ISSN Print: 2664-6536
ISSN Online: 2664-6544
Impact Factor: RJIF **5.4**
IJBB 2025; 7(2): 58-66
www.biosciencejournal.net
Received: 02-06-2025
Accepted: 03-07-2025

Uzma Sayyed
Department of Botany, DPG Degree College, Gurugram, Haryana, India

Versha
Department of Botany, DPG Degree College, Gurugram, Haryana, India

Corresponding Author:
Uzma Sayyed,
Department of Botany, DPG Degree College, Gurugram, Haryana, India

Two-Days National Conference on Multidisciplinary Approaches for Innovation and Sustainability: Global solution for contemporary Challenges-NCMIS (DPG Degree College: 17 th-18th 2025)

Comparative nutritional and antioxidant profiling of cereal (Barley) and pseudo-cereal (Quinoa)

Uzma Sayyed and Versha

DOI: https://www.doi.org/10.33545/26646536.2025.v7.i2a.136

Abstract
Cereals and pseudo cereals serve as essential sources of nutrition worldwide, yet they differ significantly in their phytochemical composition, nutritional profile, and antimicrobial properties. This study presents a comparative analysis of these two food groups to evaluate their potential health benefits and functional applications. A range of cereals, including barley, wheat, rice, and maize, were compared against pseudo cereals such as quinoa, amaranth, and buckwheat. The analysis included quantification of key phytochemicals (phenolic compounds, flavonoids, and saponins), assessment of macronutrient and micronutrient content, and evaluation of antimicrobial activity against common foodborne pathogens.
Results revealed that pseudo cereals generally exhibited the presence of higher levels of bioactive compounds and superior protein quality, along with enhanced antioxidant properties compared to traditional cereals. These findings highlight the potential of pseudo cereals as nutritionally superior and functionally valuable alternatives, supporting their inclusion in diverse dietary and therapeutic applications. The study discovers the potential of pseudo cereals over cereals and further research also need to be done to analyze the functional properties of pseudo cereals for food security and human health.

Keywords: Cereals, pseudocereals, nutritional composition, potential antioxidant

Introduction
Cereals and pseudo-cereals are both consumed extensively worldwide as staple foods, but they differ significantly in their botanical classification. Cereals refer to the true grasses of the family *Poaceae* (Gramineae), which produce edible starchy grains that form the cornerstone of global diets. This group includes wheat (*Triticum aestivum*), rice (*Oryza sativa*), maize (*Zea mays*), barley (*Hordeum vulgare*), and oats (*Avena sativa*), among others. These grains are cultivated primarily for their high carbohydrate content and ability to provide bulk caloric intake.
In contrast, pseudo-cereals are broadleaf plants that do not belong to the grass family but are grouped with cereals due to their similar culinary uses, seed structure, and nutritional profiles. The primary pseudo-cereals include quinoa (*Chenopodium quinoa*) from the *Amaranthaceae* family, buckwheat (*Fagopyrum esculentum*) from *Polygonaceae*, and amaranth (*Amaranthus spp.*) also from *Amaranthaceae*. These crops are gluten-free and have gained significant attention in recent years due to their high protein quality, balanced amino acid profiles, and rich phytochemical content.
In recent years, the global food landscape has witnessed a notable shift toward functional nutrition, driven by consumer demand for foods that offer not only basic sustenance but also enhanced health benefits. This movement is particularly evident in the surge of interest in gluten-free, high-protein, and nutrient-dense alternatives to traditional cereal grains. The rise in gluten intolerance, celiac disease, and general avoidance of gluten-containing products has led to the search for alternatives that do not compromise on nutritional value, pseudo-cereals such as quinoa, amaranth, and buckwheat have gained widespread recognition for their naturally gluten-free status and superior nutritional profiles (Rai *et al*., 2021) [46].

One of the primary reasons for the resurgence of interest in pseudo-cereals is their abundance of health-promoting phytochemicals and functional compounds. Unlike many refined cereals, pseudo-cereals retain high levels of bioactive constituents, including polyphenols, flavonoids, saponins, and phytosterols, which contribute to their antioxidant, anti-inflammatory, and cardioprotective effects. For instance, quinoa contains quercetin and kaempferol, flavonoids known to modulate oxidative stress and reduce inflammation. Saponins, although traditionally considered anti-nutrients, are now being recognized for their antimicrobial, cholesterol-lowering, and immune-modulating properties, especially when appropriately processed to reduce bitterness without eliminating their bioactivity.

Moreover, the pigmentation of grains serves as an important visual and biochemical indicator of antioxidant richness. Pigmented varieties such as red and black quinoa, purple corn, and black rice have been shown to possess significantly higher antioxidant capacities than their non-pigmented counterparts due to the presence of anthocyanins, betalains, and proanthocyanidins, which are potent secondary metabolites with well-documented bioactivity (Zhang *et al*., 2010) [61]. For example, red quinoa is rich in betacyanin and betaxanthins, unique nitrogen-containing pigments rarely found in cereals, which contribute to both the visual appeal and radical scavenging capacity of the grain (Tang *et al*., 2015) [56]. Similarly, purple corn's antioxidant potency is attributed to high levels of cyanidin-3-glucoside and other anthocyanins, which have demonstrated anti-inflammatory and anti-obesity effects in vitro and in vivo (Pedreschi & Cisneros-Zevallos, 2007) [44].

In contrast, the antioxidant activity in traditional cereals such as wheat and rice is generally modest and primarily derived from bound phenolic acids-especially ferulic acid-located in the bran layers. These phenolics often require mechanical or enzymatic processing (e.g., fermentation, sprouting) to be released and become bioactive, limiting their immediate effectiveness in typical refined grain products (Adom & Liu, 2002) [1]. This distinction underscores the superior functional food potential of pseudo-cereals, particularly pigmented varieties, which naturally combine high nutritional value with potent bioactive properties.

Barley is a versatile cereal grain that has been cultivated for thousands of years. It is a member of the grass family and is one of the oldest domesticated crops, valued for its adaptability to various climates. It is rich in fiber, especially beta-glucan, which helps reduce cholesterol levels. Its hardy nature and short growing season make it a staple crop in many regions around the world.

In addition to its high fiber content, barley is a good source of essential nutrients such as B vitamins, iron, magnesium, zinc, and selenium. It also contains beneficial phytochemicals like phenolic acids, flavonoids, and lignans, which act as antioxidants and support overall health. Barley is known for its role in promoting heart health, improving digestion, managing blood sugar levels, and aiding in weight management. Whole grain barley and barley flour are increasingly used in health-conscious diets, and its low glycemic index makes it suitable for people with diabetes. With its nutritional richness and functional properties, barley continues to be an important food and agricultural crop globally.

Quinoa is a highly nutritious, gluten-free pseudocereal that has been cultivated for thousands of years, primarily in the Andean regions of South America, especially Peru and Bolivia. Although it is often considered a grain, quinoa is actually the seed of the Chenopodium quinoa plant, which belongs to the Amaranthaceae family. It is valued for its high protein content, including all nine essential amino acids, making it a rare plant-based source of complete protein. Quinoa is also rich in dietary fiber, B vitamins (such as folate, B1, B2, and B6), vitamin E, and essential minerals like iron, magnesium, potassium, calcium, phosphorus, and zinc.

In addition to its impressive nutritional profile, quinoa contains beneficial phytochemicals such as flavonoids (including quercetin and kaempferol) and other antioxidants, which help combat inflammation and oxidative stress. It has a low glycemic index, making it suitable for people with diabetes and those managing blood sugar levels. Quinoa is also highly versatile in cooking, used in salads, soups, breakfast dishes, and even as a substitute for rice or pasta. Its resilience to harsh growing conditions and ability to thrive in poor soils further highlight its importance as a sustainable food crop in global food security.

Ultimately, the study aims to generate evidence that supports the nutritional upgrading of food systems through the integration of underused, nutrient-dense grains like pseudo-cereals. By doing so, this research will contribute to the scientific validation and selection of grains for functional food development, fortify dietary recommendations, and offer new insights into crop diversification strategies that can align with health, sustainability, and food security goals (Vega-Gálvez *et al*., 2010) [57].

Material and Methods

Plant Material

The sample was cleaned and seeds of cereals (Barley) and pseudocereals (Quinoa) are collected. All the seeds are placed for drying at room temperature. The dried sample was blended using electronic blender into powdered form.

Preparation of Plant Extract

Extraction of the ground material was conducted according to Sultana *et al*. (2008) with some modifications. 10 grams of quinoa and barley seed samples were extracted for 24 h with 100 ml of 70% methanol, in amber flasks in a shaking water bath. Supernatant was separated by filtering through Whatman filter paper). Methanol was evaporated and dry crude extracts were weighed, and then kept in the dark until used for of various antioxidant bioassays and for determination of total phenolic, flavonoid content, and DPPH radical scavenging activity Samanta *et al*., (2024) [55].

Qualitative phytochemical analysis

Assessment of alkaloids (Mayer's test)

Mayer's reagent (40µl) was added to the sample by the side of the test tube. A creamy or white precipitate indicated the presence of alkaloids.

Assessment of saponins (Froth forming test)

The extract was diluted with distilled water and made up to 20 ml. The suspension was shaken in a graduated cylinder for 15 min. A thick (2 cm) layer of foam indicated the presence of saponins.

Assessment of phenols (Ferric chloride test)
The presence of phenolic compounds was indicated by the presence of dark green color on addition of few drops of neutral 5% ferric chloride solution to the diluted extract.

Assessment of tannins
The appearance of brownish green or blue, black colour indicates the presence of tannins by the addition of a few drops of 0.1% ferric chloride solution in a filtered extract.

Assessment of flavonoids
A portion of the extract was added in 5 ml of dilute ammonia solution, followed by addition of concentrated sulphuric acid. The appearance of yellow colour indicates the presence of flavonoids.

Assessment of terpenoids (Salkowski test)
Extract (5 ml) was mixed with 2 ml of chloroform and concentrated sulphuric acid to form a layer. The reddish-brown colour of the interface showed the presence of terpenoids.

Assessment of sterols
Addition of 0.5ml of chloroform and 1 ml of concentrated sulphuric acid in a 2 ml filtered extract. The appearance of reddish-brown colour indicates the presence of sterols.

Test for carbohydrates and sugars

- **Fehling's test:** To 1 ml of the extract, add equal quantities of Fehling solution A and B, upon heating formation of a brick red precipitate indicates the presence of sugars.

Test for fixed oils and fats

- **Saponification test:** To l ml of the extract, add few drops of 0.5 N alcoholic potassium hydroxide along with a drop of phenolphthalein. Heat the mixture on a water bath for 1-2 hours. The formation of soap or partial neutralization of alkali indicates the presence of fixed oils and fats.

Test for proteins

- **Xanthoproteic test:** To 1 ml of the extract, add l ml of concentrated nitric acid. A white precipitate is formed; it is boiled and cooled. Then 20% of sodium hydroxide or ammonia is added. Orange colour indicates the presence of aromatic amino acids.

Quantitative Phytochemical Analysis
Determination of TPC
The TPC was determined spectrophotometrically using the Folin-Cioclateu method. Briefly, 100 µL of sample extract was mixed with 500 µL of 10-fold diluted Folin-Ciocalteu's phenol reagent and allowed to react for 5 min. After that, 400 µL of Na2 CO_3 solution (7%) was added, and the final volume was brought to 2 mL with distilled water. After 1 h at room temperature, the absorbance at 760 nm was measured using UV-Vis spectrophotometer. A calibration curve was prepared using a positive control of gallic acid (GA). Results were expressed as mg GAE/g of the dr.

Determination of TFC
The total flavonoid content was determined using a colorimetric method used by Ben Khadher *et al*. (2022), with minor modifications. An aliquot (500 µL) of each quinoa extract was added to 1.5 mL distilled water, 150 µL of sodium nitrite solution (5%), and mixed for 6 min before the addition of 150 µL 10% aluminium chloride. The volume was adjusted with distilled water to 2.5 mL, and then incubated at room temperature for 6 min. The reaction was completed by adding 500 µL of sodium hydroxide (4%). The final absorbance was determined at 510 nm against a blank. The TFC was reported as mg QE/g dr against the calibration curve of quercetin (Q).

Determination of CTC
CTC was assayed using the method previously described by Sassi Aydi *et al*. (2020). The seed extracts (50 µL) were added to 3 mL of 4% vanillin (w/v in MeOH) and 1.5 mL of concentrated HCl. After that, the absorbance was measured at 500 nm after incubation in the dark, for 15 min, at room temperature. The condensed tannins content in the different quinoa extracts was expressed as mg CE/g dr.

Carotenoids (mg/g fresh wt.)=A480 + (0.114 × A663)-(0.638 × A645).

Nutritional Content Analysis
Moisture composition estimation
Procedure: A clean crucible was dried to a constant weight in an air oven at 105°C, cooled in a desiccator, weigh and labelled (W1). Then 2 g of the ground sample was accurately weighed into the previously labelled crucible and reweighed (W2). The crucible containing the sample was dried in an oven to a constant weight (W3).

Calculation

% Moisture content=W2-W3/ W2-W1× 100

Determination of ash content
Procedure: The porcelain crucible was placed in an oven for it to dry at 1000C for 10 minutes, cooled in a desiccator and measured (W1). Then 2 g of the sample that was smoothly ground was accurately weighed into initially weighed porcelain crucible and reweighed (W2). It was first ignited and then moved to a furnace of 5600C. The sample was left in the furnace for eight hours to ensure proper ashing. The crucible containing the ash was then removed cooled in the desiccator and weighed (W3).

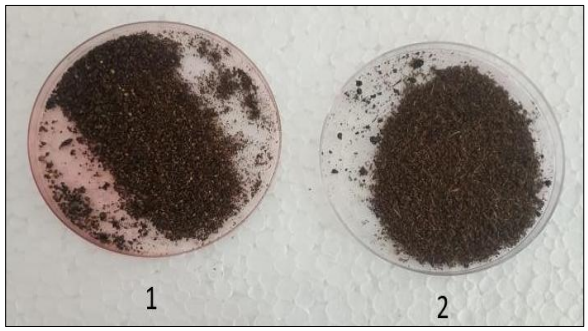

Fig 1: Burnt Seed Powder of Quinoa (1) and Barley (2)

Formula: W3-W1/ W2-W1 X 100%

Determination of Fat Content
The Soxhlet method was used to determine fat content. The seed flour was weighed (1 g) and then put in a 15-mL test

tube. Chloroform was added, and the tube was closed. It was covered tightly, shaken, and then left overnight. Later on, the sample was filtered through a filter paper into a test tube. Then, 5 mL of the sample was pipetted into a cup of known weight (A g). The sample was then placed into an oven at 100 °C for 4 hrs. Next, it was taken out, put into the desiccator for 30 mins, and then weighed (B g).

Fig 2: Extraction of Fat in Hot Air Oven.

Fat content was calculated using the following formula

% Fat content = (P × (B−A)) / (sample weight) × 100%
P=Dilution (10/5)

Determination of Protein

1. Pipette out 0.2, 0.4, 0.6, 0.8 and 1.0 ml of the working standard and 0.2 ml of the sample extract into different test tubes.
2. Make up the volume to I ml with dH20. A tube with 1 m1 of dH20 serves as the 'Control.
3. Add 5 ml of the alkaline copper solution to each tube including the control. Mix well and allow to stand at room temperature for I 0 min.
4. Now add 0.5 ml of the diluted Folin's reagent rapidly with immediate mixing and incubate at room temperature, for 30 min under dark.
5. Take O.D. of the blue colour at 660 nm.
6. Calculate the quantity of protein in that: sample-using the standard curve.

Determination of Carbohydrate

Carbs=100-(%of ash + moisture+ fibre + fat + protein)

Determination of fibre content

Two grams of finely ground sample was weighed out into round bottom flask, then 100 ml of 0.25 M sulphuric acid solution was added and the mixture boiled under reflux for 30 min. The hot solution was quickly filtered under suction. The insoluble matter was washed many times with hot water until it was free from acid. It was quantitatively transferred into the flask and 100 ml of hot
0.31 M sodium hydroxide solution was added and the mixture boiled again under reflux for 30 minutes and quickly filtered under suction. The residue was washed with hot water until it was base free. It was dried to a constant weight in the oven at 1000C, cooled in a desiccator and weighed (C1). The weighed sample (C1) was then incinerated in a furnace at 5500C for two hours, cooled in a desiccator and reweighed (C2).

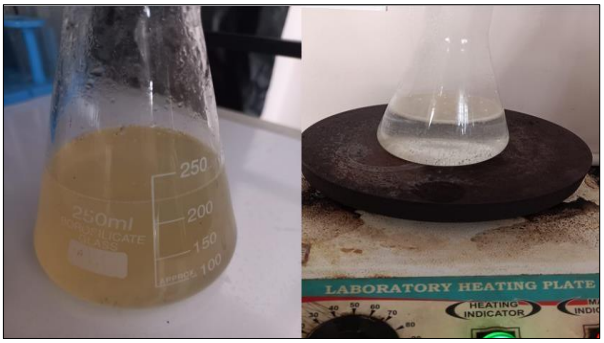

Fig 3: Fibre Extraction.

Calculation

% Crude fibre content=C1-C2/ Wt. of original sample × 100

Antioxidant Analysis by DPPH radical scavenging activity

The free radical scavenging activity of plant extracts was determined by 1, 1-diphenyl-2-picrylhydrazyl (DPPH). Briefly, 1ml of crude extracts was added to 3ml of 0.1mM methanolic DPPH solution at different concentration (50-500 µg/ml). Then, the mixtures were vigorously shaken and incubated for 30 minutes. Ascorbic acid was considered as a standard antioxidant. The DPPH radical scavenging activity was calculated by using the following equation:

DPPH Scavenging activity (%)=(A0-A1/A0) ×100

All extracts were analysed in triplicates

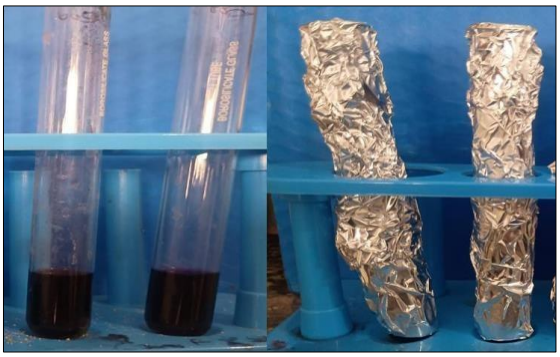

Fig 4: Antioxidant Activity by DPPH

Results and Discussion

The modern scientific community increasingly recognizes whole grains not merely as carbohydrate sources but as complex functional foods. This redefinition is based on a wealth of evidence demonstrating the synergistic effects of the fibre, vitamins, minerals, and phytochemicals present in unrefined grains. Consumption of whole grains is associated with reduced risks of cardiovascular disease, colorectal cancer, obesity, and type 2 diabetes, primarily through mechanisms such as glycaemic control, lipid metabolism regulation, and oxidative stress reduction (Fardet, 2010) [16].
The phytochemical composition of cereals and pseudo-cereals represents a crucial factor in determining their functional properties and health-promoting potential. Cereals, such as wheat, barley, and rice, are typically rich in phenolic acids, particularly ferulic acid, p-coumaric acid, and caffeic acid, which are mainly localized in the bran and aleurone layers of the grain. However, these phenolic compounds are predominantly found in bound forms,

esterified to cell wall polysaccharides, and are therefore less bioavailable unless the grain is consumed whole or processed through fermentation, enzymatic hydrolysis, or sprouting (Adom & Liu, 2002; Dykes & Rooney, 2007) [1, 14]. This bound nature limits the antioxidant efficacy of many refined cereal products, as substantial quantities of bio actives are lost during milling and polishing.

Beyond protein, pseudo-cereals are also richer in key micronutrients. Quinoa and amaranth, for example, contain higher concentrations of magnesium, iron, zinc, potassium, and calcium compared to most common cereals. These minerals are essential for a range of physiological processes, including bone metabolism, enzymatic activity, immune function, and red blood cell production (Alvarez-Jubete *et al*., 2010) [2]. Moreover, pseudo-cereals typically exhibit lower levels of phytates, or contain them in forms that are less inhibitory to mineral absorption, especially after traditional processing techniques like soaking, sprouting, or fermentation (Repo-Carrasco *et al*., 2003) [48]. These nutritional advantages position pseudo-cereals as valuable dietary supplements or alternatives, particularly in populations at risk of micronutrient deficiencies or in therapeutic nutritional programs.

Qualitative Phytochemical Analysis

Table 1: Comparative analysis of phytochemical in quinoa and barley

Sl. No.	Phytocompounds	Presence in Barley	Presence in Quinoa
1	Alkaloid	+	++
2	Flavonoid	++	+
3	Phenol	+	++
4	Tannin	+	++
5	Saponin	+	++
6	Sterols	+	++
7	Terpenoids	+	++
8	Protein	+	++
9	Fat	+	++
10	Carbohydrate	++	+

The above table represents a qualitative assessment of various phytochemicals found in Quinoa and Barley. The presence of each compound is denoted as "+" (present in lower amounts) and "++" (present in higher amounts). It is clearly indicates from above table that Alkaloids, Phenols, Tannins, Saponins, Sterols, Terpenoids, Proteins, and Fats are more abundant in Quinoa compared to Barley, confirming that Quinoa is richer in these bioactive compounds as compared to Barley Flavonoids and Carbohydrates, on the other hand, were more prominent in Barley, suggesting it may offer better antioxidant properties and energy-yielding components in this regard.

Overall, Quinoa demonstrates a broader and more intense phytochemical profile, especially in non-carbohydrate bioactives, which may contribute to its superior nutraceutical and functional food properties.

Quantitative Phytochemical Analysis

Table 2: Quantitative analysis of cereals and pseudocereals

So. No.	Content	Quantity in Barley	Quantity in Quinoa
1	TPC	0.0455mg/ml	0.06mg/ml
2	TFC	11.4mg QE/g	38.2mg QE/g
3	CTC	15.35mg/ml	13.83mg/ml

Table 3 represents the quantitative analysis of cereals (Barley) and pseudocereals (Quinoa), focusing on three key phytochemical contents: TPC (Total Phenolic Content), TFC (Total Flavonoid Content), and CTC (Condensed Tannin Content).

- **Total Phenolic Content:** TPC is slightly higher in Quinoa (0.06 mg/ml) compared to Barley (0.0455 mg/ml), indicating Quinoa has marginally more phenolic compounds, which are associated with antioxidant activity.
- **Total Flavonoid Content:** TFC shows a significant difference, with Quinoa containing 38.2 mg QE/g, much higher than Barley's 11.4 mg QE/g, suggesting that Quinoa is a richer source of flavonoids.
- **Condensed Tannin Content:** CTC is higher in Barley (15.35 mg/ml) compared to Quinoa (13.83 mg/ml), indicating a slightly stronger presence of tannins in Barley.

Overall, the data reveals that Quinoa surpasses Barley in both phenolic and flavonoid content, while Barley leads slightly in tannin concentration, underlining the differing nutritional and functional profiles of these grains.

Nutritional Analysis of Cereals and Pseudocereals

Ash

- **Barley:** Contain 1.60g in 2g of sample (in%=80%).
- **Quinoa:** Contain 1.65g in 2g of sample (in%=82.5%).

Moisture

- **Barley:** Contain 0.13g moisture in 2 g sample (in%=6.5%).
- **Quinoa:** Contain 0.2g moisture in 2 g sample (in%=10%).

Fat

- **Barley:** Contain 1.36g fat in 2g sample (in%=68%).
- **Quinoa:** Contain 0.55g fat in 2g sample (in%=27.5%).

Fibre

- **Barley:** Contain 0.0322g fibre in 2g sample (in%=1.61%).
- **Quinoa:** Contain 0.103g fibre in 2g sample (in%=5.15%).

Table 3: O.D of Barley extract at 660nm.

SL. No.	Volume of working standard/ Sample(g)	Quantity of Protein(mg)	Absorbance measured at 660nm
1	0	0	0
2	0.2	20	1.25
3	0.4	40	2.07
4	0.6	60	2.51
5	0.8	80	3
6	0.35	0.175	1.74

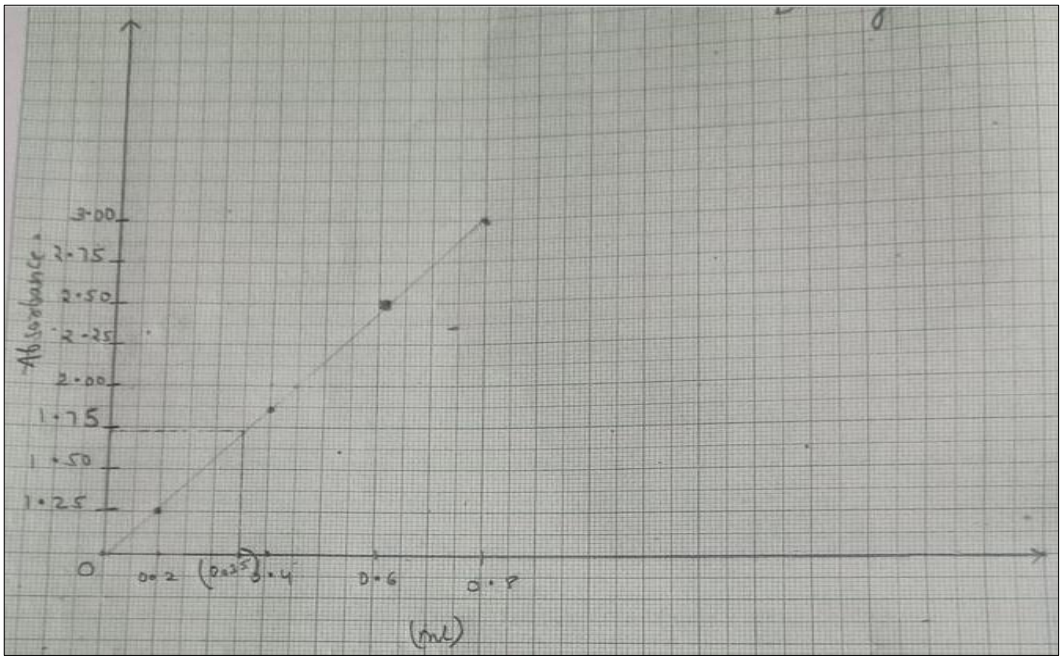

Fig 5: Absorbance graph for barley.

Table 4: O.D. of Quinoa extract at 660nm

Sl. No.	Volume of working standard/ Sample(g)	Quantity of Protein(mg)	Absorbance measured at 660nm
1	0	0	0
2	0.2	20	1.25
3	0.4	40	2.07
4	0.6	60	2.51
5	0.8	80	3
6	0.67	0.335	2.6

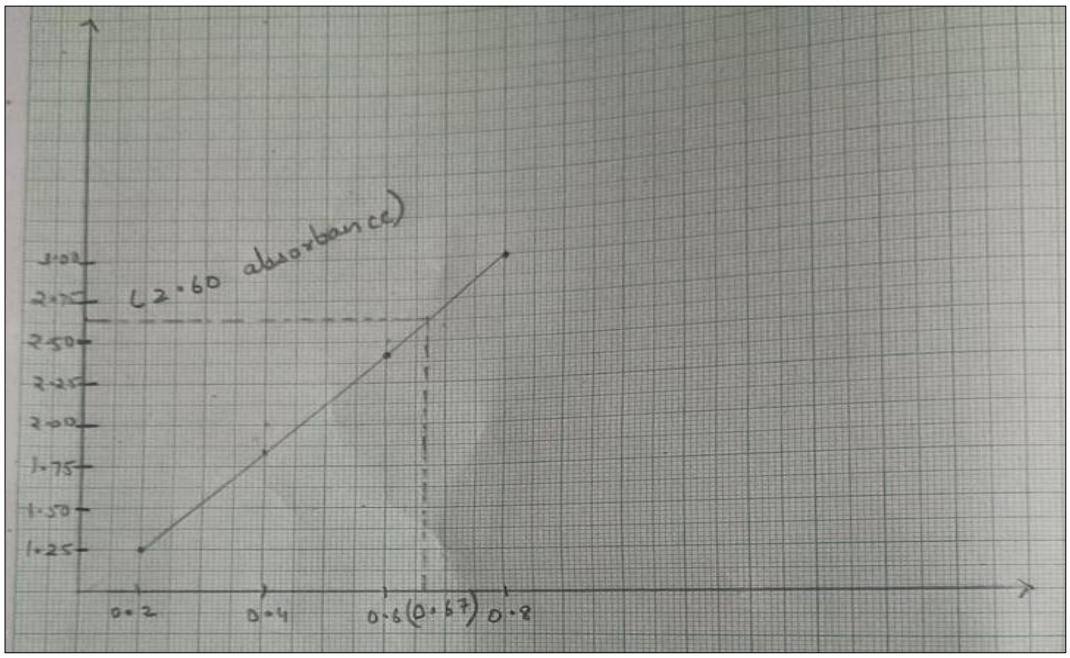

Fig 6: Absorbance Graph for Quinoa.

Table 5: Nutritional Analysis

So. No.	Nutritional Compounds	Quantity in Barley	Quantity in Quinoa
1	Carbohydrate	6.87g	7.4g
2	Protein	0.000335g	0.000175g
3	Fat	1.36g	0.55g
4	Fibre	0.322g	0.103g
5	Moisture	0.13g	0.2g
6	Ash	1.60g	1.65g

Antioxidant Activity

$[A_0-A_1] / A_0$=% Scavenging A_0 for Quinoa and Barley is 0.49. A_1 for Barley is 0.445.

A_1 for Quinoa is 0.447

Table 6: Antioxidant Activity

So. No.	Sample	Scavenging%
1	Barley	0.89
2	Quinoa	0.45

Table 6 presents the antioxidant activity of Barley and Quinoa, expressed as scavenging percentage (%).

The data shows that Barley exhibits a higher antioxidant activity (0.89%) compared to Quinoa (0.45%). This indicates that Barley has a stronger ability to neutralize free radicals, despite Quinoa having higher total phenolic and flavonoid contents as seen in earlier tables.

The result suggests that antioxidant activity is not solely dependent on the quantity of phenolics and flavonoids but may also be influenced by the specific types and bioavailability of the antioxidant compounds present in each grain.

Conclusion

This comparative study of quinoa (*Chenopodium quinoa Willd.*) and barley (*Hordeum vulgare* L.) reveals significant differences and complementarities in their phytochemical composition, antioxidant activity, and nutritional value, highlighting their potential roles as functional foods in health-promoting diets. Both grains exhibit valuable phytochemical constituents such as phenolics, flavonoids, and saponins, but quinoa demonstrated notably higher total phenolic content and antioxidant activity, suggesting a superior ability to neutralize free radicals and contribute to oxidative stress mitigation.

In terms of nutritional composition, quinoa outperformed barley in protein content, essential amino acid balance, and certain micronutrients like magnesium, iron, and zinc, which are crucial for metabolic functions and immune support. Conversely, barley exhibited higher dietary fiber and β-glucan levels, compounds well known for their cholesterol-lowering and glycemic control benefits. These findings reinforce the idea that while quinoa may be a better source of high-quality plant-based protein and antioxidants, barley contributes significantly to digestive health and cardiovascular protection.

The comparative antioxidant analysis also underlines the broader health benefits these grains offer, supporting their inclusion in diets aimed at preventing chronic diseases such as cardiovascular disorders, diabetes, and certain cancers. The variation in their phytochemical profiles suggests that both grains could be strategically incorporated into functional food formulations for targeted health outcomes.

In conclusion, both quinoa and barley exhibit complementary nutritional and bioactive properties. The data support their utilization not just as staple foods, but as ingredients in functional food systems aimed at enhancing human health. Promoting their consumption can contribute to dietary diversification and improved public health, particularly in populations vulnerable to malnutrition or chronic disease. Future studies may explore the synergistic effects of blending these grains in food products and investigate their bioavailability and functional impact in clinical settings.

References

1. Adom KK, Liu RH. Antioxidant activity of grains. Journal of Agricultural and Food Chemistry. 2002;50(21):6182-6187. https://doi.org/10.1021/jf0205099
2. Jubete AL, Arendt EK, Gallagher E. Nutritive value of pseudo-cereals and their increasing use as functional gluten-free ingredients. Trends in Food Science & Technology. 2010;21(2):106-13. https://doi.org/10.1016/j.tifs.2009.10.014
3. Apak R, Özyürek M, Güçlü K, Çapanoğlu E. Antioxidant activity/capacity measurement: Classification, physicochemical principles, mechanisms and electron transfer (ET) based assays. Journal of Agricultural and Food Chemistry. 2016;64(5):997-1027. https://doi.org/10.1021/acs.jafc.5b04739
4. Bavec F, Kolar M, Bavec M. Influence of organic production on yield and quality of grain amaranth and buckwheat. Poljoprivreda. 2011;17(2):36-40.
5. Bazile D, Jacobsen S-E, Verniau A. The global expansion of quinoa: Trends and limits. Frontiers in Plant Science. 2016;7:622. https://doi.org/10.3389/fpls.2016.00622
6. Becker R, Wheeler EL, Lorenz K, Stafford AE, Grosjean OK, Betschart AA, *et al*. A compositional study of amaranth grain. Journal of Food Science. 1981;46(4):1175-1180. https://doi.org/10.1111/j.1365-2621.1981.tb02985.x
7. Bhargava A, Shukla S, Ohri D. *Chenopodium quinoa*-an Indian perspective. Industrial Crops and Products. 2006;23(1):73-87. https://doi.org/10.1016/j.indcrop.2005.04.002
8. Brand-Williams W, Cuvelier ME, Berset C. Use of a free radical method to evaluate antioxidant activity. LWT-Food Science and Technology. 1995;28(1):25-30. https://doi.org/10.1016/S0023-6438(95)80008-5
9. Cardoso RVC, Pinheiro SS, da Silva LL, Martino HSD. Sorghum flour improves gut microbiota, antioxidant status and immune response in rats. Food Research International. 2017;104:423-429. https://doi.org/10.1016/j.foodres.2017.10.059
10. Chaudhary RC. Speciality rices of the world: Effect of WTO and IPR on its production trend and marketing. Journal of Food, Agriculture & Environment. 2003;1(2):34-41.
11. Chen PX, Tang Y, Marcone MF, Pauls KP, Zhang B, Liu R. Characterization of phenolics and antioxidant

activities of pigmented rice. Food Chemistry. 2012;135(4):2783-2791. https://doi.org/10.1016/j.foodchem.2012.07.004
12. Crozier A, Jaganath IB, Clifford MN. Dietary phenolics: Chemistry, bioavailability and effects on health. Natural Product Reports. 2009;26(8):1001-1043. https://doi.org/10.1039/b802662a
13. Diplock AT, Aggett PJ, Ashwell M, Bornet F, Fern EB, Roberfroid MB. Scientific concepts of functional foods in Europe: Consensus document. British Journal of Nutrition. 1999;81(S1):S1-27. https://doi.org/10.1017/S0007114599000471
14. Dykes L, Rooney LW. Phenolic compounds in cereal grains and their health benefits. Cereal Foods World. 2007;52(3):105-511. https://doi.org/10.1094/CFW-52-3-0105
15. FAO. The State of Food Security and Nutrition in the World. 2020. https://www.fao.org/publications/sofi/2020/en/
16. Fardet A. New hypotheses for the health-protective mechanisms of whole-grain cereals: What is beyond fibre? Nutrition Research Reviews. 2010;23(1):65-134. https://doi.org/10.1017/S0954422410000041
17. Machado FMV, Barbalho SM, Oshiiwa M, Goulart RDA, Pessan Junior O. Use of quinoa (*Chenopodium quinoa*) in the prevention of non-transmissible diseases. Journal of Nutrition and Food Sciences. 2012;2(6):1-5. https://doi.org/10.4172/2155-9600.1000160
18. Fuller DQ, Denham T, Kalin AM, Lucas L, Stevens CJ, Qin L, *et al*. Convergent evolution and parallelism in plant domestication revealed by an expanding archaeological record. Proceedings of the National Academy of Sciences. 2014;111(17):6147-6152. https://doi.org/10.1073/pnas.1308937110
19. Gilani GS, Xiao CW, Cockell KA. Impact of antinutritional factors in food proteins on the digestibility of protein and the bioavailability of amino acids and on protein quality. British Journal of Nutrition. 2012;108(S2):S315-8332. https://doi.org/10.1017/S0007114512002371
20. Bastida GJA, Pihlava JM, Pihlanto A, Kolehmainen M. Cereal phytochemicals and their health promoting effects. Journal of Cereal Science. 2015;64:33-44. https://doi.org/10.1016/j.jcs.2015.04.006
21. Gorinstein S, Pawelzik E, Delgado-Licon E, Haruenkit R, Weisz M, Trakhtenberg S. Characterization of pseudocereal and cereal proteins by protein and amino acid analyses. Journal of the Science of Food and Agriculture. 2007;87(5):882-889. https://doi.org/10.1002/jsfa.2781
22. Hall CA, Zhao B. Phytochemicals in cereals, pseudocereals and pulses. In: Fruit and Cereal Bioactives. Taylor & Francis, 2011, p. 123-142.
23. He HP, Shan L, Wang YH, Pei H. Effect of amaranth grain squalene on lipid levels and antioxidant status in rats. Journal of Agricultural and Food Chemistry. 2002;50(5):1103-1106. https://doi.org/10.1021/jf011173u
24. Hurrell R, Egli I. Iron bioavailability and dietary reference values. The American Journal of Clinical Nutrition. 2010;91(5):1461S-1467S. https://doi.org/10.3945/ajcn.2010.28674F
25. Jacobsen SE, Mujica A, Jensen CR. The resistance of quinoa (*Chenopodium quinoa* Willd.) to adverse abiotic factors. Food Reviews International. 2013;19(1-2):99-109. https://doi.org/10.1081/FRI-120018870
26. Khatoon N, Prakash J. Nutritional quality of microwave-cooked and pressure-cooked legumes. International Journal of Food Sciences and Nutrition. 2006;57(6):480-489. https://doi.org/10.1080/09637480600902045
27. Li H, Zhu F, Li G. Beverages developed from pseudocereals: Nutritional and functional properties. Comprehensive Reviews in Food Science and Food Safety, 2025.https://ift.onlinelibrary.wiley.com/doi/abs/10.1111/1541-4337.70081
28. Liu RH. Potential synergy of phytochemicals in cancer prevention: Mechanism of action. The Journal of Nutrition. 2004;134(12):3479S-185S. https://doi.org/10.1093/jn/134.12.3479S
29. Lobo V, Patil A, Phatak A, Chandra N. Free radicals, antioxidants and functional foods: Impact on human health. Pharmacognosy Reviews. 2010;4(8):118-126. https://doi.org/10.4103/0973-7847.70902
30. Lönnerdal B. Dietary factors influencing zinc absorption. The Journal of Nutrition. 2000;130(5S Suppl):1378S-1383S. https://doi.org/10.1093/jn/130.5.1378S
31. Lopez HW, Leenhardt F, Coudray C, Remesy C. Minerals and phytic acid interactions: Is it a real problem for human nutrition? International Journal of Food Science & Technology. 2003;38(8):827-839. https://doi.org/10.1046/j.1365-2621.2003.00769.x
32. Luthria DL, Liu K, Alekel DL. Comparison of phenolic acids and isoflavones in soybeans and their relationship to antioxidant activity. Journal of Agricultural and Food Chemistry. 2015;63(18):4563-4571. https://doi.org/10.1021/acs.jafc.5b00510
33. Manach C, Scalbert A, Morand C, Rémésy C, Jiménez L. Polyphenols: Food sources and bioavailability. The American Journal of Clinical Nutrition. 2005;81(1):230S-242S. https://doi.org/10.1093/ajcn/81.1.230S
34. Martínez-Villaluenga C, Peñas E, Frias J. Bioactive peptides in fermented cereal and legume-based foods. Frontiers in Nutrition. 2020;7:113. https://doi.org/10.3389/fnut.2020.00113
35. Mattila P, Pihlava JM, Hellström J. Contents of phenolic acids, alkyl-and alkenylresorcinols, and avenanthramides in commercial grain products. Journal of Agricultural and Food Chemistry. 2005;53(21):8290-8295. https://doi.org/10.1021/jf050289p
36. Mazza G, Kay CD, Cottrell T, Holub BJ. Absorption of anthocyanins from blueberries and serum antioxidant status in human subjects. Journal of Agricultural and Food Chemistry. 1999;47(9):3586-3590. https://doi.org/10.1021/jf990027+
37. Melini V, Melini F. Functional components and anti-nutritional factors in gluten-free grains: A focus on quinoa seeds. Foods. 2021;10(2):351. https://www.mdpi.com/2304-8158/10/2/351
38. Michaelsen KF, Hoppe C, Roos N, Kaestel P, Stougaard M, Lauritzen L, *et al*. Choice of foods and ingredients for moderately malnourished children 6 months to 5 years of age. Food and Nutrition Bulletin. 2009;30(3_suppl3):S343-404. https://doi.org/10.1177/15648265090303S303
39. Mir NA, Yousuf B, Gul K, Riar CS, Singh S. Cereals and pseudocereals: Introduction, classification and nutritional properties. In: Food Bioactives. CRC Press, 2019, p. 61-84.

https://www.taylorfrancis.com/chapters/edit/10.1201/9780429242793-12
40. Nandan A, Koirala P, Tripathi AD, Vikranta U, Shah K. Nutritional and functional perspectives of pseudocereals. Food Chemistry. 2024;429:137030. https://www.sciencedirect.com/science/article/pii/S0308814624007210
41. Varli NS, Sanlier N. Nutritional and health benefits of quinoa (*Chenopodium quinoa* Willd.). Journal of Cereal Science. 2016;69:371-376. https://doi.org/10.1016/j.jcs.2016.05.004
42. OECD/FAO. OECD-FAO Agricultural Outlook 2021-2030, 2021. https://doi.org/10.1787/19428846-en
43. Pandey KB, Rizvi SI. Plant polyphenols as dietary antioxidants in human health and disease. Oxidative Medicine and Cellular Longevity. 2009;2(5):270-278. https://doi.org/10.4161/oxim.2.5.9498
44. Pedreschi R, Zevallos CL. Antimutagenic and antioxidant properties of phenolic fractions from Andean purple corn (*Zea mays* L.). Journal of Agricultural and Food Chemistry. 2007;55(15):6885-6890. https://doi.org/10.1021/jf070495f
45. Pham-Huy LA, He H, Pham-Huy C. Free radicals, antioxidants in disease and health. International Journal of Biomedical Science. 2008;4(2):89-96.
46. Rai S, Kaur A, Chopra CS. Gluten-free products: Trend and perspectives. Food Reviews International. 2021;37(3):309-338. https://doi.org/10.1080/87559129.2019.1615926
47. Rayman MP. Food-chain selenium and human health: Emphasis on intake. British Journal of Nutrition. 2008;100(2):254-268. https://doi.org/10.1017/S0007114508939830
48. Carrasco RR, Espinoza C, Jacobsen SE. Nutritional value and use of the Andean crops quinoa (*Chenopodium quinoa*) and kañiwa (*Chenopodium pallidicaule*). Food Reviews International. 2003;19(1-2):179-189. https://doi.org/10.1081/FRI-120018884
49. Rocchetti G, Lucini L, Rodríguez JML, Barba FJ. Gluten-free flours from cereals, pseudocereals and legumes: Phenolic fingerprints and in vitro antioxidant properties. Food Chemistry. 2019;289:367-375. https://doi.org/10.1016/j.foodchem.2019.03.104
50. Rodríguez JP, Rahman H, Thushar S, Singh RK. Healthy and resilient cereals and pseudo-cereals for marginal agriculture: molecular advances for improving nutrient bioavailability. Frontiers in Genetics. 2020;11:49. https://www.frontiersin.org/articles/10.3389/fgene.2020.00049
51. Scalbert A, Johnson IT, Saltmarsh M. Polyphenols: Antioxidants and beyond. The American Journal of Clinical Nutrition. 2005;81(1):215S-217S. https://doi.org/10.1093/ajcn/81.1.215S
52. Scapin G, Schmidt FL, Silva LP. Nutritional potential and bioactive compounds in quinoa. Food Chemistry. 2016;221:1567-1573. https://doi.org/10.1016/j.foodchem.2016.10.116
53. Sindhu R, Khatkar BS. Pseudocereals: Nutritional composition, functional properties, and food applications. In: Food Bioactives. CRC Press, 2019, p. 105-135. https://www.taylorfrancis.com/chapters/edit/10.1201/9780429242793-6
54. Slavin J. Fiber and prebiotics: Mechanisms and health benefits. Nutrients. 2013;5(4):1417-1435.https://doi.org/10.3390/nu5041417
55. Samanta S, Sengupta S. Integrated nutrient management (INM) in sustainable plant nutrition. Int J Agric Food Sci. 2024;6(2):128-130.
56. Tang Y, Li X, Zhang B, Chen PX. Characterisation of phenolics, betanins and antioxidant activities in seeds of three *Chenopodium quinoa* Willd genotypes. Food Chemistry. 2015;166:380-388. https://doi.org/10.1016/j.foodchem.2014.06.018
57. Gálvez VA, Miranda M, Vergara J, Uribe E, Puente L, Martínez EA. Nutrition facts and functional potential of quinoa (*Chenopodium quinoa* Willd.), an ancient Andean grain: A review. Journal of the Science of Food and Agriculture. 2010;90(15):2541-2547. https://doi.org/10.1002/jsfa.4158
58. Vrancheva R, Popova A, Mihaylova D. Phytochemical analysis and antioxidant activity of seeds and grains. Jordan Journal of Biological Sciences. 2020;13(3):391-398. https://jjbs.hu.edu.jo/files/vol13/n3/Paper%20Number%2011.pdf
59. WHO/FAO/UNU. Protein and amino acid requirements in human nutrition. World Health Organization, 2007. https://www.who.int/publications/i/item/9789241209359
60. Wieslander G, Norbäck D, Lindgren T, Janson S. Buckwheat consumption and its health effects. Food & Nutrition Research. 2011;55(1):5634. https://doi.org/10.3402/fnr.v55i0.5634
61. Zhang MW, Zhang RF, Zhang FX, Liu RH. Phenolic profiles and antioxidant activity of black rice bran of different commercially available varieties. Journal of Agricultural and Food Chemistry. 2010;58(13):7580-7587. https://doi.org/10.1021/jf100646w
62. Zhang W, Boateng ID, Xu J, Zhang Y. Proteins from legumes, cereals, and pseudo-cereals: Composition, modification, bioactivities and applications. Foods. 2024;13(13):1974. https://www.mdpi.com/2304-8158/13/13/1974
63. Zhao H, Dong J, Lu J, Chen J, Li Y, Shan L, *et al*. Effects of extraction solvent mixtures on antioxidant activity evaluation and their extraction capacity and selectivity for free phenolic compounds in barley. Journal of Agricultural and Food Chemistry. 2010;58(14):7673-7679. https://doi.org/10.1021/jf100877h
64. Zhou X, Zheng Z, Huang H, Zhang J. Ferulic acid regulates oxidative stress and inflammation related gene expression in human intestinal Caco-2 cells. European Journal of Pharmacology. 2016;775:24-31. https://doi.org/10.1016/j.ejphar.2016.02.034
65. Zieliński H, Michalska A, Piskuła MK, Kozłowska H. Antioxidants in thermally treated buckwheat grouts. Molecular Nutrition & Food Research. 2009;53(S1):S128-137.