Nutrients and Antinutrients in Quinoa Seed[1]

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ABSTRACT

Quinoa seeds, manually and water dehulled, were ground into meal and milled into bran and flour. The protein content of the whole seed was 13.7%, with bran, flour, and hulls accounting for 65, 28–30, and 7% of the total protein, respectively. Seeds prepared by manual dehulling were all higher in lysine and sulfur amino acids, which are typical of legumes and cereals. Mineral analysis showed that quinoa seed fractions were all rich in Ca, P, and Fe. Examination of antinutrients indicated very little trypsin inhibitor activity. The saponin content was quite low in the quinoa variety examined, with 34% located in the hulls. Although manual dehulling reduced the saponin content, a further reduction in saponin was obtained by water extraction.

Quinoa (*Chenopodium quinoa* Willd.), a cereal crop native to South America, is receiving increasing attention because of the nutritional value of its protein (Mahoney et al 1975). Quinoa seeds are higher in protein than standard wheat or corn (Gonzalez et al 1989) and contain much higher levels of methionine and lysine compared to other cereals (Risic and Galwey, 1984). Of particular concern is the presence in some quinoa cultivars of saponins, which exert antinutritional effects (Cardoza and Tapia, 1979). A study of 17 quinoa cultivars showed that the saponin content varied from 0.14 to 0.73% (Reichert et al 1986) and that saponins were located primarily in the outer layer of the grain (Aguilar et al 1979).

The present study was conducted to analyze quinoa seed fractions obtained by manual dehulling or water extraction.

MATERIALS AND METHODS

Grain

Quinoa seeds of cultivar D-407 Colorado Semidwarf grown in Rossburn, Manitoba, were provided by H. Hrubeniuk.

Preparation of Seed Fractions

A portion of cleaned quinoa seeds was ground in a Wiley mill to provide whole seed (fraction I). The remaining seeds were divided into two lots. One lot was manually dehulled using abrasive action in a pestle and mortar, and the hulls (fraction II) were separated carefully by sieving to avoid inclusion of other seed portions. A portion of the dehulled seeds was ground in a Wiley mill to obtain dehulled quinoa meal (fraction III). The remaining dehulled seeds were conditioned to 15.5% moisture, standardized by preliminary trials, for 16 hr at room temperature (20° C) in an airtight container. The conditioned seeds were milled into bran (fraction IV) and flour (fraction V), using a Brabender Quadra mill. The second lot of seeds was soaked in water for 6 hr at room temperature, and the hulls were removed by rubbing action and washing with water five or six times. The dehulled seeds were dried at around 45° C, and a portion was ground in a Wiley mill to obtain a water-dehulled meal (fraction VI). The remaining water-dehulled seeds were conditioned and milled as described above to obtain bran (fraction VII) and flour (fraction VIII). The separation of the different fractions is outlined in Figure 1.

Analysis

Quinoa seeds, after cleaning, were evaluated for 1,000-kernel weight and hectoliter weight.

Proximate analysis was conducted according to official AOAC methods (AOAC 1984), with carbohydrates determined by difference. A factor of 5.7 was used to convert nitrogen to protein.

Minerals

Minerals estimated included Ca, P, Mg, K, Mn, Zn, and Cu, following methods of the AOAC (1984) and using a coupled plasma emission (ICP model AEL-350010 PC) spectrometer (Applied Research Laboratories, Detroit, MI). Fe content was determined colorimetrically as described by Ranganna (1979).

Amino Acid Analysis

Weighed aliquots (20–25 mg) of each fraction were hydrolyzed with 3 ml of 6*N* HCl at 110° C for 22 hr in sealed glass tubes, and the hydrolysates were vacuum dried. Na-S (5 ml), sample dilution buffer (pH 2.2), was added to each tube containing dried hydrolysate, mixed thoroughly and filtered through a 0.22-μm filter humin. The filtrates were analyzed for amino acids, using a 25-cm stainless steel column prepacked with cation exchange resin.

Antinutrients

Phytate phosphorus was determined by modifying the method of Huang and Lantzsch (1983). Each fraction was extracted with 0.6*N* HCl, which was shown by Latta and Eskin (1980) to completely extract phytate. The extract was diluted with glass-distilled water to bring the final concentration of HCl in the extract to around O.2*N*. A 0.5-ml aliquot of the diluted extract was used for phytate phosphorus, with sodium phytate (6–60 μg/ml) as a standard.

Trypsin inhibitor activity was assayed following the method of Kakade et al (1974), using *N*-benzoyl-DL-arginine-*p*-nitroanilide as substrate.

Total saponins were estimated according to the gravimetric method described by Lalitha et al (1987).

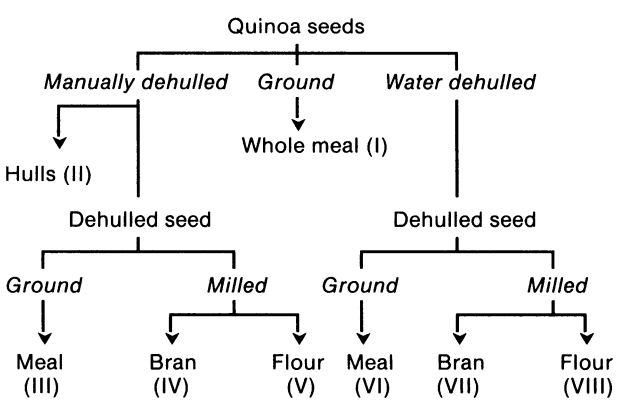

Fig. 1. Preparation of quinoa seed fractions.

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RESULTS AND DISCUSSION

Thousand-kernel weight and hectoliter weight for quinoa seeds were 28.1 ± 0.05 g and 74.7 ± 0.2 g, respectively. The value 1for 1,000-kernel weight was within the range reported by Reichert at al (1986) for the quinoa seeds examined.

Proximate analysis of the quinoa seed fractions is shown in Table I. The hulls obtained from the manually dehulled seed accounted for 8 ± 0.2% of the total seed weight. During milling of manually dehulled or water-extracted quinoa seed, the bran separated from the starch endospermic portion, producing 40% bran and 50% flour on a seed-weight basis with approximately 2% losses. Removal of the hulls had little effect on the protein content of the flour. The bran, however, accounted for 65% of the total protein compared to 28–30% in the endospermic portion and 7% in the hulls. In the flour fractions from manually dehulled seeds, the levels of protein (6.5%), fat (2.8%), ash (1.0%), and crude fiber (0.4%) were considerably lower than in the corresponding seeds. This was attributed to the removal of the bran portion, which contained 20.4% protein, 11.0% crude fat, 3.97% ash, and 5.00% crude fiber. In the case of the water-extracted seed, the content of dehulled seed was 14.2% protein, 7.2% crude fat, and 2.3% ash, compared to 5.6% protein, 2.0% crude fat, and 0.8% ash for the corresponding flour. The latter also resulted from the removal of bran, which was much higher in protein (24.3%), crude fat (13.2%), and ash (4.1%). The water-extracted seeds were slightly higher in protein and crude fat than were the manually dehulled seeds. This may be due, in part, to the leaching out of a portion of saponins, as discussed later.

Total carbohydrates accounted for 61.2% in whole ground quinoa seed, which was slightly lower than the 66.3% reported by Gross et al (1989). Carbohydrate content decreased in the bran of manually dehulled quinoa seed (45.3%), due to higher levels of protein, crude fat, and crude fiber, but it increased in the flour (73.8%), as reflected by the much lower protein, crude fat, total ash, and crude fiber contents.

The crude fiber content of whole quinoa seed was 13.7%, which was similar to levels reported by Mahoney et al (1975) but much higher than the 6.5% reported for quinoa by Gross et al (1989).

Milling of water-extracted quinoa seeds produced a bran with higher protein, crude fat, and ash contents and a flour with a lower ash content compared to the corresponding manually dehulled seed fractions. These results suggested that separation of bran and flour was more efficient during the milling of water-dehulled seeds. No information is available on the proximate analysis of quinoa seed fractions, although the results reported in this article are within the range reported by other researchers (Reichert et al 1986, Mahoney et al 1975, Gonzalez et al 1989, Gross et al 1989, Lorenz and Nyanzi, 1989).

The mineral content of the various quinoa seed fractions is summarized in Table II. The levels of calcium, iron, and potassium in the whole seed reported in this study are similar to those reported by Gonzalez and co-workers (1989). The phosphorus content of whole quinoa seed, however, was much higher in this study, 360 mg/100 g compared to the 140 mg/100 g reported by Gonzalez et al (1989). Manual dehulling substantially reduced the content of calcium from 110 to 70 mg/100 g and of manganese from 42.7 to 34.3 mg/100 g, with only marginal changes in the other minerals examined. Quinoa appeared to be a fairly good source of minerals and was particularly high in iron content.

The amino acid content of protein from the quinoa seed fractions is tabulated in Table III. Quinoa seed fractions had a lysine content ranging from 33.8 to 35.6 g/100 g of N_2, more typical of legume proteins. Glutamic acid was slightly lower in the hull and flour proteins than in whole seed and bran proteins. Sulfur amino acids were high in all quinoa seed fractions, although methionine levels were slightly lower in the bran protein than in the flour. The amino acid levels reported for whole quinoa seeds in this study, with the exception of those of cystine and methionine, were similar to levels reported by Mahoney et al (1975), and the lysine level was slightly lower than the lysine levels reported for a number of quinoa varieties by White et al (1955) and Gross et al (1989). Differences can be attributed to the higher nitrogen-to-protein conversion factor (6.25) used by these researchers, compared to the 5.7 used in this study.

The antinutrient content of quinoa seed fractions is presented

TABLE I
Proximate Composition of Quinoa Seed Fractions[a]

Seed Fraction	Moisture (%)	Crude[b] Protein (%)	Carbohydrate[c]	Crude Fat (%)	Total Ash (%)	Crude Fiber (%)
Whole ground seed	12.0 ± 0.04	13.7 ± 0.1	61.2	6.8 ± 0.0	2.82 ± 0.02	2.16 ± 0.04
Hulls	11.3 ± 0.10	13.3 ± 0.0	55.7	5.7 ± 0.02	8.40 ± 0.13	5.60 ± 0.08
Manually dehulled seeds						
Whole meal	12.2 ± 0.05	13.7 ± 0.0	62.8	6.8 ± 0.02	2.70 ± 0.09	1.80 ± 0.02
Bran	13.9 ± 0.05	20.4 ± 0.0	45.3	11.0 ± 0.02	3.97 ± 0.03	5.00 ± 0.04
Flour	15.6 ± 0.10	6.5 ± 0.0	73.8	2.8 ± 0.02	1.00 ± 0.17	0.35 ± 0.02
Water-dehulled quinoa						
Whole meal	7.5 ± 0.05	14.2 ± 0.0	...	7.2 ± 0.02	2.31 ± 0.04	ND[d]
Bran	13.9 ± 0.05	24.3 ± 0.0	...	13.2 ± 0.01	4.09 ± 0.03	ND
Flour	15.5 ± 0.05	5.6 ± 0.0	...	2.0 ± 0.01	0.77 ± 0.03	ND

[a] All values are on dry basis and are means ± SD of duplicates.
[b] Dry basis, N × 5.7.
[c] Calculated by difference.
[d] Not determined.

TABLE II
Mineral Content (db) of Quinoa Seed Fractions[a]

Seed Fraction	Ca (mg/100 g)	P (mg/100 g)	Fe (mg/100 g)	Mg (%)	K (%)	Mn (ppm)	Cu (ppm)	Zn (ppm)
Whole seed	110 ± 5	360 ± 10	9.2 ± 0.1	0.50 ± 0.05	0.90 ± 0.10	42.7 ± 2.0	9.5 ± 0.5	7.9 ± 0.5
Hulls	450 ± 12	320 ± 8	15.6 ± 0.2	0.96 ± 0.10	2.61 ± 0.20	107.7 ± 3.0	18.4 ± 1.0	5.1 ± 0.4
Manually dehulled seeds								
Seed	70 ± 4	350 ± 12	10.0 ± 0.0	0.43 ± 0.00	0.70 ± 0.10	34.3 ± 2.0	9.1 ± 0.0	7.9 ± 0.3
Bran	90 ± 2	550 ± 12	13.6 ± 0.3	0.57 ± 0.02	1.03 ± 0.05	56.1 ± 1.0	12.0 ± 0.5	3.0 ± 1.0
Flour	40 ± 3	140 ± 6	6.6 ± 0.0	0.14 ± 0.00	0.32 ± 0.02	13.7 ± 1.0	7.2 ± 0.3	5.5 ± 0.8

[a] All values are mean ± SD of duplicates.

TABLE III
Amino Acids Content (g/100 g of N_2, db) of Quinoa Seed Fractions[a]

Amino Acids	Whole Ground Seed	Manually Dehulled Hulls	Manually Dehulled Seed	Manually Dehulled Bran	Manually Dehulled Flour
Lysine	33.8 ± 1.6	34.4 ± 1.3	34.4 ± 0.8	34.2 ± 0.3	35.6 ± 0.9
Histidine	16.6 ± 0.9	16.4 ± 0.4	16.9 ± 0.5	17.4 ± 0.3	15.2 ± 0.5
Arginine	48.8 ± 3.2	41.6 ± 1.6	49.1 ± 1.7	51.2 ± 0.8	42.5 ± 2.0
Aspartic acid	16.7 ± 1.6	8.1 ± 0.7	17.2 ± 1.4	17.9 ± 1.1	17.4 ± 0.9
Threonine	22.7 ± 0.9	23.9 ± 0.5	22.8 ± 0.8	23.1 ± 0.5	23.1 ± 0.9
Serine	26.8 ± 1.2	27.2 ± 0.6	27.0 ± 1.1	26.6 ± 0.8	27.3 ± 1.3
Glutamic acid	18.4 ± 1.7	9.0 ± 0.7	19.0 ± 1.5	19.6 ± 1.2	19.2 ± 1.0
Proline	21.6 ± 0.9	23.2 ± 0.6	21.7 ± 0.6	21.6 ± 0.4	22.8 ± 0.9
Glycine	33.4 ± 1.3	36.4 ± 0.6	33.3 ± 1.1	32.9 ± 0.6	34.6 ± 1.3
Alanine	25.3 ± 1.1	26.9 ± 0.6	25.4 ± 0.8	25.3 ± 0.6	26.4 ± 1.0
Cystine[b]	3.7 ± 0.4	3.9 ± 0.9	3.3 ± 0.1	3.8 ± 0.2	3.2 ± 0.4
Valine	29.2 ± 1.1	30.7 ± 0.7	29.2 ± 0.6	28.9 ± 0.5	31.4 ± 1.0
Methionine[b]	2.1 ± 0.1	1.6 ± 0.3	1.7 ± 0.2	2.3 ± 0.0	2.8 ± 0.2
Isoleucine	23.9 ± 1.3	25.3 ± 0.6	24.3 ± 0.6	24.1 ± 0.5	25.6 ± 0.9
Leucine	3.72 ± 2.0	38.2 ± 1.0	37.8 ± 1.0	37.3 ± 0.6	39.9 ± 1.2
Tyrosine	15.6 ± 0.7	16.8 ± 1.0	15.5 ± 0.6	15.6 ± 0.2	16.9 ± 0.7
Phenylalanine	23.4 ± 1.4	24.0 ± 0.7	23.8 ± 0.4	23.4 ± 0.2	25.0 ± 0.5
Asparagine[c]	30.7 ± 0.4	40.0 ± 0.4	30.3 ± 0.1	29.4 ± 0.2	31.9 ± 0.6
Glutamine[c]	68.0 ± 2.5	71.6 ± 1.2	68.4 ± 1.6	68.7 ± 1.0	62.5 ± 3.0
Tryptophan[d]	...	...	...	...	...
Protein, % (db)	15.0 ± 0.1	14.6 ± 0.0	15.1 ± 0.0	22.4 ± 0.0	7.1 ± 0.0

[a] All values are means ± SD of duplicates.
[b] Performic acid oxidation before hydrolysis was not done.
[c] Calculated from ammonium value.
[d] Tryptophan was not estimated.

TABLE IV
Some of the Antinutrients of Quinoa Seed Fractions[a]

Seed Fraction	Phytate Phosphorus (mg/100 g)	Trypsin Inhibitor[b] Activity (units inhibited/ml of extract)	TUI (%)	Tannins (%)	Total Saponin (%)
Whole seed	174.4 ± 2.6	4.0 ± 0.00	10.0	0.53 ± 0.03	2.05 ± 0.07
Hulls	76.9 ± 0.6	6.5 ± 0.50	16.3	0.92 ± 0.05	8.80 ± 0.30
Manually dehulled					
Whole meal	183.6 ± 5.5	1.25 ± 0.25	2.5	0.46 ± 0.04	1.39 ± 0.10
Bran	166.7 ± 3.1	0.75 ± 0.25	1.8	0.61 ± 0.02	2.73 ± 0.06
Flour	82.6 ± 0.5	0.00 ± 0.00	0.0	0.28 ± 0.01	1.05 ± 0.05
Water-dehulled					
Whole meal	187.6 ± 5.6	0.75 ± 0.25	1.8	0.39 ± 0.00	0.70 ± 0.00
Bran	174.0 ± 3.1	0.75 ± 0.25	1.8	0.66 ± 0.04	1.72 ± 0.09
Flour	80.2 ± 0.2	0.00 ± 0.00	0.0	0.23 ± 0.01	0.32 ± 0.03

[a] All values are on a dry basis and are means ± SD of duplicates.
[b] One gram of sample extracted with 50 ml of 0.01*N* NaOH, and 1 ml of extract diluted to 50 ml. One milliliter of diluted extract was taken for assay. Total standard units of trypin enzyme were 40.

in Table IV. Phytate was higher in the bran than in the flour or hulls and represented 38–41% of phytate in the whole seeds. Tannins were highest in the hulls (0.92%) compared to either the bran (0.61–0.66%) or the flour (0.23–0.28%). Nevertheless, the bran still contained 46–50% of the total tannins in the whole seed. Approximately 34% of saponins were present in the hull, indicating that dehulling could remove a large portion of the saponins. The saponin content of the bran was double that found in the flour and represented the next major source this antinutrient. Washing the seeds during water extraction reduced the saponin content threefold compared to manual dehulling, leaving 0.32% and 1.05% saponins in the flours, respectively. The total amount of saponins in quinoa seeds was much lower than that found in soybean and some pulses (Jood et al 1986).

CONCLUSION

This study reports the first detailed analysis of quinoa seed fractions. The hulls, bran, and flour account for 10, 40, and 50% on a whole-seed-weight basis. The bran contained the major portion of nutrients, whereas 40–45% of the total saponins were located in the hulls. Dehulling of quinoa seeds reduced the saponin content by almost one half, and a combination of water extraction and milling further reduced the saponins in the flour.

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