Physicochemical and Functional Properties of Selected Cereal and Pseudo-Cereal Flours: A Comparative Review

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Abstract

Cereal flours and pseudo-cereal flours are food grains that are consumed globally for their varied nutrient qualities. In modern trends, pseudo-cereal flours such as Quinoa, Amaranth, and Buckwheat are being recognised and preferred for their beneficial nutrient profiling and favourable functional attributes over their cereal alternatives like Rice, Wheat, and Oats. An extensive and thorough knowledge of the physicochemical and functional properties of these grain flours is vital for the effective incorporation of said foods into the mainstream diet and value-added food formulations. The objectives of this comparative study are to research various cereal and pseudo-cereal flours commonly consumed, to evaluate and analyse the physicochemical and functional properties of selected cereal and pseudo-cereal flours, and to compare and study the physical, chemical, and functional compound profile of the two categories to determine advantages of either food group. This comparative study is researched and gathered based on secondary data available in online platforms like published research articles, scientific journals, web books, and standard food science references. The selected cereal (Rice, Wheat, Oats) and pseudo-cereal (Quinoa, Amaranth, Buckwheat) flours were analysed based on physicochemical properties such as moisture content, pH, and colour values and odour, as well as functional properties including water absorption capacity, oil absorption capacity, swelling power, solubility, foaming capacity, and emulsifying

properties. The comparative study showed that pseudo-cereal flours displayed higher protein content, better water and oil absorption properties, and better emulsifying and foaming properties compared to conventional cereal flours. Cereal flours exhibited better starch-related properties such as swelling power and gelatinisation attributes. Variations in functional properties were mainly influenced by protein composition, starch structure, and fibre content of the flours. Pseudo-cereal flours indicated promising use in gluten-free, functional, and nutraceutical food products. Further research in practical aspects can be done to analyse the accurate properties. Different processing techniques such as sprouting, malting, fermentation, and extrusion can be studied with regards to increasing functional properties of pseudo-cereal-based food innovations.

Keywords: Cereal Flours, Pseudo-Cereal Flours, Physicochemical Properties, Functional Properties, Flour Characteristics, Comparative Review

Introduction

Cereal flours such as Rice, Wheat, and Oats are widely consumed staple foods that contribute significantly to global energy intake. Their extensive use in food systems is mainly attributed to their carbohydrate content and favourable processing characteristics. However, increasing health awareness, gluten-related disorders, and demand for nutrient-dense foods have encouraged the exploration of alternative grain sources.

Pseudo-cereal flours including Quinoa, Amaranth, and Buckwheat have gained attention due to their superior nutritional profile, higher quality protein, and gluten-free nature. Although botanically distinct from cereal flours, they exhibit comparable technological properties and are increasingly utilised in functional and specialty food products.

The application of cereal and pseudo-cereal flours in food formulation depends largely on their physicochemical and functional properties, such as moisture content, pH, colour, water and oil absorption capacity, swelling power, solubility, and emulsifying behaviour. These properties are influenced by variations in protein composition, starch structure, and fibre content. This comparative review evaluates and contrasts the physicochemical and functional characteristics of selected cereal and pseudo-cereal flours using available scientific literature, highlighting their potential advantages in modern food applications.

Nutritional Profile of Cereal Flours and Pseudo-Cereal Flours

Rice: Rice is a staple cereal mainly consumed for its carbohydrate content. Although recent nutrition literature on Rice specifically is less in number than broad cereal group reviews, comprehensive studies on cereal flours including Rice show that Rice contains high levels of carbohydrates, serving as a major energy source. Whole grain Rice provides more fibre and micronutrients compared with white, refined Rice after processing. Recent cereal review publications indicate that Rice, like other cereal flours, contributes primary carbohydrates to diets, with few essential protein compounds and micronutrients without much refining.

Wheat: Wheat is a leading cereal grain consumed globally in flour bases and is a key source of calories, proteins, and fibre, especially when consumed as whole Wheat. While refined Wheat products lose many nutrients, whole Wheat helps supplement iron, folate, zinc, and antioxidants not present in polished forms. In whole grain compositions, Wheat (8–15% protein) is among the cereal flours with intermediate protein content and is a source of dietary fibre, B-vitamins, and micronutrients when consumed.

Oats: Oats are preferred among cereal flours for their higher protein and soluble fibre (β-glucan) content. Broad reviews of whole grain flour groups highlight Oats as a nutritious source of food, containing β-glucan, a soluble fibre that supports cholesterol control and glycaemic index regulation, especially in diabetic patients. They also provide micronutrients such as magnesium, phosphorus, and iron. Dietetic sources emphasise Oats' beneficial fibre profile as β-glucan content is associated with improved heart and metabolic health outcomes.

Quinoa: Quinoa is widely recognised for its high-quality, complete protein and micronutrient profile. Quinoa is known for its distinct nutritional characteristics and contains good quality essential proteins and fats along with nutritious amounts of starch, dietary fibre, and micronutrients. Among pseudo-cereal flours, Quinoa exhibits high functional and nutraceutical properties, enriching the diet with proteins, dietary fibre,

vitamins, minerals, and antioxidants compared to common cereal flours. This includes full sets of the essential amino acids that are not typically found in traditional cereal flours such as Rice or Wheat.

Amaranth: Amaranth is nutritionally rich, especially in protein, fibre, and micronutrients. Scientific studies have shown that pseudo-cereal flours including Amaranth contain good quality essential amino acids, balanced protein chains, essential unsaturated fatty acids, whole dietary fibre, and micronutrients that are equal to or more in quantity compared to their cereal flour alternatives. Amaranth's protein content is often higher than cereal grains and it includes lysine and sulfur-containing amino acids missing in Wheat and Rice, which are crucial for a healthy metabolism.

Buckwheat: Buckwheat provides a rich nutrient profile which includes essential proteins, dietary fibre, B-vitamin complexes, and minerals. Numerous scientific review literatures confirm that pseudo-cereal flours, especially Buckwheat, are considered gluten-free and are rich in high-quality proteins, crude dietary fibres, micronutrient contents, and bioactive compounds such as phenolic acids and flavonoids that provide therapeutic effects and act as functional compounds. Buckwheat particularly contributes significant protein and micronutrients in its dry seed form to the diet.

Physicochemical Properties

Physicochemical properties of cereal and pseudo-cereal flours are essential indicators of their quality, stability, and suitability for food processing. Key parameters such as moisture content, pH, colour values, bulk density, and sensory attributes influence shelf life, storage behaviour, and consumer acceptability of flour-based products. Moisture content plays a critical role in determining microbial stability and handling characteristics, while pH affects flavour, processing behaviour, and enzymatic activity.

Cereal flours such as Rice, Wheat, and Oats generally exhibit uniform colour, moderate moisture levels, and physicochemical characteristics favourable for conventional food applications. Pseudo-cereal flours including Quinoa, Amaranth, and Buckwheat often display greater variation in colour and bulk density due to differences in seed structure and pigment composition. Their relatively higher mineral and protein content may influence pH and water-binding behaviour. Differences in physicochemical properties between cereal flours and pseudo-cereal flours are primarily attributed to variations in starch composition, protein structure, and fibre content, which collectively affect flour functionality and processing performance.

Functional Properties

Functional properties of cereal and pseudo-cereal flours play a crucial role in determining their suitability for food processing and product development. These properties include water absorption capacity, oil absorption capacity, swelling power, solubility, foaming capacity, and emulsifying properties, which influence texture, mouthfeel, and stability of food products. Conventional cereal flours such as Rice, Wheat, and Oats generally exhibit superior starch-related functionalities, particularly swelling and gelatinisation behaviour, making them suitable for bakery and extruded products.

In contrast, pseudo-cereal flours like Quinoa, Amaranth, and Buckwheat demonstrate enhanced protein-based functional properties, including higher water and oil absorption, improved emulsifying capacity, and better foaming stability. These characteristics are attributed to their higher protein content, favourable amino acid composition, and dietary fibre profile. Variations in functional properties between cereal flours and pseudo-cereal flours are primarily influenced by differences in protein structure, starch composition, and fibre content, highlighting the potential of pseudo-cereal flours in gluten-free, functional, and value-added food formulations.

Comparison

The following tables provide details about the compared nutritional and physicochemical qualities of the selected cereal flours and pseudo-cereal flours.

Protein Content

Table 1 Protein Content in Selected Cereal Flours

Cereal Flours	Protein %
Rice	6.6–8.4%
Wheat	8.0–17.5%
Oats	8.7–16%

Table 2 Protein Content in Selected Pseudo-Cereal Flours

Pseudo-Cereal Flours	Protein %
Quinoa	13.0–14.0%
Amaranth	11.7–18.4%
Buckwheat	21.6–25.3%

As cited by Zhang, W., Boateng, I. D., Xu, J., & Zhang, Y. (2024), pseudo-cereal flours like Quinoa, Buckwheat, and Amaranth often have higher protein than Rice, Oats, or Wheat in flour forms.

Carbohydrate/Starch Content

Table 3 Carbohydrate/Starch Content in Selected Cereal Flours

Cereal Flours	Carbohydrates %
Rice	70–80%
Wheat	70–75%
Oats	60–70%

Table 4 Carbohydrate/Starch Content in Selected Pseudo-Cereal Flours

Pseudo-Cereal Flours	Carbohydrates %
Quinoa	60–70%
Amaranth	65–75%
Buckwheat	70–75%

As cited by Zhang, W., Boateng, I. D., Xu, J., & Zhang, Y. (2024), pseudo-cereal flours like Quinoa, Buckwheat, and Amaranth have lower carbohydrates (simple carbohydrates/starches) than Rice, Oats, or Wheat flours, providing a lower glycaemic index.

Crude Fibre Content

Table 5 Crude Fibre Content of Selected Cereal Flours

Cereal Flours	Crude Fibre Content %
Rice	1.6–2.8%
Wheat	2–5%
Oats	10–15%

Table 6 Crude Fibre Content of Selected Pseudo-Cereal Flours

Pseudo-Cereal Flours	Crude Fibre Content %
Quinoa	2.5–4.0%
Amaranth	6–8%
Buckwheat	8–12%

As cited by Zhang, W., Boateng, I. D., Xu, J., & Zhang, Y. (2024), pseudo-cereal flours like Quinoa, Buckwheat, and Amaranth often exhibit higher crude fibre values than Rice, Oats, or Wheat, making them gut friendly and a therapeutic food alternative.

Fat Content

Table 7 Fat Content of Selected Cereal Flours

Cereal Flours	Fat Content %
Rice	<2%
Wheat	1–2%
Oats	5–10%

Table 8 Fat Content of Selected Pseudo-Cereal Flours

Pseudo-Cereal Flours	Fat Content %
Quinoa	4–7%
Amaranth	5–7%
Buckwheat	2–4%

As cited by Zhang, W., Boateng, I. D., Xu, J., & Zhang, Y. (2024), pseudo-cereal flours like Quinoa, Buckwheat, and Amaranth often have higher fat content, essentially unsaturated fats that are good for the regulation of cholesterol and cardiac health when compared to their cereal alternatives.

Ash Content

Table 9 Ash Content of Selected Cereal Flours

Cereal Flours	Ash Content %
Rice	0.4–0.7%
Wheat	1.5–2%
Oats	1.5–2.0%

Table 10 Ash Content of Selected Pseudo-Cereal Flours

Pseudo-Cereal Flours	Ash Content %
Quinoa	2–3%
Amaranth	2–3%
Buckwheat	2–3%

As cited by Zhang, W., Boateng, I. D., Xu, J., & Zhang, Y. (2024), pseudo-cereal flours like Quinoa, Buckwheat, and Amaranth often have higher ash content than Rice, Oats, or Wheat.

Moisture Content

Table 11 Moisture Content of Selected Cereal Flours

Cereal Flours	Moisture Content %
Rice	11–13%
Wheat	10–12%
Oats	9.0–12.0%

Table 12 Moisture Content of Selected Pseudo-Cereal Flours

Pseudo-Cereal Flours	Moisture Content %
Quinoa	11–14%
Amaranth	12–14%
Buckwheat	11–14%

Pseudo-cereal flours tend to exhibit higher moisture content compared to their cereal alternatives. This can inhibit storage qualities and would require proper drying or processing to extend shelf life and preserve sensory and nutritional qualities.

pH

Table 13 pH of Selected Cereal Flours

Cereal Flours	pH
Rice	6.2–6.8
Wheat	6.0–6.8
Oats	6.2–6.9

Table 14 pH of Selected Pseudo-Cereal Flours

Pseudo-Cereal Flours	pH
Quinoa	6.3–6.9
Amaranth	6.2–6.8
Buckwheat	6.3–6.9

Both cereal flours and pseudo-cereal flours range in the weak acid/neutral range. This property helps stabilise keeping qualities and also prevents enzyme catalysation in stored flour.

Applications

Cereal flours such as Rice, Wheat, and Oats are widely used in staple foods, bakery products, noodles, and breakfast recipes due to their favourable starch-related properties, including swelling, gelatinisation, and texture formation. These characteristics support their extensive use in traditional and industrial food processing.

Pseudo-cereal flours like Quinoa, Amaranth, and Buckwheat exhibit superior protein quality and functional properties such as higher water and oil absorption capacity, emulsifying ability, and foaming capacity. These attributes make them suitable for gluten-free products, protein-enriched foods, functional foods, and nutraceutical formulations. The incorporation of pseudo-cereal flours in composite flours enhances nutritional quality while maintaining desirable processing characteristics.

Role of Sustainability

Cereal flours and pseudo-cereal flours contribute significantly to sustainable food systems by supporting food security and dietary diversification. While conventional cereal flours provide high yields, pseudo-cereal flours such as Quinoa, Amaranth, and Buckwheat offer added sustainability benefits due to their ability to grow under diverse agro-climatic conditions with lower input requirements. Their resilience to environmental stress and superior nutritional and functional properties supports the development of nutrient-dense, plant-based foods. Incorporation of pseudo-cereal flours into composite flours promotes crop diversification, biodiversity, and long-term environmental and nutritional sustainability.

Conclusion

- Pseudo-cereal flours like Quinoa and Amaranth (12–18%) often have higher protein than Rice or Wheat flours.
- Pseudo-cereal flours and whole cereal flours both contribute fibre, with pseudo-cereal flours often being richer in soluble and insoluble fractions.
- Pseudo-cereal flours have more unsaturated fatty acids (e.g., linoleic acid) than typical cereal flours.
- Quinoa, Amaranth, and Buckwheat deliver higher mineral content (Mg, Fe, Zn) and B-vitamins compared with refined Rice and processed cereal flours. They also contain phenolic acids, flavonoids, and antioxidants that contribute to potential health benefits such as cardioprotection and anti-inflammatory effects.
- Pseudo-cereal starches generally have smaller granule size and unique amylose/amylopectin ratios, which contributes to greater water binding, swelling, and gel formation, relevant in bakery, thickening, or ready-to-eat products.
- Oats contain an important dietary fibre called β-glucan, which helps form a gel useful in foods intended to help lower cholesterol or slow digestion.
- Rice and Wheat starches exhibit different pasting and gel profiles (Rice often higher in starch and lower in fibre), which influence texture in products like noodles, bread, and batters.
- Pseudo-cereal flours have a high content of bioactive compounds like phenolic compounds, flavonoids, and antioxidants that contribute to metabolic health, anti-inflammatory potential, and cardioprotective benefits.
- Oats also contain functional β-glucans tied to metabolic health, though Rice and Wheat have fewer antioxidant phytochemicals on average, especially after milling or processing.
- Moisture content of cereal flours generally ranges lower than pseudo-cereal flours, ensuring good shelf stability. Pseudo-cereal flours may exhibit slightly higher moisture due to their higher lipid and fibre content.
- Pseudo-cereal flours like Quinoa, Amaranth, and Buckwheat provide additional sustainability benefits as they can grow under a variety of agro-climatic conditions with minimal input required.
- Their resistance to environmental stress as well as their superior nutritional and functional qualities help to advance the creation of nutrient-dense plant-based diets.

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