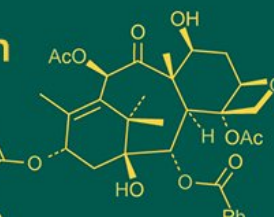


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Formulation and quality evaluation of quinoa-enriched functional spaghetti: Nutritional, antioxidant, cooking, color, and textural characteristics

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Abstract

Food security and nutrition-related health challenges are intensifying globally due to rapid population growth, rising chronic diseases, and an aging population. This study aimed to develop functional spaghetti enriched with quinoa flour to enhance its nutritional and health-promoting properties. Quinoa, a nutrient-dense and climate-resilient pseudocereal, was incorporated into spaghetti formulations to improve protein, fiber, and antioxidant content. The prepared samples were analyzed for proximate composition, cooking quality, antioxidant activity, total phenolic content, color, and textural properties using standard methods. Results revealed that increasing quinoa incorporation significantly improved protein (up to 15.23%), fat, fiber, and ash content, while reducing carbohydrate levels. Antioxidant activity and total phenolic content were markedly enhanced, with maximum DPPH inhibition of 54.46% observed in quinoa-rich samples. However, cooking quality parameters such as cooking loss increased, while water absorption and swelling capacity decreased due to the absence of gluten. Color analysis indicated darker, more reddish-yellow tones in quinoa-enriched spaghetti. Textural analysis showed variations in hardness, springiness, and chewiness, reflecting structural changes in gluten-free formulations. Overall, quinoa fortification significantly enhanced the nutritional and functional attributes of spaghetti, suggesting its potential as a health-oriented alternative to conventional pasta.

Keywords: Quinoa, functional food, spaghetti, antioxidant activity, nutritional enhancement, cooking quality

Introduction

Food security and health are pressing global challenges, especially in developing nations, as the population is expected to rise to over 9 billion by 2050, increasing food demand by 70% to 100% (Godfray *et al.*, 2010) [18]. Currently, nearly 1 in 8 people suffer from chronic undernourishment (FAO, IFAD, WFP, 2014) [6], and metabolic diseases like diabetes and obesity are widespread (Standl *et al.*, 2019) [19]. The aging population will further exacerbate these issues, with a higher incidence of age-related illnesses like osteoporosis and cardiovascular diseases (Song *et al.*, 2024) [18]. Sustainable food production is crucial to address these challenges. Functional foods, which offer specific health benefits beyond basic nutrition, have become increasingly important. Spaghetti, a popular food staple due to its low cost, low glycemic index, and ease of preparation, is primarily composed of carbohydrates and protein but is deficient in essential nutrients like dietary fiber, vitamins, and minerals (Sissons *et al.*, 2016) [17]. The addition of non-traditional, nutrient-rich ingredients is recommended to improve its nutritional profile (Bustos *et al.*, 2015). Quinoa (*Chenopodium quinoa* Willd), a highly nutritious and climate-resistant pseudocereal, offers significant potential to enhance the nutritional value of spaghetti. Rich in bioactive compounds with health benefits, quinoa can thrive in adverse conditions, making it a valuable crop for sustainable food production (Ruiz *et al.*, 2016) [14]. Incorporating quinoa into spaghetti could provide a functional, nutritious alternative, aligning with the growing demand for healthier food options.

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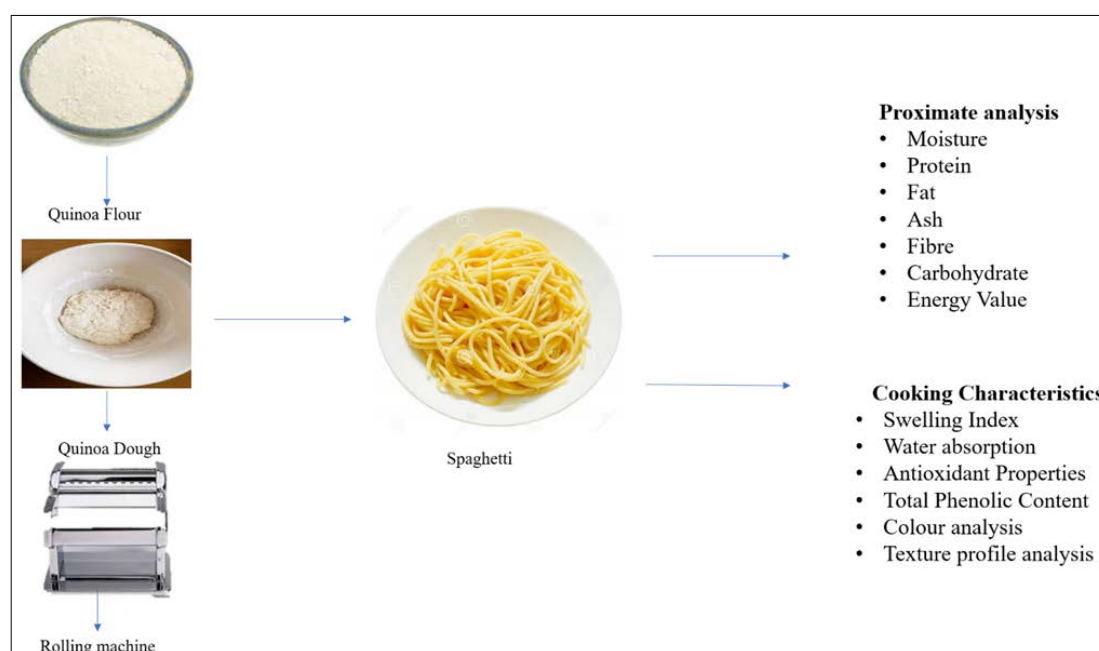


Fig 1: Preparation and Evaluation of Quinoa Spaghetti

Materials and methods

Quinoa flour was purchased from Keshav Global Exim, Ahmedabad, and Refined wheat flour was purchased from the local market of Varanasi, India. All chemicals, solvents, and reagents were analytical grade. Chemicals were obtained from HiMedia Laboratories Limited, Mumbai, India, and Sigma Aldrich Bengaluru, India.

Preparation of spaghetti

The production of quinoa spaghetti begins with the collection of high-quality quinoa seeds. These seeds are carefully sourced from reliable suppliers or cultivated under controlled conditions to ensure optimal quality and consistency. Once harvested, the quinoa seeds are thoroughly washed to remove any impurities, dust, or foreign particles. This cleaning process is essential to ensure that the seeds are free from contaminants before further processing. After washing, the quinoa seeds are subjected to a drying process. This is typically done by spreading the seeds out in a well-ventilated area or using specialized drying equipment. The drying process ensures that the seeds reach an appropriate moisture content, which is crucial for effective grinding and to prevent spoilage during storage. The dried quinoa seeds are then ground into a fine flour using a milling machine or other grinding equipment. The grinding process is critical in achieving the desired consistency and texture of the flour, which will form the base for the spaghetti dough. The quinoa flour is combined with additional ingredients, such as water, salt, or any other binding agents, depending on the recipe or desired product characteristics. The ingredients are mixed thoroughly to form a uniform dough. This step is essential to ensure proper texture and elasticity in the final product. The mixed

dough is kneaded to develop the desired texture and consistency. Kneading is a crucial step in the spaghetti-making process, as it helps to activate the gluten-free binding agents, providing the dough with the necessary firmness and elasticity required for spaghetti shaping. After kneading, the dough is allowed to rest for a period of time. This resting phase helps to relax the dough, making it easier to roll and shape. It also allows the ingredients to fully hydrate and integrate, contributing to a more cohesive dough structure. Following the resting period, the dough is passed through a rolling machine to achieve a thin, even layer. The rolling process helps to standardize the thickness of the dough, which is critical for uniform cooking and texture in the final product. The rolled dough is then cut into the desired shapes using specialized cutters. For spaghetti, this typically involves cutting the dough into long, thin strands. The shape of the spaghetti can be adjusted depending on the product specification or consumer preference. Once the spaghetti has been cut, it is dried again to reduce its moisture content. The drying process helps preserve the spaghetti, ensuring it remains shelf-stable and ready for packaging. This step also helps maintain the spaghetti's texture and prevents it from becoming mushy during cooking. The dried quinoa spaghetti is then carefully packaged in low-density polyethylene (LDPE) bags. These bags are commonly used in food packaging due to their flexibility and ability to provide a moisture barrier, ensuring the product remains fresh and protected from contamination. Finally, the packaged quinoa spaghetti is stored in a cool, dry place to maintain its quality and prevent spoilage. Proper storage conditions are essential to prolong the shelf life of the product and ensure that it retains its texture and nutritional value until it reaches the consumer.

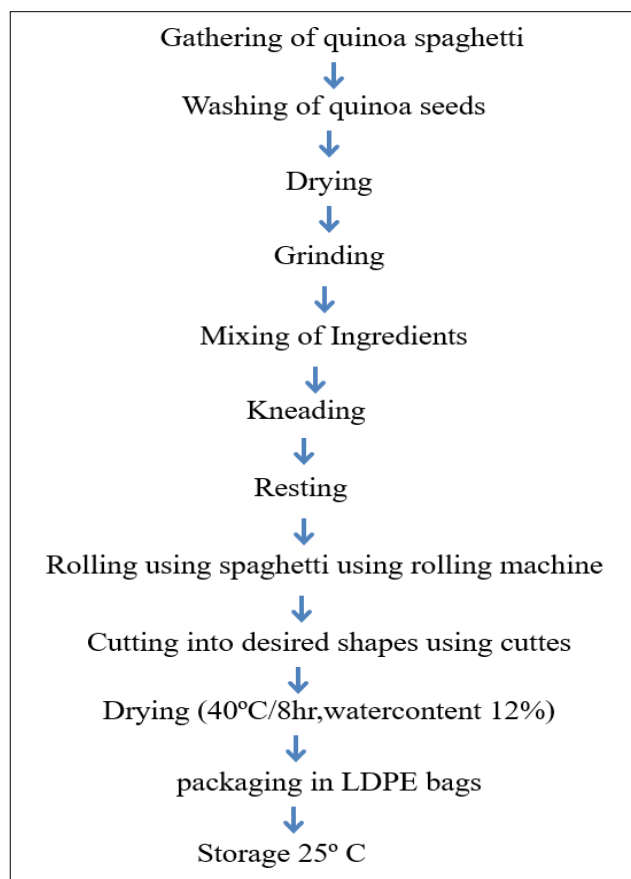


Fig 2: Flow chart of functional spaghetti

Proximate analysis of functional spaghetti

The moisture, protein, fat, fiber and ash contents of spaghetti samples were determined using the (AOAC method, 1975) [2]. The carbohydrate content of the sample was determined by the difference method

$$\% \text{carbohydrate} = 100 - (\% \text{Moisture} + \% \text{Fat} + \% \text{Protein} + \% \text{Ash}).$$

Energy value in terms of Total calorie content was measured as per (Hailu Kassegn, 2018) [9].

$$\text{Total calorie content} = (\% \text{carbohydrate} \times 3.87) + (\% \text{Fat} \times 8.79) + (\% \text{Protein} \times 4.27).$$

Cooking characteristics of functional spaghetti

Cooking quality characteristics of functional spaghetti, where cooking loss was determined according to AACC approved method (2000) [1].

Swelling index and water absorption

Swelling index was determined according to (Devi & Sit, 2019) [5]. Water absorption was determined according to (Bianchi *et al.*, 2021) [3]. This involved taking 25 grams of spaghetti and cooking it for the recommended 12 minutes; the cooking liquid was then drained and allowed to cool until it reached a temperature of 20°C. After that, an analytical scale (Precisa XB-220a) was used to record the weight of the cooked and dry spaghetti. The swelling index (SI) and water absorption index (IA) were calculated through the following formula:

$$\% \text{SI} = \frac{\text{Weight of cooked spaghetti}}{\text{Weight of dry spaghetti}} \times 100$$

$$\% \text{IA} = \frac{\text{Weight of cooked spaghetti} - \text{Weight of dry spaghetti}}{\text{Weight of dry spaghetti}} \times 100$$

Determination and extraction of antioxidant properties and total phenolics content of functional spaghetti

The DPPH scavenging ability of the sample extract was determined according to (Cervato *et al.*, 2000) [4] with minor adjustments. 1 ml of the diluted extract was mixed with 3 ml of a 60 µM DPPH methanol solution. The mixture was then incubated in the dark at room temperature for 30 minutes. Afterward, the absorbance was recorded at 517 nm using a spectrophotometer (Jenway, 6405 UV/Vis, United Kingdom). A control sample containing methanol and DPPH solution was also tested. The DPPH inhibition percentage was calculated using the following equation:

$$\% \text{DPPH inhibition} = \frac{\text{Abs 517 (reference)} - \text{Abs 517 (Sample)}}{\text{Abs 517 (reference)}} \times 100$$

Where,

Abs517 reference is the absorbance reading of the reference, and Abs517 sample is the absorbance reading of the sample. The total phenolics content of the samples was determined using the Folin-Ciocalteu method as described by (Singleton *et al.*, 1999) [16]. Briefly, 300 µL of the sample extract was mixed with 1.5 mL of Folin-Ciocalteu reagent and 1.2 mL of 7.5% Na₂CO₃ solution in a test tube. The mixture was then incubated in the dark at room temperature for 30 minutes. The absorbance was measured at 765 nm against a blank. The total phenolics concentration was calculated and

expressed as gallic acid equivalent (GAE) in mg/g of the sample.

Colour analysis

The color of both uncooked and cooked spaghetti samples was measured using a colorimeter (Minolta CR-400, Inc., Japan). Readings were taken at various random points on the surface of the uncooked and cooked spaghetti. The measurements recorded included lightness (L^*), redness (a), and blueness (b) values.

Textural profile analysis

Textural parameters of Functional spaghetti such as Hardness, Fracturability, Cohesiveness, Springiness, Gumminess, and Chewiness were analyzed using a Brookfield Ametex CT3 texture analyzer at 2.0 mm/s TA 75 Probe, United State (Padalino *et al.*, 2017).

Results and discussion

Nutritional value of spaghetti

The results of nutritional analysis of quinoa flour-based spaghetti are shown in Table 1. The protein content

increased from 10.56% in sample MS00 to 15.23% in sample QS00, demonstrating a significant rise as the proportion of quinoa flour increased. Meanwhile, fat content also showed an upward trend, increasing from 1.45% in MS00 to 6.87% in QS00. Conversely, carbohydrate content decreased from 77.89% in MS00 to 63.14% in QS00, indicating a shift in macronutrient distribution with the incorporation of quinoa flour. Moisture content rose from 3.22% in MS00 to 9.45% in QS00, while ash content saw a slight increase from 1.12% in MS00 to 2.61% in QS00. Additionally, the crude fiber content increased from 0.98% in MS00 to 3.14% in QS00. These changes highlight how the nutritional composition of the spaghetti samples was influenced by the varying treatments. Similar trends were observed by (Torres *et al.*, 2021) ^[20], who reported increases in protein and fiber content and decreases in carbohydrate content when quinoa flour was incorporated into bakery products. This suggests that quinoa flour consistently enhances the nutritional profile of various food products by increasing protein and fiber content while reducing carbohydrate levels.

Table 1: Effect of different formulation treatments on the proximate composition of spaghetti. Values are expressed as mean $\pm$ SD ($n = 3$). Different superscript letters within the same row indicate significant differences among treatments ($P < 0.05$)

Parameters	Treatments				
	MS00	QS50	QS60	QS80	QS00
Fat %	1.301 $\pm$ 0.002 ^a	3.501 $\pm$ 0.002 ^e	4.121 $\pm$ 0.007 ^c	5.061 $\pm$ 0.006 ^d	6.102 $\pm$ 0.001 ^f
Protein %	10.201 $\pm$ 0.004 ^a	12.101 $\pm$ 0.280 ^f	12.482 $\pm$ 0.444 ^d	13.245 $\pm$ 0.018 ^e	14.101 $\pm$ 0.002 ^g
Carbohydrates %	83.601 $\pm$ 0.013 ^a	75.102 $\pm$ 0.030 ^f	72.996 $\pm$ 0.047 ^d	69.538 $\pm$ 0.009 ^e	64.231 $\pm$ 0.040 ^g
Moisture %	3.331 $\pm$ 0.040 ^a	6.156 $\pm$ 0.027 ^d	6.725 $\pm$ 0.012 ^c	7.764 $\pm$ 0.009 ^d	9.106 $\pm$ 0.013 ^e
Ash %	1.111 $\pm$ 0.009 ^a	1.754 $\pm$ 0.014 ^e	1.965 $\pm$ 0.013 ^c	2.251 $\pm$ 0.009 ^d	2.564 $\pm$ 0.012 ^f
Crude Fiber %	0.543 $\pm$ 0.006 ^a	1.504 $\pm$ 0.006 ^d	1.704 $\pm$ 0.009 ^b	2.102 $\pm$ 0.007 ^c	2.531 $\pm$ 0.010 ^e

Cooking characteristics of spaghetti

The cooking quality characteristics of spaghetti including cooking loss, water absorption, and swelling capacity, are crucial for determining its overall quality and consumer acceptance. A lower cooking loss indicates higher quality spaghetti, as it signifies fewer soluble starches and other components leaching into the cooking water, which can otherwise make the water thick and less desirable. In the study by (Torres *et al.*, 2021) ^[20] similar trend was observed as in this study, the cooking loss increased significantly ($p < 0.05$) as the proportion of quinoa flour increased, with the lowest loss observed in the MS00 sample (2.53 g/100 g) and the highest in QS50 (7.44 g/100 g). This suggests that the control sample (MS00) retains its structure better during cooking, potentially due to a more robust gluten network, which is essential for maintaining the integrity of the spaghetti during the cooking process. Water absorption

decreased as the quinoa flour content increased, with MS00 showing the highest absorption (3.78 ml/g) and QS00 the lowest (1.24 ml/g). This trend indicates that lower water absorption in higher quinoa content samples might be due to the absence of gluten, which typically aids in binding water. The ability of spaghetti to absorb water is vital for achieving the desired texture and mouthfeel, as it influences the final product's firmness and palatability. Similarly, swelling capacity, which indicates the amount of water absorbed by starch and proteins during cooking, decreased with increasing quinoa content, from 71.57% in MS00 to 39.14% in QS00. According to (Gaikwad *et al.*, 2021) ^[7], this reduction in swelling capacity suggests that the spaghetti may become less desirable in texture as quinoa flour replaces traditional wheat flour, which is known for its superior swelling properties.

Table2: Effect of different formulation treatments on the cooking characteristics of spaghetti. Values are expressed as mean $\pm$ SD ($n = 3$). Different superscript letters within the same row indicate significant differences among treatments ($P < 0.05$)

Samples	Loss due to cooking (G/100G)	Water absorption (ML/G)	Swelling capacity %
MS00	2.53 $\pm$ 0.010 ^a	3.78 $\pm$ 0.011 ^a	71.57 $\pm$ 0.001 ^a
QS50	7.44 $\pm$ 0.009 ^e	1.52 $\pm$ 0.026 ^f	44.00 $\pm$ 0.003 ^e
QS60	7.43 $\pm$ 0.030 ^d	1.96 $\pm$ 0.009 ^e	50.34 $\pm$ 0.004 ^e
QS80	7.34 $\pm$ 0.026 ^c	2.41 $\pm$ 0.020 ^d	56.33 $\pm$ 0.001 ^d
QS00	7.24 $\pm$ 0.010 ^e	1.24 $\pm$ 0.015 ^g	39.14 $\pm$ 0.003 ^f

Antioxidant properties of spaghetti

The DPPH assay is widely used to evaluate antioxidant activity, which is based on the ability to donate hydrogen

atoms (Scherer and Godoy, 2009) ^[15]. Antioxidant activity values above 0.5 indicate strong antioxidant properties. The table shows that all samples in this study demonstrated

significant antioxidant activity, with the QS00 sample showing the highest DPPH free radical inhibition at 54.46%. This is notably higher than the MS00 sample, which had only 3.24% inhibition, indicating that the quinoa flour significantly boosted the antioxidant properties of the spaghetti.

Phenolic compounds are known for their antioxidant properties, and the total phenolic content in the samples reflects this. The control sample MS00 had the lowest phenolic content (1.20 mg GAE/g), while the QS00 sample had the highest (6.71 mg GAE/g), suggesting that the increase in quinoa flour content directly contributes to the

phenolic content. This finding is consistent with previous studies showing that phenolic-rich foods have strong antioxidant activity.

As indicated in other studies, the phenolic content and antioxidant activity can decrease after cooking due to thermal degradation and leaching of phenolic compounds into the cooking water (Verardo *et al.*, 2011; Hirawan *et al.*, 2010) [10, 21]. This table, however, only shows the results before cooking, which suggests that incorporating quinoa flour into spaghetti could effectively enhance its antioxidant potential.

Table 3: Antioxidant properties of spaghetti formulated with different treatment combinations. Values are expressed as mean $\pm$ SD (n = 3). Different superscript letters within the same row indicate significant differences among treatments ($P < 0.05$)

Samples	% DPPH free radical Inhibition	Total Phenolics (mg GAE/G)
MS00	03.24 $\pm$ 0.161 ^a	1.20 $\pm$ 0.026 ^a
QS50	47.35 $\pm$ 0.064 ^e	6.39 $\pm$ 0.025 ^d
QS60	38.05 $\pm$ 0.055 ^e	6.21 $\pm$ 0.066 ^c
QS80	29.17 $\pm$ 0.070 ^d	5.91 $\pm$ 0.010 ^b
QS00	54.46 $\pm$ 0.115 ^f	6.71 $\pm$ 0.031 ^e

Color analysis

The colour analysis as per Table 4 demonstrated significant differences between control and quinoa-incorporated (T4) samples. The control sample exhibited higher lightness (L*), with values of 70.65 (cooked) and 54.86 (uncooked), compared to the T4 sample's values of 61.77 (cooked) and 48.53 (uncooked), indicating that quinoa incorporation darkened the spaghetti. The T4 samples also showed increased redness, with a* values of 4.91 (cooked) and 2.93

(uncooked), compared to the control's 1.46 (cooked) and 2.53 (uncooked). Additionally, the T4 samples had higher yellowness, with b* values of 16.85 (cooked) and 13.59 (uncooked), compared to the control's 15.32 (cooked) and 12.24 (uncooked). These findings align with recent studies by (Pathre *et al.*, 2020), which indicate that quinoa incorporation can significantly alter the color profile of food products, impacting their visual appeal and consumer acceptance.

Table 4: Effect of different formulation treatments on the color parameters (L*, a*, and b*) of cooked and uncooked spaghetti

Sample	State	L*	A*	B*
MS00	Cooked	70.65	1.46	15.32
	Uncooked	54.86	2.53	12.24
QS50	Cooked	61.77	4.91	16.85
	Uncooked	48.53	2.93	13.59

Textural profile analysis

Textural parameters of Functional spaghetti such as Hardness, Adhesiveness, Resilience, Cohesiveness, Springiness, and Chewiness were analyzed using Brookfield Ametex CT3 texture analyzer at 2.0 mm/s TA 75 Probe. The textural properties of spaghetti samples are analyzed here in the following Table 5 and Table 6. Comparing the control spaghetti to the spaghetti fortified with quinoa, a noteworthy rise was observed in every TPA measure. Likewise, comparable trends were seen in spaghetti fortified with quinoa and control, with hardness continuing to decrease in

response to higher concentrations of quinoa flour. The hardness of the fortified spaghetti could be mostly determined by the strength of its gluten network (Ogawa and Adachi, 2017) [11]. Springiness and chewiness show increasing values with higher concentrations of quinoa flour. There were no significant differences observed in the values of cohesiveness and resilience. However, the parameters of cohesiveness and springiness provided insights into how well the sample retained its structure during cooking, explaining the higher values observed for the quinoa-fortified spaghetti compared to the control sample.

Table 5: Effect of different formulation treatments on the texture profile attributes of spaghetti. Values are expressed as mean $\pm$ SD (n = 3). Different superscript letters within the same row indicate significant differences among treatments ($P < 0.05$)

Sample	Hardness (G)	Resilience	Cohesiveness	Springiness (MM)	Chewiness (MJ)
MS00	3378 $\pm$ 3.21 ^a	0.40 $\pm$ 0.01 ^a	0.85 $\pm$ 0.02 ^a	3.01 $\pm$ 0.01 ^a	87.45 $\pm$ 0.05 ^a
QS60	1476 $\pm$ 1.52 ^c	0.46 $\pm$ 0.01 ^c	2.02 $\pm$ 0.02 ^c	2.02 $\pm$ 0.02 ^d	91.65 $\pm$ 0.05 ^d
QS80	1187 $\pm$ 2.00 ^d	0.32 $\pm$ 0.02 ^c	0.87 $\pm$ 0.01 ^d	4.52 $\pm$ 0.01 ^e	46.82 $\pm$ 0.02 ^e
QS50	1185 $\pm$ 1.00 ^e	0.41 $\pm$ 0.01 ^d	1.12 $\pm$ 0.02 ^e	2.83 $\pm$ 0.01 ^f	36.83 $\pm$ 0.07 ^f
QS00	1925 $\pm$ 1.00 ^f	0.53 $\pm$ 0.01 ^e	0.94 $\pm$ 0.02 ^f	2.93 $\pm$ 0.01 ^g	52.90 $\pm$ 0.05 ^g

Table 6: Different superscript letters within the same row indicate significant differences among treatments ($P < 0.05$)

Sample	Hardness (G)	Resilience	Cohesiveness	Springiness (MM)	Chewiness (MJ)
MS00	4643.66±1.52 ^a	0.47±.02 ^a	0.70±.01 ^a	2.35±.01 ^a	74.00±1.00 ^a
QS60	2009.00±1.00 ^d	0.58±.01 ^c	0.92±.01 ^c	1.67±.01 ^d	31.40±1.00 ^d
QS80	1937.66±2.51 ^e	0.40±.01 ^d	0.73±.01 ^d	2.15±.01 ^e	14.35±.05 ^e
QS50	1617.66±2.51 ^f	0.32±.01 ^e	0.48±.02 ^e	1.43±.02 ^f	11.50±.50 ^f
QS00	2363.66±1.52 ^g	0.47±.00 ^e	0.70±.02 ^e	1.72±.02 ^g	28.41±.07 ^g

Conclusion

The incorporation of quinoa flour into spaghetti formulations significantly improved the nutritional quality by increasing protein, dietary fiber, fat, ash content, and antioxidant properties, while reducing carbohydrate levels. The enhanced phenolic content and DPPH scavenging activity confirm the potential of quinoa-based spaghetti as a functional food with added health benefits. However, the substitution of wheat flour with quinoa adversely affected cooking quality and structural properties, as evidenced by increased cooking loss and reduced water absorption and swelling capacity, primarily due to the absence of gluten. Color and textural characteristics were also altered, with quinoa-enriched samples exhibiting darker appearance and modified texture profiles. Despite these changes, the improved nutritional and functional benefits outweigh the minor compromises in cooking and sensory attributes. Therefore, quinoa-fortified spaghetti can be considered a promising alternative for developing nutrient-rich, functional food products that support health and sustainability goals.

References

1. ACC. Approved methods of the American Association of Cereal Chemists. Methods 44-19, 08-03, 46-13, 66-50. St. Paul (MN): American Association of Cereal Chemists; 2000.
2. AOAC. Official methods of analysis of the Association of Official Analytical Chemists. 12th ed. Washington (DC): Association of Official Analytical Chemists; 1975. p. 417-490.
3. Bianchi F, Tolve R, Rainero G, Bordiga M, Brennan CS, Simonato B. Technological, nutritional and sensory properties of pasta fortified with agro-industrial by-products: A review. *Int J Food Sci Technol*. 2021;56(9):4356-4366.
4. Cervato G, Carabelli M, Gervasio S, Cittera A, Cazzola R, Cestaro B. Antioxidant properties of oregano (*Origanum vulgare*) leaf extracts. *J Food Biochem*. 2000;24(6):453-465.
5. Devi R, Sit N. Effect of single and dual steps annealing in combination with hydroxypropylation on physicochemical, functional and rheological properties of barley starch. *Int J Biol Macromol*. 2019; 129:1006-1014.
6. FAO, IFAD, WFP. The state of food security in the world 2014: Strengthening the enabling environment to improve food security and nutrition. Rome: FAO; 2014.
7. Gaikwad KK, Pawar VS, Pawar GS, Shingote AB. Effect of addition of quinoa flour on cooking and sensorial qualities of noodles. *Biol Forum Int J*. 2021;13(2):660-665.
8. Godfray HCJ, Beddington JR, Crute IR, Haddad L, Lawrence D, Muir JF, *et al*. Food security: The challenge of feeding 9 billion people. *Science*. 2010;327(5967):812-818.
9. Hailu Kassegn H. Determination of proximate composition and bioactive compounds of the Abyssinian purple wheat. *Cogent Food Agric*. 2018;4(1):1421415.
10. Hirawan R, Ser WY, Arntfield SD, Beta T. Antioxidant properties of commercial, regular and whole-wheat spaghetti. *Food Chem*. 2010;119(1):258-264.
11. Ogawa T, Adachi S. Moisture distributions and properties of spaghetti prepared or cooked under different conditions. In: *Rheology of Biological Soft Matter: Fundamentals and Applications*. Cham: Springer; 2017. p. 119-148.
12. Padalino L, Mastromatteo M, Lecce L, Cozzolino F, Del Nobile MA. Manufacture and characterization of gluten-free spaghetti enriched with vegetable flour. *J Cereal Sci*. 2013;57(3):333-342.
13. Pathare PB, Opara UL, Al-Said FAJ. Colour measurement and analysis in fresh and processed foods: A review. *Food Bioprocess Technol*. 2013; 6:36-60.
14. Ruiz KB, Biondi S, Martinez EA, Orsini F, Antognoni F, Jacobsen SE. Quinoa A model crop for understanding salt-tolerance mechanisms in halophytes. *Plant Biosyst*. 2016; 150:357-371.
15. Scherer R, Godoy HT. Antioxidant activity index (AAI) by the 2,2-diphenyl-1-picrylhydrazyl method. *Food Chem*. 2009;112(3):654-658.
16. Singleton VL, Orthofer R, Lamuela-Raventós RM. Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin-Ciocalteu reagent. In: *Methods Enzymol*. Vol. 299. San Diego (CA): Academic Press; 1999. p. 152-178.
17. Sissons M. Spaghetti. In: Wrigley C, Corke H, Seetharaman K, Faubion J, editors. *Encyclopedia of Food Grains*. 2nd ed. Oxford: Academic Press; 2016. p. 79-89.
18. Song Q, Shu X, Li Y, Zhao Y, Yue J. Association of handgrip strength asymmetry and weakness with functional disability among middle-aged and older adults in China. *J Glob Health*. 2024;14: Article 04115.
19. Standl E, Khunti K, Hansen TB, Schnell O. The global epidemics of diabetes in the 21st century: Current situation and perspectives. *Eur J Prev Cardiol*. 2019;26(2 Suppl):7-14.

20. Torres OL, Lema M, Galeano YV. Effect of using quinoa flour (*Chenopodium quinoa* Willd.) on the physicochemical characteristics of an extruded pasta. Int J Food Sci. 2021; 2021:8813354.
21. Verardo V, Gómez-Caravaca AM, Messia MC, Marconi E, Caboni MF. Development of functional spaghetti enriched in bioactive compounds using barley coarse fraction obtained by air classification. J Agric Food Chem. 2011;59(17):9127-9134.