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Effects of micro-comminution on the functional nutrients and antioxidant activity of quinoa cereal

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Abstract

The effects of micro comminution on the functional nutrients and antioxidant activity of quinoa cereal were investigated. The particle size distribution of quinoa cereal powder after micro comminution processing was investigated, as well as the nutritional and functional components and antioxidant characteristics. Simultaneously, correlations between antioxidant activity and product development and deep processing of quinoa cereal were investigated. The results indicate that: the fat, polysaccharide, and total phenol contents increased significantly ($P < 0.05$), while the total dietary fibre content decreased significantly ($P < 0.05$); the total antioxidant, DPPH, ABTS, and linoleic acid system contents of micro crushed quinoa oatmeal increased gradually, while the hydroxyl radical scavenging rate and TBA value decreased; when the grain size of micro crushed quinoa oatmeal was decreased. Micro crushing technique has the potential to boost quinoa cereal's nutritional content and antioxidant activity.

Keywords: quinoa cereal; micro comminution; functional nutrition; the oxidation resistance.

Practical Application: Micro-comminuting quinoa cereal has a beneficial effect on its functional nutrients and antioxidant activity. Micro-comminuting technology has the potential to significantly increase the nutritional value and antioxidant activity of quinoa cereal.

1 Introduction

Quinoa, commonly known as quinoa in South America and elsewhere, is a tiny amaranthaceous chenopodium dicotyledonous plant endemic to the Andes Mountains. It is an integral part of the Inca aboriginal traditional cuisine and is referred to as the "mother of grains" by NASA. The United Nations Food and Agriculture Organization (FAO) has selected "whole foods" and "super grains" as the most acceptable and ideal for human consumption. It is the only monomer plant capable of meeting the body's fundamental nutritional requirements (Lin et al., 2019; Bhargava et al., 2006; Ng & Wang, 2021) and is widely planted in Europe, Africa and Shanxi, Gansu, Qinghai and Xinjiang in China (Ballegaard et al., 2021; Palombini et al., 2013). Quinoa is high in antioxidants, dietary fibre, amino acids, saponins, flavonoids, and vitamins. It possesses significant antioxidant capacity, anti-inflammatory, antibacterial, and immunological enhancing properties (Tang et al., 2015; Valenzuela-González et al., 2022). Quinoa cereal is not suitable for direct consumption; most food additions contain quinoa functional component extract and quinoa cereal coarse powder.

Micro comminution technology is a relatively recent type of processing that pulverises samples smaller than 100 μm and is commonly employed in health care goods and functional food processing (Chen et al., 2006; Wang et al., 2022). When sample particles are submicron in size, the surface area rises exponentially, increasing the pace of water absorption, taste release, and active ingredient use, hence increasing the rate of nutrient absorption and physiological function of food (Wu et al., 2012; Silva et al., 2020). Micro comminuting research now focuses mostly on tea, wheat, oats, and other foods (Ma et al., 2016). Zhu et al. (2015) demonstrated that micro crushing might enhance wheat bran's ability to scavenge DPPH, superoxide, and hydroxyl free radicals. Liu et al. (2016) thought that superfine grinding enhanced the solubility of polysaccharides, total reducing power, DPPH and ABTS radical scavenging activities of oat bran, while also increasing the antioxidant activity of polysaccharides.

Now, there is little research on quinoa cereal. To increase the rate of quinoa cereal use in meals, an experiment was conducted using quinoa cereal as the raw material and fine crushing technology for processing. The particle size distribution of quinoa cereal powder was investigated, as well as the nutritional and functional components and antioxidant characteristics. Simultaneously, correlations between antioxidant activity and product development and deep processing of quinoa cereal were investigated to offer a theoretical foundation for product development and deep processing.

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2 Materials and methods

2.1 Materials and reagents

Quinoa cereal from Ningxia Guyuan was bought at Chuzhou Haywoode Supermarket. Total Antioxidant Capacity Assay Kit was purchased from Sigma Aldrich (Shanghai) Trading Co., LTD (Shanghai, China). All other chemical reagents are of analytical purity.

2.2 Sample preparation

Quinoa cereal was crushed and sieved using a micro powder drying equipment. 355 μm (50 mesh), 150 μm (100 mesh), 90 μm (150 mesh), and 74 μm (200 mesh) sieved samples were packed and sealed and stored at -20 °C for subsequent use.

2.3 Determination of main indicators

Hydrolysis technique for determining the starch content (Burešová et al., 2010); Soxhlet extraction method for determining the crude fat content (Luthria et al., 2004). Kjeldahl nitrogen assessment of crude protein content (Zhou et al., 2009). The total dietary fibre content was determined using an enzyme gravimetric technique (Yin et al., 2004). Polysaccharide content determination using the phenol-sulfuric acid technique (Sun et al., 2009). Total phenol concentration determination using the folin-phenol reagent (Pontoni et al., 2017).

2.4 Determination of antioxidant activity

The aqueous extract of quinoa cereal was prepared according to the technique described by Özkaya et al. (2017), and the supernatant was collected for the assessment of antioxidant properties.

Sigma Aldrich's kit was used to assess the total antioxidant capacity. The DPPH free radical's scavenging capacity of samples were determined follow the descriptions by Yeler & Nas (2021). The rate of hydroxyl radical clearance was calculated using the method of Tohma et al. (2017) with some modification. The ability of ABTS to scavenge free radicals was measured using the technique described by Yang et al. (2020). The thiobarbituric acid technique was used to estimate the TBA value (Wang et al., 2015). The oxidation resistance of the linoleic acid system was measured using the method of Vásquez-Ocmín et al. (2010) with some modification.

2.5 Data statistics and analysis

Three replicates were taken from each sample. Excel 2016 was used to organise and visualise the measured data. The outcomes are denoted with. Using SPSS software, determine the correlation between each test index.

3 Results and analysis

3.1 Effects of micro comminuting on the nutritional composition of quinoa cereal

Table 1 summarized the nutritional content of micro crushed quinoa cereals with varying particle sizes. As shown in Table 1, the smaller the grain size of quinoa cereal after micro powder technology processing, the greater the increase in crude fat content ($P < 0.05$), which could be explained by the reduction in grain size of quinoa cereal, the increase in surface area, the increase in grain size gap, and the exposure of more fat in the cortex. Quinoa cereals with grain sizes greater than 150 μm have a higher crude protein content. There was no correlation between the starch content of quinoa cereal and grain size ($P < 0.05$).

3.2 Effects of micro crushing on functional components of quinoa cereal

Table 2 illustrated the effect of micro crushing on the functional components of quinoa grain. As shown in Table 2, quinoa cereal grain size is reduced using micro powder technology, polysaccharide, and total phenol content increase first. The polysaccharide and total phenol content of unreached and reached fine crushing quinoa cereal grain size are significantly different ($P < 0.05$), and when crushing grain size is 90 μm, polysaccharide and total phenol content peaks. This is similar with the findings of Xiao et al. (2022) and Yu et al. (2022). The explanation for

Table 1. Basic nutrients of micro crushed quinoa cereal (dry matter).

Crushing Particle Size/μm	Crude Fat/g·(100 g)$^{-1}$	Crude Protein/g·(100 g)$^{-1}$	Starch/g·(100 g)$^{-1}$
355 μm	3.95 ± 0.04^{d}	12.48 ± 0.05^{a}	56.27 ± 1.12^{a}
150 μm	5.42 ± 0.08^{c}	12.52 ± 0.04^{a}	56.31 ± 0.06^{a}
90 μm	5.63 ± 0.14^{b}	9.93 ± 0.53^{b}	56.35 ± 0.12^{a}
75 μm	7.51 ± 0.05^{a}	9.80 ± 0.08^{b}	56.29 ± 0.11^{a}

The data was represented as mean ± SD. Different letters in the same column indicate significant difference ($P < 0.05$).

Table 2. Effect of micronization on functional components of oat bran (dry matter).

Crushing particle size/μm	Polysaccharides/g·(100 g)$^{-1}$	Total phenol/mg·(100 g)$^{-1}$	Dietary fiber/g·(100 g)$^{-1}$
355	1.89 ± 0.03^{c}	391.84 ± 0.52^{d}	6.87 ± 0.05^{b}
150	2.32 ± 0.31^{c}	401.23 ± 0.03^{c}	6.98 ± 0.22^{a}
90	6.82 ± 0.45^{a}	451.23 ± 0.14^{a}	6.67 ± 0.04^{c}
75	3.26 ± 0.36^{b}	429.82 ± 0.06^{b}	3.72 ± 0.45^{d}

Data were repeated three times. Different letters in the same column indicate significant difference ($P < 0.05$), and there is no comparison in the same row.

this might be that micro comminution breaks the cell wall of quinoa grain and increases the surface area of powder particles, increasing the rate of polysaccharide and total phenol solubility. The dietary fibre content of micro crushed quinoa grain reduced considerably ($P < 0.05$), which is consistent with the findings of Bender et al. (2020) and Repo-Carrasco-Valencia & Serna (2011). The explanation for this might be because when quinoa cereal is subjected to physical shear stress, the macromolecular structure is damaged and a portion of the link is split into little molecules. Additionally, the melting of macromolecules and the transition of insoluble chemicals into soluble ones demonstrate that smaller particle sizes are not always preferable.

3.3 Effects of micro comminution on total antioxidant capacity of water extract from quinoa cereal

The impact of micro grinding on the total antioxidant capacity of quinoa grain water extract is depicted in Figure 1. As seen in Figure 1, the total antioxidant capacity of quinoa cereal rose considerably with grain size reduction ($P < 0.05$). Quinoa cereal powder 50 mesh (355 m) improved the total antioxidant capacity by 2.86 percent, 9.87 percent, and 11.65 percent, respectively, as compared to 100 mesh (150 μm), 150 mesh (90 μm), and 200 mesh (75 μm). Clearly, the overall antioxidant capacity of the aqueous extract of quinoa grain powder was greatest at 200 mesh (74 μm), which facilitated the antioxidant's solubility.

3.4 Effect of micro comminution on the clearance rate of water extract of quinoa cereal

Figure 2 depicts the effect of a water extract of quinoa grain with varying particle sizes on the rate of free radical scavenging. As seen in Figure 2, the scavenging effect of quinoa granola extract on DPPH and ABTS free radicals rose significantly and progressively as the crushing particle size of quinoa granola decreased. At 200 mesh (75 μm), the free radical scavenging rates of DPPH and ABTS reached a maximum of 90.82 percent and 70.78 percent, respectively, which was 30.58 percent and 7.68 percent higher than those of quinoa cereal at 50 mesh (335 μm), which was similarly with Rosa et al. (2013) and Acosta et al. (2022). In conclusion, micro comminution can enhance the rate of free radical scavenging and antioxidant activity of quinoa grain water extract. Additionally, extracts of quinoa granola with varying particle sizes demonstrated a significant scavenging effect on hydroxyl radicals ($P < 0.05$). The clearance rate of quinoa granola steadily dropped when the grain size was reduced. When the grain size was 50 mesh (355 μm), the hydroxyl radical clearance rate was the highest, at 81.25 percent, which was 10.28 percent greater than when the grain size was 200 mesh (75 μm). This may be due to the crushing of polyphenols in quinoa grain, resulting in a decrease in the quantity of phenolic hydroxyl functional groups. Additionally, studies have demonstrated that polyhydroxy phenols are more effective in scavenging free radicals than monohydroxy ring compounds (Alrahmany & Tsopmo, 2012).

3.5 Effects of micro comminution on TBA value of water extract of quinoa cereal

The impact of micro grinding on the malondialdehyde level of quinoa cereal water extract is shown in Figure 3. As seen in Figure 3, the smaller the grain size of quinoa cereal, the lower the malondialdehyde level, and the trend was statistically significant ($P > 0.05$). There was no significant difference in malondialdehyde content between 150 mesh (90 μm) and 200 mesh (75 μm) quinoa grain size particles ($P > 0.05$), with the lowest concentration at 200 mesh (75 μm) and the highest concentration at 50 mesh (355 μm). In contrast to the changing trend in total antioxidant capacity, the rate of free radical scavenging by DPPH and ABTS remained constant. This finding is similarly with that of Wang et al. (2017) and Dhiman & Prabhakar (2021). This is because micro crushing impairs the organism's

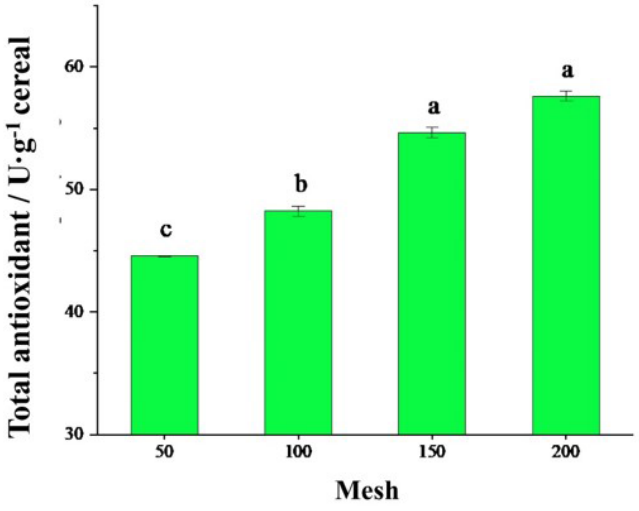

Figure 1. Effect of micro comminution on total antioxidant capacity of quinoa cereal.The letter of a, b, and c represent the significant difference at P<0.05 level.

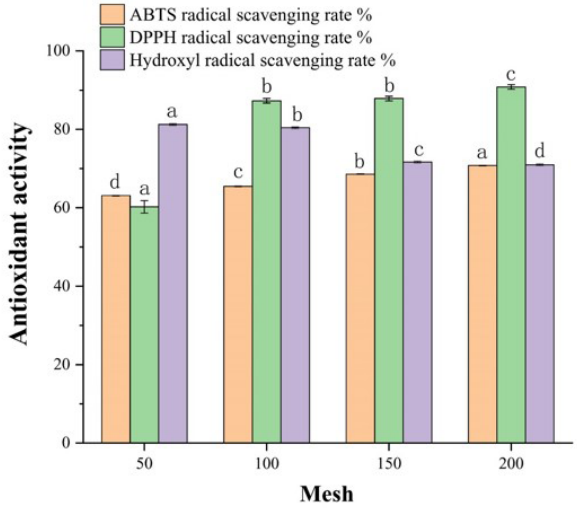

Figure 2. Effect of micro comminution on free radical scavenging rate of quinoa cereal. The letter of a, b, and c represent the significant difference at P<0.05 level.

antioxidant system. Free radical ageing is associated with lipid peroxidation, and the malonaldehyde generated promotes cell membrane deterioration, enhancing the antioxidant activity of quinoa grain and retarding lipid peroxidation.

3.6 Effects of micro grinding on antioxidant activity of linoleic acid system in quinoa cereal

Figure 4 illustrates the effect of micro grinding on the antioxidant capacity of the quinoa cereal's linoleic acid system. As seen in Figure 4, all four particle sizes of quinoa cereal have some inhibitory activity against linoleic acid peroxidation. The prevention of linoleic acid peroxidation increased first, then dropped, and then increased again. The inhibition rate of quinoa cereal was 2.64 percent, 20.86 percent, 66.24 percent, 32.66 percent, 38.73 percent, and 51.86 percent, respectively, when the grain size was 75 μm (200 mesh). After 2 days of storage, the inhibition rate of linoleic acid peroxidation reached a maximum and thereafter dropped. This might be because of the instability of -OH in polyphenols' structures, which results in autooxidation when it works as an antioxidant. It may also be connected to environmental parameters such as the pH of the mixture and the quantity of antioxidant components (Sun et al., 2014) Clearly, micro crushed quinoa cereal improves the linoleic acid system and boosts antioxidant activity.

3.7 Correlation analysis

Table 3 shows the association analysis between quinoa cereal functional components and antioxidants. As shown in Table 3, the total antioxidant capacity and the system's antioxidant capacity to linoleic acid were significantly positively correlated with total phenolic content ($P < 0.01$), significantly positively with polysaccharide content ($P < 0.05$), significantly negatively correlated with malondialdehyde ($P < 0.01$), and significantly ($P < 0.05$). The indices have the following order of importance: malondialdehyde > total phenol > dietary fibre > polysaccharide. The clearance of DPPH free radicals was favourably connected with the total phenol concentration ($P < 0.05$) and negatively correlated with the malondialdehyde concentration ($P < 0.05$). The ABTS radical scavenging rate was favourably connected with total phenol content ($P < 0.01$) and negatively correlated with malondialdehyde and dietary fibre content (P0.01), with malondialdehyde content having the greatest impact followed by total phenol content > dietary fibre > polysaccharide. The link between hydroxyl radical scavenging rate and dietary fibre and malondialdehyde concentration was very significant ($P < 0.01$), and the correlation coefficients were more than 0.91. The negative connection between the rate of scavenging hydroxyl radicals and the total phenol level was exceptionally strong ($P < 0.01$). The

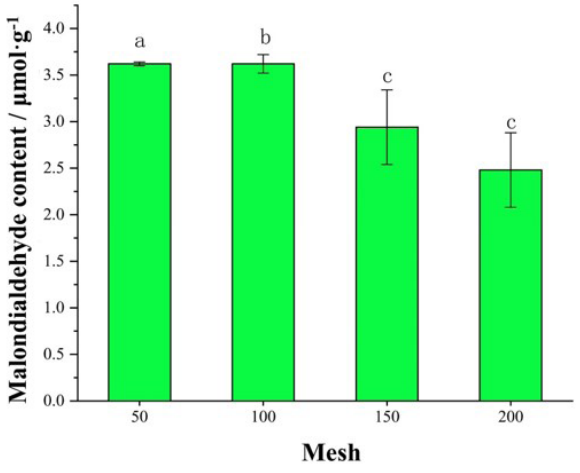

Figure 3. Effect of micro comminution on malondialdehyde content of quinoa cereal. The letter of a, b, and c represent the significant difference at P<0.05 level.

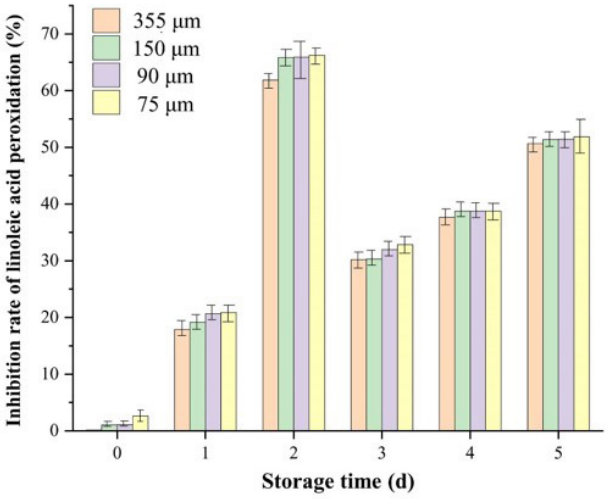

Figure 4. Effects of micro comminution on antioxidation of linoleic acid system of quinoa cereals.

Table 3. Correlation analysis between functional components and antioxidant indexes of quinoa cereal.

Composition	Total oxidation resistance	DPPH free radical scavenging rate	ABTS free radical scavenging rate	Hydroxyl radical scavenging rate	TBA values	Oxidation resistance to linoleic acid
Polysaccharide	0.616*	0.442	0.563	-537	-0.710**	0.683*
Total phenol	0.870**	0.704*	0.844**	-0.814**	-0.927**	0.881**
Dietary fiber	-0.843**	-0.452	-0.817**	0.920**	0.763**	-0.625*
Malondialdehyde	-0.981**	-0.829**	-0.976**	0.942**	1	-0.783**

*Significant correlation ($P < 0.05$). **Extremely significant correlation ($P < 0.01$). DPPH: 1,1-Diphenyl-2-picrylhydrazyl Free Radical; ABTS: 2, 2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid); TBA: Total Bile Acids.

connection between the TBA value and the polysaccharide and total phenol content was highly significant ($P < 0.01$).

Link research revealed a strong correlation between total phenol, dietary fibre, and the antioxidant index, with correlation values above 0.70. Polysaccharides, total phenols, and dietary fibre may all have a role in the antioxidant response.

4 Conclusion

The lipid, polysaccharide, and total phenol levels increased considerably ($P < 0.05$), but the total dietary fibre content fell significantly ($P < 0.05$). The overall antioxidant capacity, DPPH, ABTS, and linoleic acid system of micro crushed quinoa grain rose steadily, whereas the rate of scavenging hydroxyl radicals and TBA value declined. Quinoa cereal with 75 μm (200 mesh) grain size has the best antioxidant activity. Correlation analysis revealed a strong correlation between malondialdehyde, dietary fibre, and the antioxidant index, with a correlation value exceeding 0.70. Micro-comminuting quinoa cereal has a beneficial effect on its functional nutrients and antioxidant activity. Micro-comminuting technology has the potential to significantly increase the nutritional value and antioxidant activity of quinoa cereal.

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