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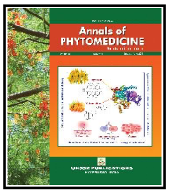

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Exploring the effect of sprouting on nutritional profile of quinoa (*Chenopodium quinoa* Willd.) and ready-to-eat snack 'Waffle'

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Abstract

The effect of sprouting on nutritive value of quinoa (*Chenopodium quinoa* Willd.) and a ready-to-eat snack 'Waffle' developed from raw and sprouted quinoa flour was studied. The sprouting process significantly increased the *in vitro* protein digestibility, dietary fiber content and minerals, *viz.*, iron, calcium, potassium, and phosphorus by 63.54, 6.87, 49, 33.87, 18.38, and 13%, respectively. In comparison, the starch content decreased significantly by 25.9% with sprouting. The antinutritional factors reduced significantly on sprouting while antioxidant activity increased. Based on the sensory evaluation, the 'Waffles' made with 60% sprouted quinoa flour were found to be the most acceptable of the multiple combinations of whole wheat flour and quinoa flour used to develop Waffles. For Indian children aged 7-12, one serving of 60% sprouted and 100% raw quinoa flour Waffles can meet approximately 17-26%, and 9-13% of the recommended daily allowances of protein and calories, respectively. Thus, quinoa flour incorporated Waffles can be regarded as a healthy alternative for individuals of all ages, where nutritional deficiency diseases and lifestyle disorders coexist and pose a threat to human health.

1. Introduction

Quinoa (*Chenopodium quinoa* Willd.), has become well-known for its unique nutritional and functional qualities and its ability to be grown in harsh climates. It can thrive in challenging climates, including drought, extreme temperatures, and salty soil. An exceptional balance of essential amino acids can be found in quinoa along with its richness in protein, vitamins, minerals and dietary fiber content. This grain has higher protein content (8-22%) than any other commonly consumed cereals. The limiting amino acids in traditional cereals' protein, *viz.,* threonine (2.1-8.9%), methionine (0.3-9.1%) and lysine (2.4-7.8%) are present in significant amounts in quinoa protein. As per the daily recommended amounts of amino acids indicated by the FAO and WHO, quinoa fulfills the amino acid requirements for adults by providing 180% of histidine, 274% of isoleucine, 338% of lysine, 212% of methionine and cysteine, 320% of phenylalanine and tyrosine, 331% of threonine, 228% of tryptophan, and 323% of valine (Gordillo-Bastidas *et al.*, 2016).

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Different varieties of quinoa contain dietary fiber content in the range of 12-14%. Certain biologically active compounds found in quinoa, including glucans, phenols, and saponins are vital for the prevention and cure of several illnesses because of their health-promoting properties like anti-cancerous and hypo-cholestrolemic effects. Quinoa's bioactive ingredients are similar to those of millets (Sibi *et al.*, 2024). FAO recognized quinoa as an important crop that can contribute to future food security. NASA even includes quinoa in astronaut rations due to its exceptional nutritional value (Carrasco and Soto, 2010).

Processing enhances food safety, quality, and shelf-life. Germinating quinoa seeds and then drying them in an oven increases their phenolic content and antioxidant activity, making them suitable for functional foods (Bhathal *et al.*, 2015). Like rice, quinoa can be enjoyed in various ways, such as in soups, can be puffed and used as breakfast cereal, or ground into flour for baked goods like pancakes. Ready-to-eat snacks are popular among children, adolescents, and young adults due to their convenience and ease of preparation. Waffles are wheat-based ready-to-eat snacks made from batter, which are leavened and cooked between two hot iron plates with multiple patterns to give them a distinctive surface and form. Waffles are a good source of protein since they are made from fresh eggs, milk, and fat. They are consumed as bread, cakes, or sweet dishes with various toppings like vegetables, fruits, and nuts. The purpose of the current study was to explore the impact of sprouting on nutritive quality of quinoa flour and a ready-to-eat snack 'Waffle' developed using raw and sprouted quinoa flour.

2. Materials and Methods

2.1 Plant authentication and sample preparation

The plant was authenticated by Dr. D. S. Rawat, Assistant Professor, Department of Biological Sciences, College of Basic Sciences and Humanities, G. B. Pant University of Agriculture & Technology, Pantnagar, Uttarakhand. The Voucher Specimen Number (GBPUH-1642) and the herbarium was deposited in the same department for future reference. Quinoa seeds were obtained from Organic India, an online retail store, while other ingredients including wheat flour, sugar, baking soda, baking powder, butter, vanilla extract, salt, milk were procured from local market. Two types of quinoa flour were developed in the current study, *i.e.*, raw and sprouted. The flours were sealed in airtight containers and further Storage in air tight container

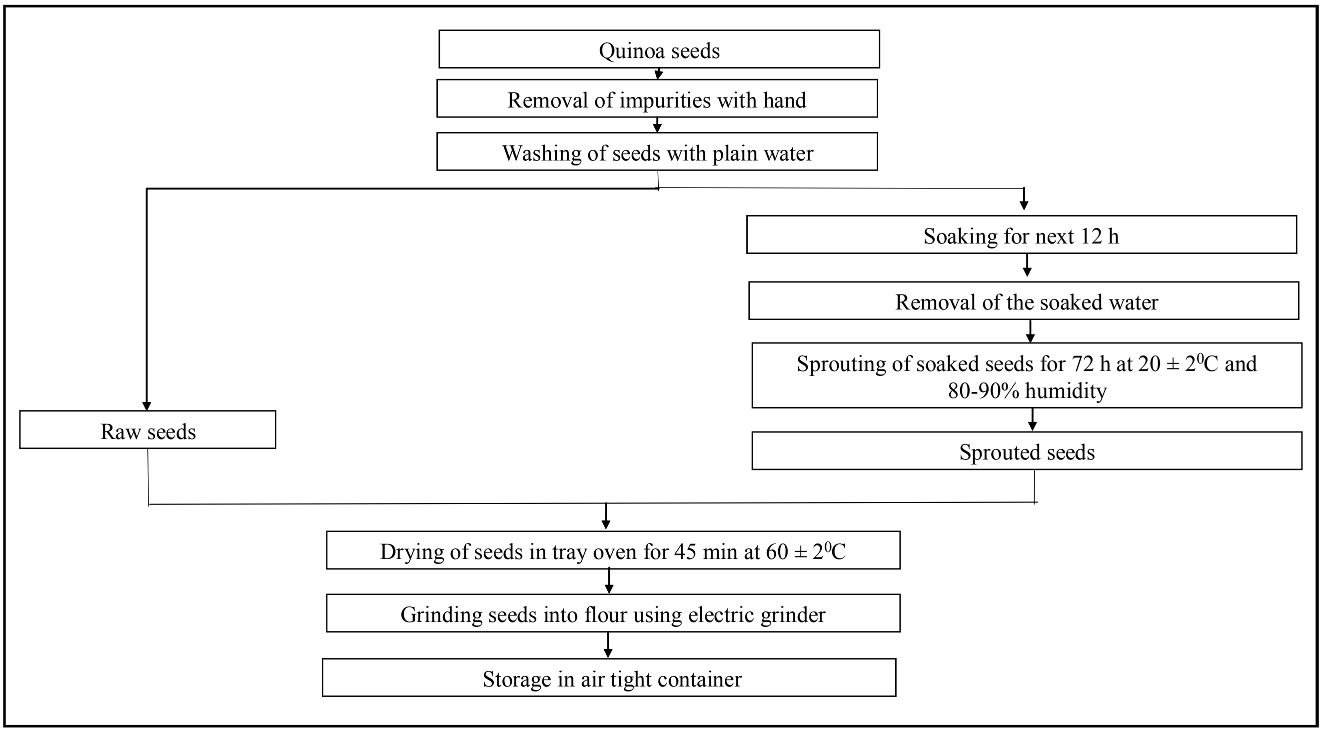

Figure 1: Flow chart for preparation of quinoa flours.

For the preparation of flour from raw quinoa seeds, firstly quinoa seeds were manually cleaned for impurities. The cleaned seeds were washed 2-3 times with clean water, spread out on trays, and oven-dried for 45 min at 60 ± 2^0C. The dry seeds were milled into flour using an electric grinder (Figures 1 and 2). For the development of flour from sprouted seeds, cleaned and washed quinoa seeds were kept for soaking for 12 h, followed by draining off the soaked water and spreading on the muslin cloth placed on the tray. The tray was placed in an incubator for 72 h at 20 ± 2^0C and 80-90% humidity (Carciochi *et al*., 2014). After every 24 h, water was sprinkled on the seeds to provide moisture for the sprouting. The length of quinoa shoot was found to be 7, 10, and 15 mm on 24, 48, and 72 h of germination, respectively. After completion of sprouting process, seeds were dried and ground into flour using an electric grinder as shown in Figures 1 and 2.

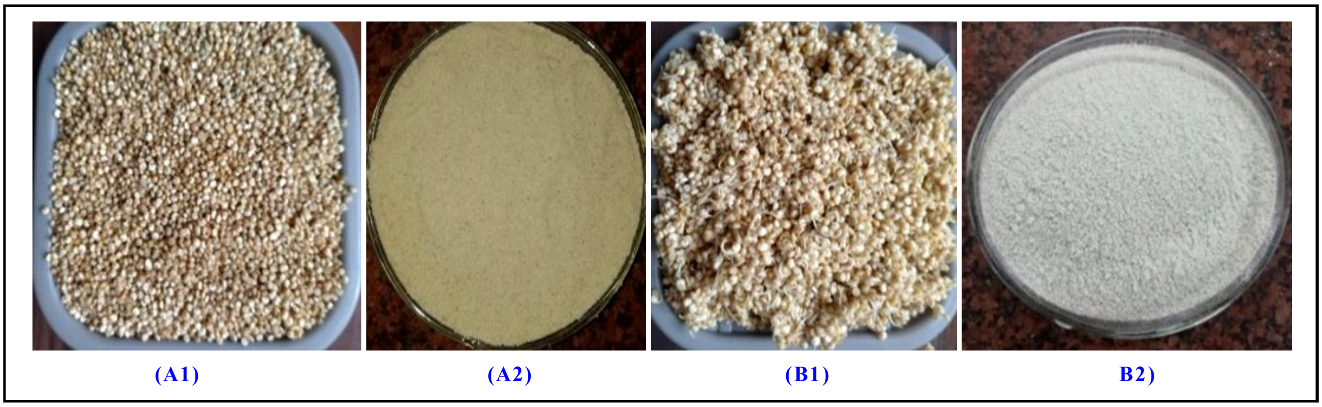

Figure 2: (A1) Raw quinoa seeds, (A2) Raw quinoa flour, (B1) Sprouted quinoa seeds, and (B2) Sprouted quinoa flour.

2.2 Chemicals and reagents

The reagents required for experiments, including Rutin standard, diphenyl-1-picrylhydrazyl (DPPH), Folin-Denis reagent, Folin-Ciocalteau reagent, and gallic acid, *etc*., were bought from Hi Media Laboratories Pvt. Limited. Analytical grade chemicals and reagents were used for experiments.

2.3 Nutritional analysis

Quinoa flours were analyzed for proximate composition using standard methods of AOAC (2012). The crude protein was estimated with the Micro-Kjeldahl approach (AOAC, 2012) using an automatic Kel-Plus Classic-dx device, and physiological energy in the samples was computed (Mudambi and Rao, 1989). The minerals including calcium, magnesium, potassium, and phosphorus were determined with AAS (Atomic Absorption Spectrophotometer). Ash solution for mineral analysis was prepared using the Wet digestion method of Raghumuralu *et al.* (2003) and iron was estimated using Wong's method (1928). Starch and dietary fiber were determined using methods of AOAC (2000) and Asp and Johansson (1981), respectively. Protein bioavailability was evaluated in terms of *in vitro* protein digestibility (Akeson and Stahman, 1964; DeGroot and Slump, 1961).

2.4 Estimation of antinutritional factors

Under antinutritional factors, both raw and sprouted quinoa samples were analyzed for tannins (AOAC, 1970), phytic acid (Jain and Mogra, 2006), and saponin content (Obadoni and Ochuko, 2001).

2.5 Estimation of antioxidants and DPPH free radical scavenging activity

Quinoa flours were analyzed for total phenols and flavonoid content using the methods of Singleton *et al.* (1995). DPPH free radical scavenging activity was assessed following the method of Brand-William *et al.* (1995).

2.6 Development of ready-to-eat snack 'Waffle' using raw and sprouted quinoa flour

In this study, Waffles were developed using raw and sprouted quinoa flours (QF) in combination with whole wheat flour in various proportions, *viz*., 100:0, 40:60, 20:80 and 0:100 (WWF:QF). The purpose of this step was to develop an optimal Waffle with maximum acceptability. Control Waffle (C) was prepared with 100% whole wheat flour, while T1 (40% whole wheat flour and 60% raw quinoa flour), T2 (20% whole wheat flour and 80% raw quinoa flour), T3 (100% raw quinoa flour), T4 (40% whole wheat flour and 60% sprouted quinoa flour), T5 (20% whole wheat flour and 80% sprouted quinoa flour), and T6 (100% sprouted quinoa flour) Waffles were prepared with different combinations of raw and sprouted quinoa flours. Waffles were prepared as per the procedure given in the flowchart (Figure 3) where WWF means whole wheat flour and QF represents quinoa flour.

Sieving of flour (WWF+QF) (100 g), baking powder (5 g), and baking soda (2 g) together

↓

Addition of sugar (47 g) and salt (as per taste) and mixing of all the dry ingredients

↓

Mixing of wet ingredients, *viz.,* milk (180 ml), butter (22 g) and vanilla (4 ml) in a bowl using a blender

↓

Addition of flour mixture to the wet ingredients

↓

Leaving batter undisturbed for 10 min at room temperature

↓

Pre-heating of oven at 220 ^{0}C for 10 min

↓

Greasing of waffle mold with butter and pouring batter into the mold with gentle tapping to remove trapped air

↓

Placing the mold in tray and baking in oven for 15 min

↓

Removing the mold and removing waffle from tray and placing the half cooked waffles upside down on the tray

↓

Baking in oven for another 10 min

↓

Cooling of waffles to room temperature

Figure 3: Development of ready-to-eat snack 'Waffles'.

2.7 Sensory evaluation of Waffles

Sensory quality is an important parameter to assess the product's acceptability among consumers. The present study involved 30 semi-trained panelists to evaluate the sensory attributes of Waffles developed with varying proportions of raw and sprouted quinoa flour. Different sensory variables including texture, colour, taste, flavour, and overall acceptability were assessed using a score card with a maximum of 10 marks (Chowdhary *et al.*, 2011). Along with this, the acceptability of products was also rated using 9-point Hedonic rating scale (Amerine *et al.*, 2013).

2.8 Nutritional composition of Waffles and their nutrient adequacy in the daily diet of Indian children

The nutritive value of control Waffle with 100% whole wheat flour (WWF) and developed Waffles with 100% raw quinoa flour (RQF) and 60% sprouted quinoa flour (SQF) were analyzed using standard methods. Per cent nutrient adequacy of Waffles in the daily diet of Indian children was calculated and compared with the Recommended Dietary Allowances (RDA) (ICMR-NIN, 2020).

2.9 Statistical analysis

Web Agri Stat Package was used for the statistical analysis of data related to nutritional composition, antioxidant content and antinutritional factors. Paired t-test was used to examine the effect of sprouting on the nutritional composition of quinoa. The data pertaining to proximate composition, dietary fiber content, and sensory evaluation was subjected to One-way ANOVA for finding out the significance of difference (Khan and Khan, 1994).

3. Results

3.1 Nutritive value of quinoa flours

The results pertaining to the nutritive value of quinoa flours are given in Table 1. Moisture in raw and 72 h sprouted quinoa flour was 11.01 ± 1.16 and 9.03 ± 0.13%, which is comparable to the findings of Thakur *et al.* (2021) as 10.84 and 8.34%, respectively. Quinoa flour's total ash and fat content decreased by 30.18 and 17.3%, respectively, as a result of sprouting, which was significant (p<0.05). The total ash values for raw and sprouted quinoa flour were 2.22 ± 0.31 and 1.55 ± 0.21%, which was in a range of 1.66-3.46 and 1.45-3.12%, respectively, as expressed by Beniwal *et al.* (2019) and Demir and Bilgici (2020). Crude fat in raw and sprouted quinoa flour was 5.2 ± 0.26 and 4.3 ± 0.30%, respectively, which is in the range given by Bhathal *et al.* (2017) for raw and sprouted quinoa flour. The protein content was found to be 13.4% in raw flour which significantly (p<0.05) increased by 47.76% with sprouting. Jyoti *et al.* (2022) showed comparable values of crude protein (13.01%) in raw quinoa flour. The *in vitro* protein digestibility was observed as 82.9 and 88.6%, respectively, for raw and sprouted quinoa flours.

Carbohydrates are one of the primary nutritious food groups comprising cellulose, sugar, starch, and other similar materials that the body can break down to create energy. Raw and sprouted quinoa flours had respective carbohydrate contents of 64.16 and 58.16%, which slightly varies from the values presented by Thakur *et al.* (2021) (60.12 and 58.02%) and Bhathal *et al.* (2015) (71.71 and 73.37%). Raw quinoa flour's starch content decreased by 25.97% as a result of sprouting, which was significant (p<0.05).The crude fiber in raw quinoa flour was 4.01 ± 0.27%. Sprouted quinoa flour in this study had higher (7.16 ± 0.11%) crude fiber content than 4.58%, as showed by Bhathal *et al.,* (2017). Higher crude fiber levels of 5.56 and 8.50% were expressed by Thakur *et al.* (2021) for both raw and sprouted quinoa flour.

Table 1: Nutritive value of quinoa flours

Parameter	Raw quinoa flour	Sprouted quinoa flour	p-value
Moisture (%)	11.01 ± 1.16	9.03 ± 0.13	NS
Total ash (%)	2.22 ± 0.31	1.55 ± 0.21	0.01*
Crude protein (%)	13.4 ± 0.74	19.8 ± 0.96	0.032*
Crude fiber (%)	4.01 ± 0.27	7.16 ±0.11	0.001*
Crude fat (%)	5.2 ± 0.26	4.3 ± 0.30	0.0007*
Carbohydrate (%)	64.16	58.16	NS
Physiological energy (kcal/ 100 g)	357	351	NS
Starch (%)	51.6 ± 0.70	38.2 ± 0.30	0.0004*
Total dietary fiber (%)	12.81 ± 0.65	21.95 ± 0.14	0.004*
Soluble dietary fiber (%)	4.89 ± 0.03	5.2 ± 0.04	0.001*
Insoluble dietary fiber (%)	7.92 ± 0.03	16.75 ± 0.06	0.002*
In vitro protein digestibility (%)	82.9 ± 1.75	88.6 ± 0.62	0.013*

p-value at 5% level of significance, *Significant difference, NS-Non-significant difference

Dietary fiber is a naturally occurring material present in plants that is resistant to digestion and absorption and are fully or partially fermented in the colon. The total dietary fiber, soluble dietary fiber, and insoluble dietary fiber were estimated to be 12.81, 4.89, and 7.92% for raw quinoa flour and 21.95, 5.2, and 16.75%, respectively, for sprouted quinoa flour in the present study. Contreras-Jimenez *et al.* (2019) showed the soluble dietary fiber content of raw and sprouted quinoa flour in the range of 3.71-3.85% and 3.55-3.75%, respectively, while the insoluble dietary fiber content ranged from 7.91-7.99% and 8.56-9.37%.

Quinoa is high in minerals. It is a rich source of cations like calcium, magnesium, iron, and zinc and has a high content of iron in particular. In the present study, iron, calcium, magnesium, potassium, and phosphorus content in raw quinoa flour were found to be 6.79, 82.67, 118.5, 489.31, and 363.03 mg/ 100 g, respectively (Figure 4). Magnesium considerably reduced by 23.7% after sprouting, whereas iron, calcium, potassium, and phosphorus increased significantly (p<0.05) up to 49, 33.87, 18.39, and 13%, respectively, as a result of the sprouting process.

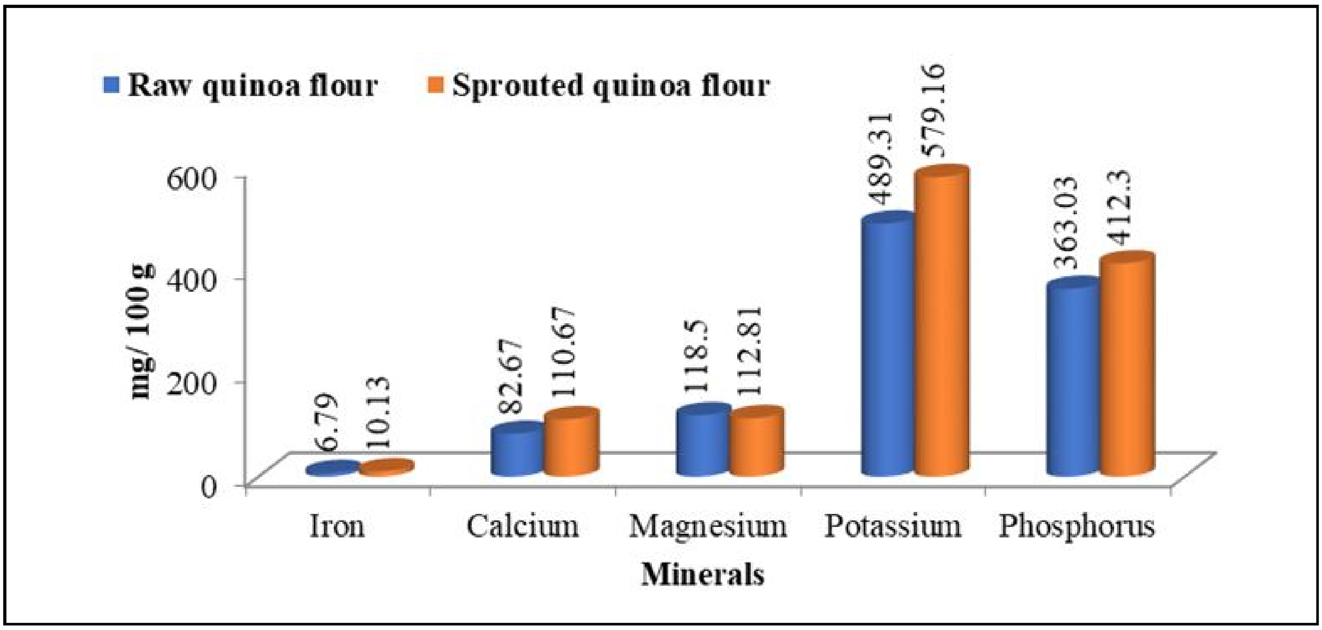

Figure 4: Mineral content of raw and sprouted quinoa flours.

3.2 Antinutritional factors

Table 2 depicts the findings on antinutritional factors present in raw and sprouted quinoa flours. Phytates inhibit the assimilation of certain divalent cations like zinc, iron, calcium, and other nutrients and thus its presence in food must be minimised. The raw quinoa flour's phytic acid level dropped significantly ($p<0.05$) from 0.84 g% to 0.51 g% with sprouting.

Table 2: Antinutritional factors in quinoa flours

Parameter	Raw quinoa flour	Sprouted quinoa flour	*p*-value
Phytic acid (g/100 g)	0.84 ± 0.08	0.51 ± 0.09	0.03*
Tannins (%)	0.048 ± 0.01	0.038 ± 0.01	NS
Saponins (g/100 g)	1.20 ± 0.02	0.56 ± 0.015	0.02*

p- value at 5% level of significance, *Significant difference, NS- Non-significant

The tannin content of quinoa seeds is typically less than 0.6%, which is substantially less than that of rice grains, *i.e.*, 1.3% (Valencia-Chamorro, 2003). The current study found similar results, with the tannin concentration of raw quinoa flour being 0.048%, which decreased to 0.038% with sprouting. Grain bitterness is caused by secondary metabolites called saponins, which are mostly found in the pericarp of the grains. The current research showed saponin concentration of 1.20 g% in raw quinoa flour which is lower than the range of 1.42-1.63 g% (Bhinder *et al.,* 2021; Beniwal *et al.,* 2019).

3.3 Antioxidants

Table 3 shows the findings pertaining to the antioxidant composition and DPHH free radical scavenging activity of raw and sprouted quinoa flours. The potential health advantages of phenols as antioxidants and anti-inflammatory and cardio-protective agents make them essential to the human diet. Raw and sprouted quinoa flour had total phenol content of 1.22 and 2.01 mg GAE/g, respectively. These results were lower than those of Demir and Bilgici (2020), who reported 1.48 and 3.13 mg GAE/g, respectively, but higher than those of Thakur *et al.* (2021) for the quinoa flours.

Flavonoids represent another category of phenolic compounds located in fruits, vegetables and certain cereals, contributing to the colour of most of the fruits and vegetables. These compounds are generally not found in common grains however they are found in abundance in quinoa. In the current investigation, sprouting significantly ($p<0.05$) increased the total flavonoid concentration of raw quinoa flour from 2.78 mg RE/g to 4.01 mg RE/g. Free radicals are the unstable chemicals that are produced during regular cell metabolism. These free radicals have the capacity to accumulate inside cells and damage other molecules, such as DNA, lipids, and proteins. Foods with a strong DPPH free radical scavenging activity can help reduce these free radicals.The raw quinoa flour's DPPH free radical scavenging activity in this investigation was 44.23%, which increased to 51.89% with sprouting.

3.4 Development of ready-to-eat quinoa 'Waffles'

In the present study, control Waffles were made using 100% whole wheat flour following the standard recipe. Both raw and sprouted quinoa flours were added to the control Waffle at the levels of 60, 80, and 100%. One control whole wheat flour and three combinations of 40:60, 20:80, and 0:100 (WWF: QF) for raw (T1, T2 and T3) and sprouted (T4, T5 and T6) quinoa flours were used to make seven different Waffle combinations. All developed products were subjected to sensory evaluation using Score card and Hedonic scale methods to find out the most acceptable product. Table 4 shows the results obtained from Score card method.

Table 3: Antioxidant components of quinoa flour

Parameter	Raw quinoa flour	Sprouted quinoa flour	*p*-value
Total phenols (mg GAE/g)	1.22 ± 0.16	2.01 ± 0.18	0.01*
Flavonoids (mg RE/g)	2.78 ± 0.19	4.01 ± 0.33	0.009*
DPPH free radical scavenging activity (%)	44.23 ± 1.17	51.89 ± 1.59	0.01*

p- value at 5% level of significance, *Significant difference

Table 4: Sensory score card of Waffles

Waffle	Colour	Taste	Texture	Flavour	Overall acceptability
C	8.59 ± 0.87	8.29 ± 0.89	8.19 ± 0.88	8.19 ± 1.03	8.42 ± 0.80
T1	8.00 ± 0.84	7.18 ± 1.13	7.54 ± 1.20	8.27 ± 1.33	7.51 ± 1.01
T2	7.8 ± 0.90	7.11 ± 1.10	7.41 ± 0.97	6.96 ± 0.97	7.20 ± 0.90
T3	7.95 ± 0.82	7.74 ± 1.02	7.71 ± 0.95	8.59 ± 1.05	7.66 ± 1.07
T4	8.42 ± 0.79	8.72 ± 0.71	8.24 ± 0.95	8.65 ± 0.83	8.57 ± 0.75
T5	7.89 ± 0.83	8.19 ± 0.67	7.98 ± 0.82	8.05 ± 0.75	8.07 ± 0.65
T6	7.78 ± 0.94	8.16 ± 0.80	7.92 ± 0.85	7.96 ± 0.81	8.00 ± 0.79
CD (1%)	0.44	0.47	0.49	0.51	0.45
CV	10.90	11.91	12.52	13.06	11.26

The control, 60% RQF, 80% RQF, 100% RQF, 60% SQF, 80% SQF, and 100% SQF Waffles received an overall acceptability score of 8.42, 7.51, 7.20, 7.66, 8.57, 8.07, and 8.00, respectively. The results showed that the Waffles made with 100% RQF and 60% SQF had the highest scores of 7.66 and 8.57 among all developed combinations with incorporations of quinoa flours, while, the control Waffles had a score of 8.42. This indicated that the sprouting improved the acceptability of quinoa Waffles over wheat Waffles.

Hedonic scale indicates the extent of evaluators overall liking and disliking for the product. The results presented in Table 5 shows that 60% sprouted flour incorporated Waffles were ‘Liked extremely’ by maximum panel members (23%), followed by the control Waffles as 20% panelists rated it as “Like extremely”. Most of the products were “liked moderately” as it was chosen for maximum number of times ranging from 20-53%. The only sample that was rated as “Dislike slightly” was 80% raw quinoa flour incorporated Waffles. No sample was rated below the category of ‘dislike slightly’.

Table 5: Hedonic scores of Waffles

Sample	Per cent of panel members					
	Like extremely	Like very much	Like moderately	Like slightly	Neither like nor dislike	Dislike slightly
C	20	53	20	7	-	-
T1	6	17	53	7	17	-
T2	-	10	30	36	17	7
T3	3	23	40	34	-	-
T4	23	27	50	-	-	-
T5	13	33	37	17	-	-
T6	10	47	33	10	-	-

Table 6: Nutrient composition of control and most acceptable quinoa Waffle

Nutrient/100 g Waffle	Control Waffle	100% RQF Waffle	60% SQF Waffle
Crude protein (g)	5.79^{c}	6.72^{b}	9.38^{a}
Crude fat (g)	10.31^{b}	11.58^{a}	10.91^{b}
Iron (mg)	0.33^{b}	2.35^{a}	2.38^{a}
Calcium (mg)	80.96^{b}	101.66^{a}	98.96^{a}
Physiological energy (kcal)	285^{b}	297^{a}	290^{a}

^{abc}Significant differences between values with various superscript letters

3.5 Nutritional contribution of Waffles in daily diet of Indian children

Table 6 shows that both raw and sprouted quinoa flour Waffles had better nutritional profile with significantly (p<0.05) higher values of crude protein, crude fat, iron, calcium, and physiological energy than the control Waffles.

Sprouted quinoa flour Waffles had a considerably (p<0.05) higher crude protein content as compared to control Waffles. Iron, calcium, and energy content were highest in raw quinoa flour Waffles, which were significantly (p<0.05) higher than the control Waffles yet non-significantly (p<0.05) higher than sprouted quinoa flour Waffles.

The per cent nutrient adequacies fulfilled by one serving of Waffle (75 g) are presented in Figures 5 and 6.

The figures show that one serving of 100% raw and 60% sprouted quinoa flour Waffles were able to meet 9.8-13.12% and 17.75-26.6% of the RDA for energy and protein, respectively, for the children belonging to the age group of 7-12 years. Similarly, one serving of quinoa Waffles was able to meet 11-15% and 11-17% of the daily calcium and iron requirement for children aged 7-12 yrs. Hence, consuming quinoa Waffles can contribute significantly to a child's calcium and iron intake and prevent both macro and micronutrient deficiencies.

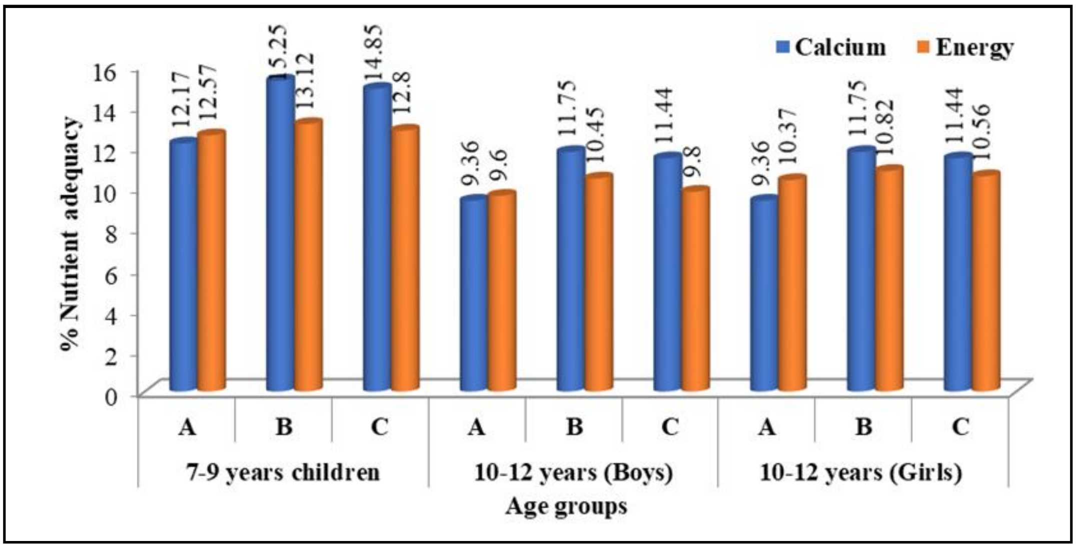

Figure 5: Per cent adequacy of energy and calcium (A: Control Waffle, B: Waffle prepared with 100% RQF, and C: Waffle prepared with 60% SQF and 40% WWF).

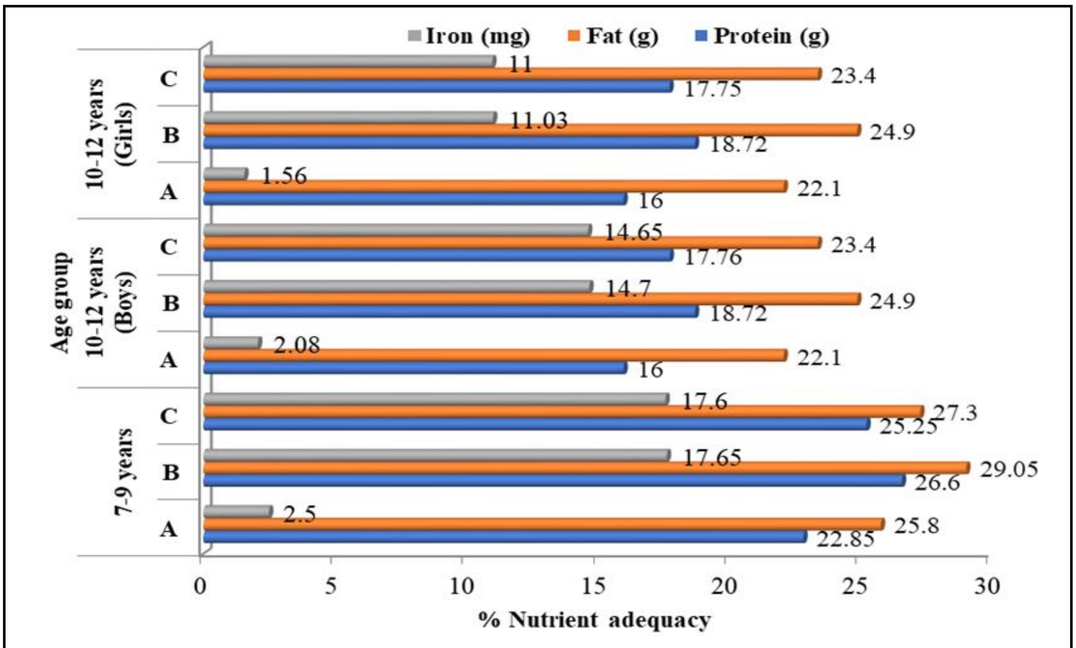

Figure 6: Per cent adequacy of protein, iron and fat (A: Control Waffle, B: Waffle prepared with 100% RQF, and C: Waffle prepared with 60% SQF and 40% WWF).

4. Discussion

Quinoa, a pseudocereal, is known as a “superfood” because of its rich nutrient and bioactive compounds composition and health benefits, which are comparable to the millets. The current research assessed the effect of sprouting on the nutritive value of quinoa (*Chenopodium quinoa* Willd.) and the development of a ready-to-eat snack ‘Waffle’ with the incorporation of raw and sprouted quinoa flours. Following sprouting, quinoa flour’s moisture content dropped by 17.9%, which is consistent with the observations of Bhinder *et al*. (2021). Even though, there was no significant decrease in moisture content, quinoa flour’s stability and shelf-life will be improved by lowering microbial activity. It was observed that the ash content significantly decreased with sprouting (30.18%), which may be due to the leaching of some minerals during the washing, soaking, and germination steps. The crude fat decreased by 17.3% as a result of enhanced lipolytic enzyme activity during the sprouting process, which may aid in extending the shelf-life of flour.

Protein availability at the intestinal absorption level is shown by *in vitro* protein digestibility. The present study showed an increase in both the parameters depicting the quantity and quality of protein, *i.e.*, crude protein and *in vitro* protein digestibility. The rise in protein parameters with sprouting may be due to the enhancement of protein solubility, the reduction in the level of protease inhibitors, and the increase of intrinsic protease hydrolysis activity (Pathak and Singh, 2022; Dobhal and Raghuvanshi, 2023). Kulla *et al*. (2021) showed the crude protein in raw and 6 h sprouted little millet flour as 12.05 and 11.14%, foxtail millet flour as 11.14 and 10.75%, and barnyard millet flour as 10.19 and 10.9%, respectively. The higher crude protein content and *in vitro* protein digestibility of quinoa flour contribute to its greater ability to absorb water. Water absorption capacity is an important functional property affecting the sensory attribute of the food products developed with quinoa flour (Dobhal and Raghuvanshi, 2018).

Sprouting may reduce the starch content of quinoa flour while have no effect on the total carbohydrate content. Alpha-amylase converts complex carbohydrates like starch into simpler forms that the sprouts during early stage sprouting might utilize. The reduction in starch content with sprouting might be due to the higher activity of this enzyme. Following sprouting, the crude fat and carbohydrate content in quinoa flour decreased which led to a non-significant decrease in physiological energy (1.5%) as well.

The current study confirmed that sprouting may be a useful method for increasing the amount of fiber in the diet as it increased the crude fiber content of quinoa flour by 74.6%. Fiber content in food can be analysed in 2 terms, *i.e.*, crude fiber and dietary fiber. Since crude fiber analysis only measures a portion of the plant cell wall components, primarily cellulose and lignin, and ignores soluble fibers and other non-cellulosic polysaccharides present in food, it significantly underestimates the actual fiber content, sometimes by as much as 50% or more. For this reason, estimating dietary fibre is crucial while creating food products for human health (Mezzatesta *et al*., 2020). The current study revealed that both raw and sprouted quinoa flours are rich sources of dietary fiber, with values of 12.81 and 21.95%, respectively. Following sprouting, new polysaccharides were synthesized and total dietary fiber content increased by 71.35%. The insoluble fiber promotes faster food passage through the digestive tract and adds bulk to feces. In the current study, the insoluble dietary fiber and soluble dietary fiber content of raw quinoa flour increased by 111.49 and 6.34%, following sprouting. This could be due to the leaching of soluble fibers during the washing, steeping, and sprouting processes. The soluble fiber dissolves plays a cardio-protective role in the body by preventing cholesterol from accumulating in the walls of blood vessels. Additionally, this type of dietary fibre aids in blood sugar level stabilization, which is beneficial for diabetics.

Quinoa has a lot of minerals. It has high iron content in particular and is a good source of other divalent cations like calcium, magnesium, iron, and zinc. These minerals are distributed in different layers of cereals as the embryo is rich in potassium and magnesium, whereas calcium and phosphorus are present in higher amounts in the pericarp. The decrease in magnesium content of raw quinoa flour with sprouting in the present study may be due to its loss during washing, steeping and sprouting. The decrease in antinutritional factor content, which was also noticeable in this study, may have contributed to the increase in amounts and availability of cations like iron, magnesium, and phosphorus.

Quinoa contains some antinutritional elements, such as tannins, saponins, and phytates, which may have a negative impact on the nutritional and other quality parameters of food products made with quinoa. In the current investigation, phytic acid decreased by 39.28% with sprouting, which is lower than the decrease reported by Padmashree *et al*. (2018) as 50%. The breakdown of phytic acid to phosphorus, which is to be utilized by the seeds during sprouting, could be the possible cause of the reduction in the content of this antinutritional factor. Saponins are the secondary products of metabolism that may be responsible for the bitterness of the seeds. These compounds have hemolytic, membranolytic, and fungitoxic properties which categorize them under the antinutritional factors (Singh and Trivedi, 2017). Depending on the concentration of saponins, quinoa is usually classified as either ‘sweet’ or ‘bitter’. Sweet genotype seeds had saponin levels between 0.02 and 0.04%, while bitter genotype seeds had levels between 0.14 and 2.3%. Processing methods such as mechanical dehulling by abrasion, sprouting or washing before cooking might lower the saponin concentration of quinoa grains (Guclu-Ustundag and Mazza, 2007). This was also seen in the current investigation, when quinoa flour’s saponin concentration significantly decreased (54.9%) during sprouting, possibly as a result of leaking during washing and soaking.

The main forms of polyphenols in quinoa include flavonoids, tannins, total phenols, and orthodihydroxy phenols. In the current study, the total phenol content in quinoa flour significantly increased by 64.75% with sprouting. Flavonoids are the compounds with several health advantages, including antioxidant activity, and positive role in preventing the risk of diabetes mellitus, cancers, and cardiovascular diseases. The present investigation found that sprouting significantly ($p<0.05$) increased the flavonoid content in raw quinoa flour (44.24%). The increase in antioxidant compounds has been linked to either the synthesis of new or the breakdown of bound polyphenolic compounds with the help of enzymes. Food must be oxidized in body to produce energy, but if the oxidation process occurs too often, free radical species may accumulate. The body is negatively impacted by free radicals (Gupta and Gupta, 2015) and thus, foods with high DPPH free radical scavenging capacity are beneficial in quenching the free radicals. The present study showed an increase of

17.31% in the DPPH free radical scavenging activity of raw flour with sprouting, reaching to value of 51.89%.

'Waffles' are wheat-based ready-to-eat snacks. The present study involved the development of 'Waffles' with the incorporation of raw and sprouted quinoa flours. The results of sensory evaluation based on score card method showed that the Waffles made with 100% raw and 60% sprouted quinoa flour had the highest scores of 7.66 and 8.57, respectively, among all combinations. The values for nutrient composition of 100 g Waffles showed that raw as well as sprouted quinoa flour Waffles had a higher content of crude protein, crude fat, iron, calcium, and physiological energy values as compared to control Waffles. Priya Rani *et al*. (2024) showed almost similar crude protein content of 9.5% but higher physiological energy of 417 kcal in 50% sprouted quinoa flour gluten-free chikki.

One serving (75 g) of raw (100%) and sprouted (60%) quinoa flour Waffles was able to meet 9.8-13.12% of the RDA for energy and 17.75-26.6% of protein requirements for children of 7-12 years. It was also able to meet 11-15% of the daily calcium requirement and 11-17% of the iron requirement for children belonging to the age group of 7-12 years. Adequate calcium consumption throughout a child's development is vital for proper bone mineralization, achieving peak bone strength, and minimizing the risk of osteoporosis in adulthood. Consuming quinoa Waffles can contribute significantly to a child's calcium intake and support bone health. Iron deficiency, the world's most prevalent nutritional deficiency, is a significant health concern, particularly in developing nations but also prevalent in industrialized countries. The high nutritive value of quinoa flours and Waffles makes it an appropriate option for value addition to children's diets for preventing both macro and micronutrient deficiencies.

5. Conclusion

The present study concludes that both raw and 72 h sprouted quinoa flour are highly nutritious. Quinoa flours were successfully used to replace whole wheat flour in development of Waffles. Raw and sprouted quinoa flour incorporated Waffles were found to be nutrient-rich snacks that can be a healthy option for people of all ages. In today's world, where nutritional deficiencies and lifestyle disorders are prevalent, quinoa Waffles can offer a healthy alternative. A single serving of quinoa flour incorporated Waffles is able to meet about 9.8-26.6% daily requirements of macro and micronutrients for children aged 7-12 years, making quinoa flour and Waffles, a healthy alternative for value addition to children's diets for preventing the triple burden of malnutrition, *i.e*., undernutrition, overnutrition, and the hidden hunger.

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Conflict of interest

The author declares no conflicts of interest relevant to this article.

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