000 years ofhistory. Botanical name of the quinoa is *Chenopodium quinoa*, belong to family *Chenopodium*. Quinoa plants tolerate a wide range of pH conditions of the soil (pH 6.0 to 8.5) and is able to grow in both cold (5 ^{0}C) as well as hot climatic conditions (35 ^{0}C). Plant was mainly cultivated in Andean region, Ecuador, Peru, Bolivia, Chile and it is substituted by foreign crops such as wheat and barley (Valencia-Chamorro, 2004) [34]. Quinoa grains are flat, round in shape with 1.5to 40 mm diameter and colour of the grains varies based on variety fromwhite to gray, black with tone of yellow, rose, red, purple and violet (Gordillo-Bastidas *et al*., 2016) [10].

Quinoa is a nutritious grain and good source of protein with high biological value with carbohydrates of low glycemic index and contain essential amino acids particularly lysine, methionine with good amount of essential fatty acids(linoleic acid, oleic acid and palmitic acids). Even Quinoa grains contains good amount of minerals, vitamins and dietary fiber (KursatDemir, 2014) [14]. Quinoa has been found to contain bioactive compounds like polyphenols, phytosterols, and flavonoids with possible nutraceutical benefits (isoflavons andlipids). Besides nutrient compounds, it also contain anti nutrients (phytic acid, saponin and tannin) which mainly concentrated in the outer layer of the grai (Maradini *et al*., 2015) [17]. Apart from this, quinoa has excellent functional properties such as solubility, galation, water holding capacity, emulsifying and foaming property (Mostafa M, 2017) [19].

Traditional foods which are healthy with good nutrient density and longer shelf life can be prepared through various conventional methods. Traditional foods play an important role in rural development particularly small and middle size enterprises as they prevent unfair trade competition (Albayrak and Gunes Erdogan, 2010) [2]. In the Indian context, different cooking methods such as boiling, roasting, frying, steaming methods were normally followed for conventional preparations. In boiling food is cooked uniformly and protein gets denatured, starch gets gelatinized and collagen gets hydrolysed. While in case of frying food gets cooked very fast which in turn increase the calorific value with improved taste and it is suitable for snack items. Further, in steaming method of cooking the foods are cooked slowly and are easily digestible with good nutritional profile (Srilakshmi, 2007) [31].

Literature cited indicated that researchers indifferent parts of world conducted studies on development of quinoa salad, porridges, soup and health drinks and has been recently used to develop breakfast cereals; granola bars (Garcia *et al*., 2018) [9]. Owning to its nutritional benefits, it is used for the production of healthy snacks (Priyanka *et al*., 2017) [24]. Pasta (Mostafa, 2017) [19] biscuits (Ibrahium, 2015) [11] breads (Salazar *et al*., 2017) [27] cookies (Nisar *et al*., 2018) [21] and other processed products. As per reports of research conducted in various parts of world it can be observed that by using traditional cooking methods products were developed from cereals and pulses such as RTC upma mix from quinoa (shaivya, 2016) [28], kesaribath from soy semolina (Yadav *et al*., 2007) [37], laddu from garden cress seed (Uma Rani and Sucharitha, 2016) [33], chikki from multigrains (Abhirami and Karpagapandi, 2018) [1] and chakli or muruku from multigrains (Saiyed and Sengupta, 2014) [26]. However, the comparative study of quinoa incorporated products in different cooking methods was not reported so far. Hence the present study was undertaken with an objective to develop quinoa based traditional products by incorporating quinoa under different cooking methods and evaluated the effect on nutritional, anti nutritional and consumer acceptability.

Materials and Methods

Procurement of ingredients

Basic raw material quinoa was procured from “Dhatu Organics and Naturals”, Organic Food Store, Mysore and other ingredients used in the product development were purchased in a singal lot from local market and refrigerated until further use.

Processing of quinoa

Quinoa grains were subjected to different pre-treatments to reduce the bitterness content present in the grain. The different pre-treatments such as washing in normal water, washing in hot water, soaking in citric acid solution (0.5 and 1%) and soaking in sodium bicarbonate (0.5 and 1%) solution for six hrs were carried out as her kavali *et al* (2019) [13]. Pre-treated quinoa grains were ground to make semolina and flour using milling machine (Domestic flour mill) and sieved in 18and 60 BS mesh respectively.

Standardization of products

Products were standardized by incorporating quinoa in different cooking methods. In case of boiling the products standardised were Upma (savory bath) and Kesaribath (sweet bath). The different ratios such as 100:0, 90:10, 80:20, 70:30, 60:40 of quinoa semolina: wheat semolina were used for standardization. While in frying method, the products such as Chakli and Nippattu were standardized using different ratios (90:10, 80:20, 70:30, 60:40, 50:50) of quinoa flour and rice flour. Under roasting category, the laddu and chikki were standardized using 100:0, 90:10, 80:20, 70:30, 60:40 ratio of quinoa flour: basen flour for laddu and the same ratio for chikki (quinoa + groundnut). Control products of upma and kesaribath were prepared using 100% wheat semolina, the control chakli and nippattu were prepared using 100% rice flour where as laddu and chikki were prepared with100% basen flour and 100% groundnut respectively.

Proximate analysis

Proximate composition of the products developed under different cooking methods was analyzed for moisture, protein, fat (AOAC, 1980) [4] carbohydrate by difference method (Livesey, 1995) [16]. The mineral solution was prepared by dissolving the ash obtained after ashing the samples in a muffle furnace in dilute hydrochloric acid (1:1v/v). Mineral solution was used for the estimation of iron, calcium, zinc and copper. The clear extract was fed Atomic Absorption Spectrophotometer (Agilent Technologies 200 series AA spectra 240 AA) for estimation of above minerals. Depending upon mineral to be determined, standard and sample solution may be aspirated into the flame directly or after suitable dilution to attain working range of the instrument. The optimum operating condition recommended by the instrument manual was used. Standard solution was read at least 3-4 ranges before and after sample readings. Flushing of burner with deionised water between samples was done and checked for zero setting. Prepared calibration curve from the reading of standards. Determine the concentration of samples from the standard graph (Anal, 1967) [3].

$$\text{ppm mineral} = \frac{(\mu\text{g mineral/ml}) \times \text{dilution factor}}{\text{ml of aliquots} \times \text{g sample}}$$

Anti nutritional analysis

Antinutritional factors such as phytic acid and tannin were estimated according to standard procedure of AOAC (1990) [5] and saponin content was estimated as described by obadonal and ochuko (2001) [22].

Statistical analysis

Analysis of data was carried out in triplicates and results were expressed as mean of three replication±SD and ‘t’ test was performed with aid of WASP software to assess the significance between the samples at 0.05% level.

Consumer acceptability

The quinoa incorporated products cooked under different cooking methods was served to different categories of people such as school children (n=50), labourers (n=50), college boys (n=50) and college girls (n=50) to elicit the general acceptability of the products as per Shobha and Joshi (2015) [29].

Result and Discussion

Stadaradization of quinoa incorporation in product development

Among four pre treatments tested, soaking in sodium bicarbonate solution (1%) showed significant reduction in bitterness of quinoa grains. Accourding to Lilian and Abugoch (2009) [15] saponin was known to be major bitterness contributing compound present in quinoa seeds, which is reduced significantly when soaked in one% sodium bicarbonate solution.

Among the various ratios tested, the ratio containing 60:40 (boiling and roasting), 50:50 (frying) of quinoa with other ingredients was found to be acceptable in sensory qualities (data not showed)

It is observed from the data presented in Table1 that significant difference was noticed with respect to protein (11.5%), fat (5.66%) calcium (80.2%), energy (359.9%) iron (10.56%) and zinc (4.25%) content between flour and semolina samples. Higher amount of above contents were observed in flour compared to semolina which may be due to fact that there is loss of bran and endosperm while making semolina, which might have contributed for lower nutritional composition in semolina.

The obtained results for the proximate composition of quinoa flour were found similar findings were reported by Maradini-filho (2017) [18] and Vega-Galvez *et al*.,(2010) [36] where in quinoa flour found to contain 16.3% protein, 7% fat, 2.7% ash and carbohydrate (74%) contents.

Table 1: Nutritional composition of Quinoa flour and semolina (per 100 g)

Nutrients	Quinoa flour	Quinoa semolina
Energy (Kcal)	359.9±0.11ᵃ	331.5±0.4ᵇ
Carbohydrate (g)	65.85±0.19ᵇ	72.76±0.23ᵃ
Moisture (g)	10.69±0.4ᵃ	8.23±0.30ᵇ
Protein (g)	11.5±0.02ᵃ	9.5±0.7ᵇ
Fat (g)	5.66±0.208ᵃ	2.5±0.68ᵇ
Crude fibre (g)	4.69±0.35ᵇ	5.09±0.1ᵃ
Ash(g)	1.76±0.02ᵇ	2.15±0.70ᵃ
Calcium (mg)	80.2±0.26ᵃ	60.1±0.8ᵇ
Iron (mg)	10.56±0.4ᵃ	8.4 ±0.43ᵇ
Zinc (mg)	4.25±0.03ᵃ	3.3±0.6ᵇ

The values represent the mean±SD. Mean followed by the different letter between rows indicated significant difference at 5% and same letter indicated non significant.

Nutritional composition of developed products

Nutritional composition of control and quinoa incorporated upma and kesaribath (Fig 4 and 5) is given in Table 2. Quinoa incorporated upma was found to contain low carbohydrate (39.31%) and significantly higher amount of protein (14.3%), crude fibre (3.76%), calcium (90.7%), iron (5.39%) and zinc (4.32%) contents compared to wheat upma, which is good for diabetic subjects. In case of kesaribath, the nutrients are significantly differed in few parameters like protein (13.12%) fibre (2.9%), calcium (80.8%) and fat (13.14%) contents. Quinoa incorporated upma and kesaribath showed good nutrient content due to quinoa incorporation which is basically good source of protein, fat, fibre, calcium and minerals compared to control upma and kesaribath prepared out of wheat semolina.

Similar results were reported for the nutritional composition of quinoa upma mix developed by Shaivya and Sunita (2016) [28], where in quinoa upma mix had 13.29% of protein, 23.17% of fat and 53.49% of carbohydrate and the products were highly recommended for all age group people suffering from degenerative diseases and heart diseases. Even our results are in agreement with study by Dhumketi *et al*., (2017) [8] on instant upma mix from foxtail millet and soy grits, indicated good amount of protein, fat and crude fibre contents. Even the research conducted by Yadav *et al*., (2007) [37] on optimization of soy-fortified instant sooji halwa mix was also fairly good in protein, fat and carbohydrate content.

Table 2: Nutritional composition of upma and kesaribath (per 100 g)

	Upma		Kesaribath	
Nutrients	**Control**	**Quinoa**	**Control**	**Quinoa**
Energy (kcal)	288.1±0.5ᵃ	271±0.25ᵇ	342.2±0.54ᵃ	328.2±0.52ᵇ
Carbohydrate (g)	48.4±0.6ᵃ	39.31±0.81ᵇ	51.2±0.49ᵃ	42.7±0.5ᵇ
Moisture (g)	32.2±0.47ᵇ	34.2±0.65ᵃ	24.8±0.6ᵇ	26.5±0.4ᵃ
Protein (g)	12.45±0.53ᵇ	14.3±0.51ᵃ	11.47±0.62ᵃ	13.12±0.14ᵇ
Fat (g)	5.13±0.48ᵇ	6.34±0.38ᵃ	11.6±0.10ᵃ	13.14±0.51ᵇ
Crude fibre (g)	1.26±0.13ᵇ	3.76±0.15ᵃ	0.72±0.35ᵇ	2.9±0.49ᵃ
Ash (g)	0.56±0.04ᵇ	2.09±0.10ᵃ	0.29±0.15ᵇ	1.67±0.49ᵃ
Calcium(mg)	64.27±0.52ᵇ	90.7±0.45ᵃ	30.61±0.52ᵇ	80.8±0.36ᵃ
Iron (mg)	2.50±0.53ᵇ	5.39±0.52ᵃ	2.48±0.57ᵃ	3.31±0.39ᵃ
Zinc (mg)	3.32±0.56ᵇ	4.32±0.18ᵃ	2.3±0.49ᵃ	2.8±0.70ᵃ
Copper (mg)	0.52±0.03ᵇ	1.33±0.32ᵃ	0.74±0.42ᵃ	0.71±0.41ᵃ

The values represent the mean± SD. Means followed by the different letter between rows indicated significant difference at 5% and same letter indicated non significant

Perusal of Table 3 provides the nutritional composition of fried quinoa incorporated products in comparison to control (Fig 6 and 7). The fried quinoa incorporated products (chakli and nippattu) were found to contain significantly higher amount of protein (16.3% 7 17.4%), fat (23.2% & 20.2%), calcium (80.6% & 120.6%) and iron (6.34% & 8.08%). Quinoa incorporated nippattu was significantly differed from control nippattu (rice flour nippattu), where as in chakli, ash, zinc, copper were did not differed significantly but other parameters differed significantly. Quinoa incorporated chakli and nippattu were hard in texture compared to rice chakli, it may be because of low starch content in quinoa so that incorporation of quinoa may affect the texture of fried products but nutritional composition was superior to rice chakli which may be because of the fact that the quinoa itself is a good source of protein, fat, fibre, calcium, iron compared to rice (Narasinga Rao B.S *et al*., 2009) [20].

Similar results were reported for the nutritional composition of sorghum-finger millet Chakli by Patekar *et al*., (2017) [23] potein and fat content were highest in sorghum-finger millet chakli as compared to the control chakli. Saiyed and Sengupta (2014) [26] also stated that multigrain chakli had protein content of 14.3% with a energy (351kcal) and carbohydrate content (39.25gm)/ 100g and traditional chakli contain saturated fat but multigrain chakli contain ω3 and ω6 fatty acid. The study conducted by Chavan *et al*., (2016) [6] on even the sorghum chakli showed similar kind of nutritional composition.

Table 3: Nutritional composition of quinoa chakli and nippattu (per 100 g)

	Chakli		Nippattu	
Nutrients	**Control**	**Quinoa**	**Control**	**Quinoa**
Energy (kcal)	444.8±0.50a	467.3±0.98b	442.3±0.2b	453±0.60a
Carbohydrate (g)	61.23±0.68a	48.1±0.98b	60.38±0.7a	50.45±0.48b
Moisture (g)	2.9±0.52b	3.2±0.51a	2.99±0.50b	3.3±0.45a
Protein (g)	13.3±0.51a	16.3±0.50b	15.4±0.5b	17.4±0.45a
Fat (g)	16.3±0.5b	23.3±0.51a	15.53±0.55b	20.2±0.36a
Crude fibre (g)	4.27±0.54b	6.3±0.09a	3.45±0.50b	5.83±0.06a
Ash (g)	1.91±0.09a	2.54±0.56a	2.25±0.23b	3.22±0.30a
Calcium (mg)	40.6±0.4b	80.6±0.49a	81.3±0.36a	120.6±0.52b
Iron (mg)	2.61±0.55a	6.34±0.4b	4.94±0.14b	8.08±0.16a
Zinc (mg)	2.43±0.51a	3.57±0.49a	2.24±0.23b	3.13±0.20a
Copper (mg)	0.45±0.37a	0.63±0.47a	0.032±0.02a	0.076±0.015a

The values represent the mean ± SD. Means followed by the different letter between rows indicated significant difference at 5% and same letter did not differ significantly.

Under roasting method of cooking, the sweet products such as laddu and chikki were developed (Fig 8 and 9) Nutritional composition of control and quinoa incorporated laddu and chikki is provided in Table 4. Quinoa incorporated laddu and chikki contained moisture (4.3 and 3.36%) protein (18.3, 16.3%) fat (20.4, 17.4%) crude fibre (4.26, 5.9%) ash (2.28, 3.30%) calcium (100.6, 110.9%) iron (6.46, 8.23%,) and zinc (3.36,3.42%). However, the acceptability of quinoa incorporated chikki was lower compared to boiled products, which may be due to the fact that breaking strength of quinoa incorporated chikki in mouth was hard compared to control chikki, which reduced its consumer acceptace of the product.
Similar study conducted by Sujatha and Kowsalya (2016) [32] on iron rich ladoo supplimented with green leafy vegetables showed that it contained fairly good amount of carbohydrate, protein, fat and iron content. Even our results are supported by Uma rani and Sucharitha (2016) [33] on iron rich ladoo prepared by incorporation of garden cress seed showed that chikki was good in term of protein, fat, carbohydrate, calcium and iron content. Even the results of this study was also supported by Vasu pallavi *et al*., (2014) [35] on nutra-chikki, which indicated significantly higher protein, calcium and iron contents in nutra chikki due to fortification with $CaCO_3$ and ferrous fumerate when compared control chikki. Our work also supported by the results of Abhirami and Karpagapandi (2016) [1] on muiltigrain nutri chikki contained significant amount of protein and iron.

Table 4: Nutritional composition of quinoa laddu and chikki (per 100 g)

	Laddu		Chikki	
Nutrients	**Control**	**Quinoa**	**Control**	**Quinoa**
Energy (kcal)	472±0.1a	458.9±0.86b	462.6±0.52a	437±0.91b
Carbohydrate (g)	55.2±0.4a	49.4±0.61b	53.1±0.75a	54.2±0.49a
Moisture (g)	3.3±0.45a	4.3±0.52a	2.36±0.45a	3.36±0.50a
Protein (g)	17.4±0.50a	18.3±0.51a	18.4±0.5a	16.3±0.45b
Fat (g)	20.2±0.47a	20.4±0.56a	19.3±45a	17.4±0.5b
Crude fibre(g)	1.46±0.37b	4.26±0.47a	3.3±0.52b	5.9±0.2a
Ash (g)	2.44±0.47a	2.28±0.41a	3.23±0.49a	3.30±0.50a
Calcium(mg)	62.1±0.26b	100.6±0.55a	82.8±0.20b	110.9±0.1a
Iron (mg)	5.41±0.44b	6.46±0.20a	5.17±0.29b	8.23±0.31a
Zinc (mg)	2.40±0.4b	3.36±0.24a	2.44±0.39b	3.42±0.54a
Copper (mg)	0.25±0.04a	0.04±0.015b	0.45±0.47a	0.36±0.24a

The values represent the mean ± SD. Mean followed by the different letter between rows indicated significant difference at 5% and the same letters did not differ significantly.

Anti nutritional composition

The major anti nutrients present in quinoa includes saponin, phytic acid and tannin (Vega-Galvez *et al*., 2010) [36] among three, the saponin is mainly responsible for bitterness in grains.
Phytic acid, tannin and saponin was significantly higher in Quinoa flour (2.78%, 1.95%, 0.63%) compared to quinoa semolina (2.6%, 1.74%, 0.6%). Phytic acid is located in external layer as well as in the endosperm. Valencia-Chamorro (2003) [34] reported that phytic acid concentration was 1.18% in quinoa. Similar results for tannin content in quinoa flour (0.23-0.28%) was reported by Chawhan *et al*., (1992) [7]. The tannin content was highest in the hull (0.92%) compared to either bran (0.61-0.66%).
Phytic acid, tannin and saponin content were significantly more in quinoa flour samples (Fig.1) compared to quinoa semolina, which may be due to more surface area exposed in case of flour compared to semolina which rendered more accessibility during estimation.

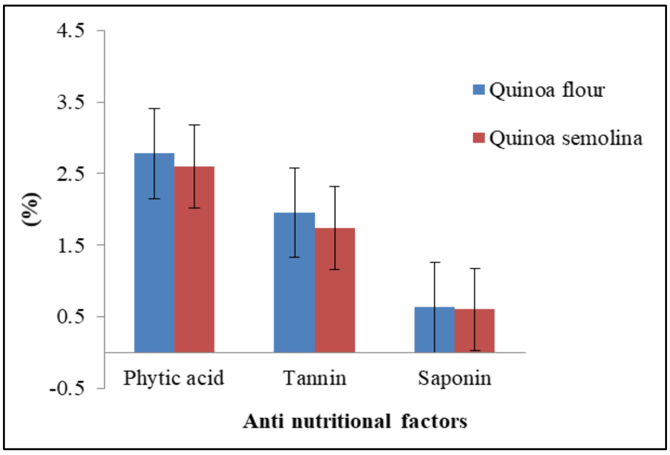


Fig 1: Anti nutritional composition of quinoa flour and semolina

It is clear from the figure 2 that phytic acid, tannin and saponin contents were significantly more in quinoa incorporated products compared to control products. However, they were reduced due to processing when compared to flour and semolina. Study conducted by Singh and Mehra (2017) [30] on pearl millet laddu showed that phytic acid (647.8 mg), and polyphenols contents were reduced in laddu preparation. Even Jain and Grover (2017) [12] developed garden cress chikki and found that the oxalates and phytic acid contents in garden cress chikki were reduced due to heat processing. Maximum amount of anti nutrients (Fig 2) are reduced in boiled products compared to fried products. Which may be because of higher time of cooking in water resulted in slow leaching along with heat treatment, rendered maximum reduction in boiled products (Upma and kesaribath).

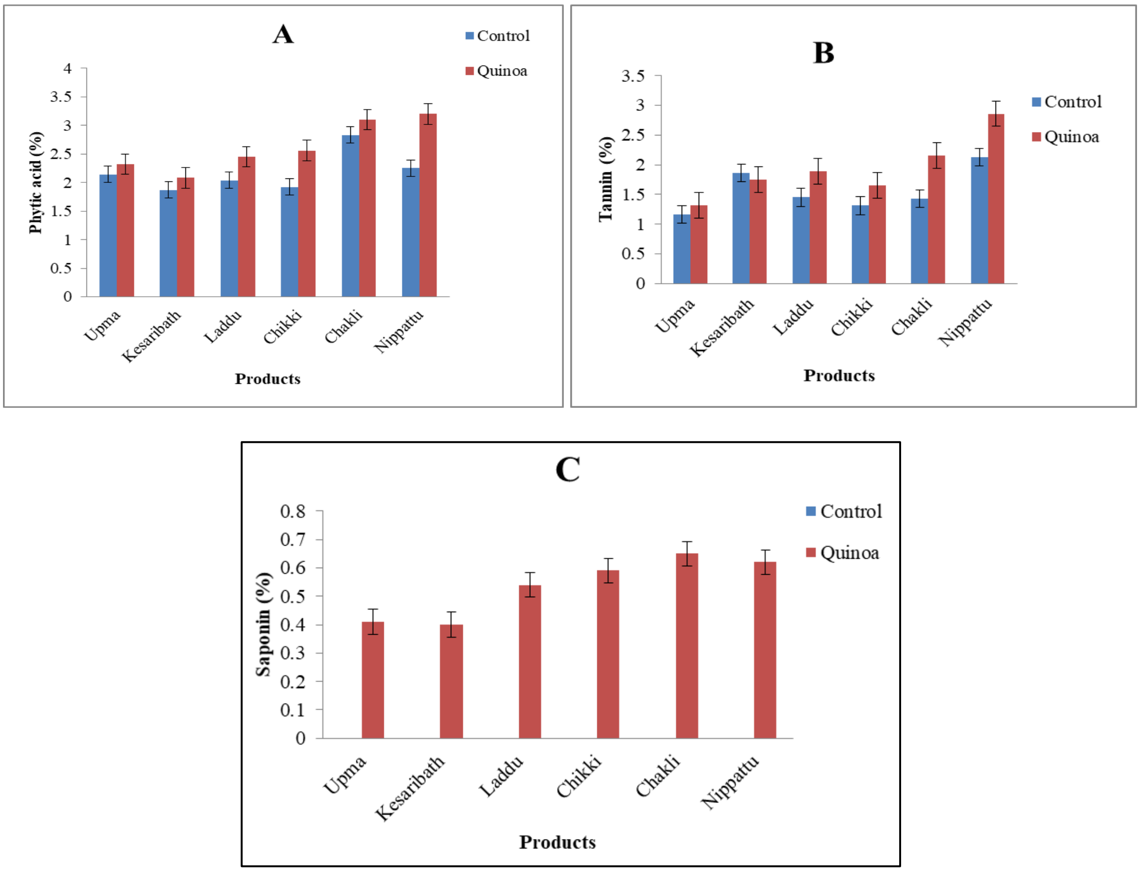


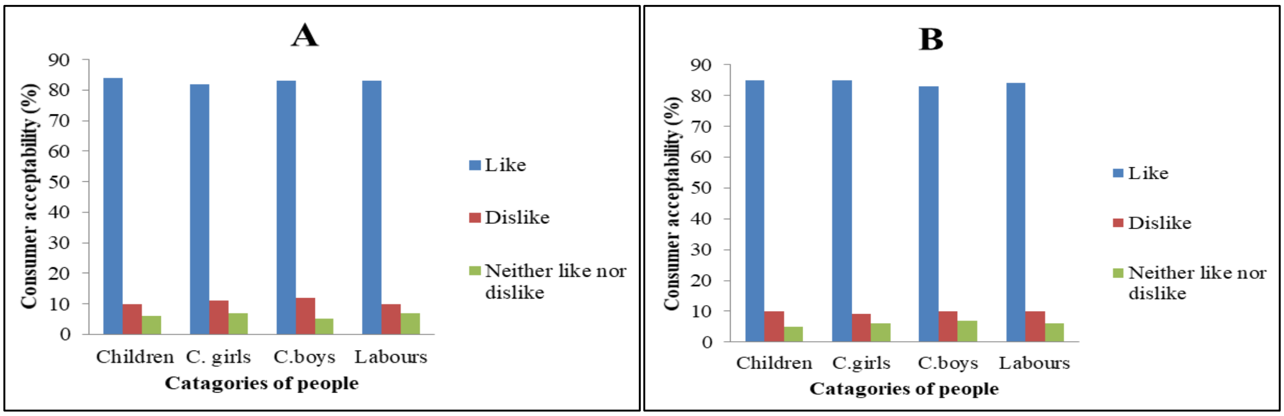
Fig 2: A: Phytic acid B: Tannin C: Saponin content of quinoa incorporated products

Consumer acceptability studies

Consumer acceptability is the most important attribute for product development. Matching consumer needs is a priority in market oriented firms and in this sense consumer acceptability of a food product is considered as trigger for subsequent purchases and factor to contribute to the firm's success in the long-run (Resano *et al*., 2010) [25].

Among the four types of quinoa based cooked products, the consumer of varied type of consumers (labourers, school children, college boys and girls) indicated that the boiled products (quinoa upma and kesaribath) were liked by maximum member (82-84% and 83-85%) of consumers (Fig 3).

The reason behind maximum number of consumers liked the boiled products (upma, kesaribath) was due to less bitterness accompanied by good swelling capacity imparted by quinoa semolina, where as other products were hard in texture (chakli, nippattu, chikki) along with bitter after taste, which decreased their acceptability scores



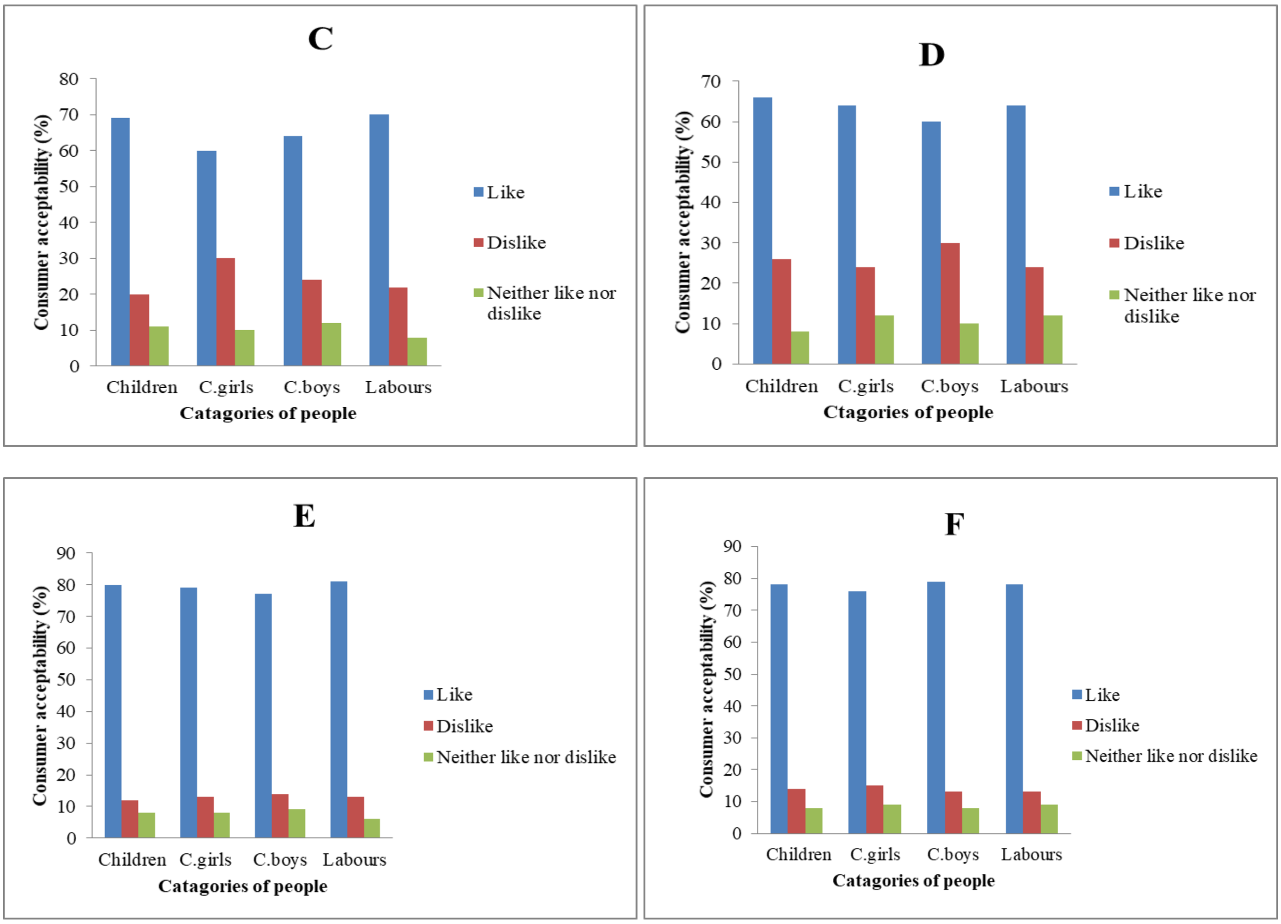


Fig 3: Consumer acceptability score of quinoa incorporated products (A: Upma B: Kesaribath C: Chakli D:Nippattu E: Laddu F: Chikki)

Fig 4: control and quinoa incorporated upma

Fig 6: The fried quinoa incorporated products chakli

Fig 5: control and quinoa incorporated kesaribath

Fig 7: The fried quinoa incorporated products nippattu

Fig 8: The roasting quinoa incorporated products laddu

Fig 9: The roasting quinoa incorporated products chikki

Conclusion

The present study showed that, the quinoa can be incorporated into traditional products to the level of 50 to 60% in regular consuming products such as upma (60%), kesaribath (60%), chakli (50%), nippattu (50%), laddu (60%) and chikki (60%).The nutritional composition of the products showed that they are good in terms of protein, fiber, calcium, zinc and iron. Among the different cooking methods (boiling, frying, roasting) tested, the boiled products (upma, kesaribath) were superior in nutritional composition with maximum reduction of phytic acid, tannin and saponin contents and maximum number of consumers liked the products.

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