# Composition and Protein Nutritional Quality of Quinoa[1]

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**ABSTRACT**

Dehulled quinoa flour (Colorado D407) contained over 58% starch, 15.6% protein (N × 6.25), 2.7% sugars, 8.9% total dietary fiber, and nearly 7% lipids and ash. The proportion of soluble fiber was only 13.5% of total dietary fiber. Quinoa was rich in several micronutrients, especially potassium, iron, calcium, and riboflavin. The lysine level in quinoa protein (6.3%) was comparable to that of soybean and was typical of dicotyledonous seed protein in being deficient in methionine. Based on animal studies (protein efficiency ratio, protein digestibility, and nitrogen balance), the quality of protein in quinoa matched that of the milk protein casein.

Quinoa (*Chenopodium quinoa* Willd.) is a traditional food crop in several South American countries and has now been introduced in the United States and other temperate countries (Carmen 1984).

Quinoa seed contains saponins, bitter compounds in the seed coats that affect the color and palatability of food products (Johnson and Croissant 1985). Reichert et al (1986) used abrasion milling to dehull quinoa and reduce saponin levels. A barley pearling machine, modified for on-farm use, was developed for pericarp and saponin removal from quinoa (Johnson 1987).

Quinoa is a starchy, dicotyledonous seed, not a cereal grain (Chauhan et al 1992), with application in quinoa-wheat flour blends in bakery products (Lorenz and Coulter 1991). Several studies have characterized the proximate and amino acid contents of quinoa (DeBruin 1964, Reichert et al 1986, Chauhan et al 1992). However, the composition of carbohydrates and protein nutritive value (Mahoney et al 1975) have not been extensively investigated. The objectives of this study were to characterize the total chemical composition of the only quinoa cultivar grown in Colorado and to assess the protein quality in biological tests with rats.

## MATERIALS AND METHODS

### Sample Processing

The quinoa cultivar D407 was grown in the San Luis Valley of Colorado. Pericarp and saponin were removed using the barley pearling machine as described by Johnson (1987). The separated cotyledons were milled into flour (about 25 mesh) on a Thomas Wiley laboratory mill (model 4).

### Analytical

Standard AACC (1983) methods were used to determine moisture, protein (N × 6.25), fat (ether extract), and ash. Starch content was measured by the procedure of Budke (1984) after hydrolysis with α-amylase and amyloglucosidase. Sugars were determined by the procedure of Dubois et al (1956). Fiber (total, insoluble, and soluble) was determined by the enzymatic-gravimetric method of Prosky et al (1988). Minerals, except phosphorus, were determined by atomic absorption or flame emission (sodium) spectrophotometry using an IL model Video 11 (Allied Analytical Systems, Andover, MA). Total phosphorus was determined colorimetrically (Fiske and Subbarow 1925). Thiamin and riboflavin were determined fluorometrically, and niacin was determined by the cyanogen bromide method using the standard AACC (1983) methods.

Amino acids, except tryptophan, were determined using a Dionex D-300 amino acid analyzer component system (Dionex Corp., Sunnyvale, CA). Hydrolyzed and filtered samples were stored in a freezer until analyzed for amino acids using a single-column accelerated system.

### Protein Quality (Animal Studies)

Protein quality was assessed by the protein efficiency ratio (PER) method of the AOAC (1990) using 10 rats per diet (Table I). Protein nutritive value was also assessed based on apparent protein digestibility (protein intake corrected for fecal protein losses) and nitrogen balance (nitrogen intake corrected for fecal and urinary nitrogen losses) studies conducted simultaneously; for these studies, rats were housed in metabolic cages to enable quantitative fecal and urinary collection. These collections were

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made throughout the four-week study period. The same groups of rats were used for all three measurements.

### Statistics

Data were analyzed by analysis of variance using the Statistical Analysis System (SAS 1982).

## RESULTS AND DISCUSSION

### Chemical Components

Starch was the main constituent in quinoa, representing over 58% of the seed components. Simple sugars were present at about the 3% level. Protein, fat, and ash contents of quinoa D407 fell within the range of values previously reported (Lamenca 1979, Coulter and Lorenz 1990, Lorenz and Coulter 1991, Chauhan et al 1992) (Table II). Total dietary fiber values of quinoa have not previously been reported, but they appeared to closely match the values reported for common grains and leguminous seeds (Frølich and Hestangen 1983, Varo et al 1983, Anderson 1990, Ranhotra et al 1990). Unlike legumes such as soybean and peas, quinoa was not a significant source of soluble fiber.

### Minerals and Vitamins

The major mineral elements of dehulled quinoa flour were phosphorus, potassium, and magnesium, as in most seed crops (Table II). However, some distinctions were apparent. For example, the potassium content of quinoa was two- to threefold higher than that found in major cereals and most legumes; calcium was also somewhat higher (Coulter and Lorenz 1990, Ranhotra 1991). Manganese, iron, and copper contents of quinoa matched the values recently reported for quinoa D407 grown in Canada (Chauhan et al 1992). In comparison, magnesium values were lower. This may be due to the differences in composition of the soil. The present value for zinc in quinoa was substantially higher than that reported by Chauhan et al (1992). Again, this may be due to differences in soil mineral composition or to contamination during the pearling operation to remove saponins.

Thiamin and niacin values of quinoa were lower than those in most common grains (Hoseney 1986, Coulter and Lorenz 1990, Ranhotra 1991) (Table II). The reverse was true for riboflavin.

### Amino Acid Composition

Quinoa was comparable to soybean in lysine content and could serve as an excellent protein supplement to cereals (Table III). Other investigators have reported similar values for lysine in quinoa (Mahoney et al 1975, Coulter and Lorenz 1990, Coulter and Lorenz 1991, Chauhan et al 1992).

Quinoa is a dicotyledonous seed like soybean, and methionine appears to be the first limiting amino acid in quinoa (Bodwell

TABLE I
Composition (%) of Test Diets

| Components | Casein Diet | Quinoa Diet |
|---|---|---|
| Test material | 11.5 | 64.10 |
| Mineral mix | 4.85 | 3.51 |
| Vitamin mix | 1 | 1 |
| Fiber (cellulose) | 5.7 | ... |
| Soybean oil | 7.86 | 5.03 |
| Water | 4.0 | ... |
| Corn starch | 65.09 | 26.36 |

TABLE II
Chemical and Nutrient Composition of Dehulled Quinoa Flour

| Composition | Amount |
|---|---|
| Chemical components, % | |
| Protein (N × 6.25) | 15.6 |
| Fat (ether extract) | 4.6 |
| Ash | 2.3 |
| Total dietary fiber | 8.9 |
| (Insoluble fiber) | (7.7) |
| (Soluble fiber) | (1.2) |
| Moisture | 7.8 |
| Starch | 58.1 |
| Sugars | 2.7 |
| Mineral, mg[a] | |
| Calcium | 70 |
| Phosphorus | 462 |
| Potassium | 855 |
| Magnesium | 161 |
| Iron | 6.3 |
| Manganese | 3.5 |
| Copper | 0.7 |
| Zinc | 3.2 |
| Sodium | 2.7 |
| Vitamins, mg[a] | |
| Thiamin | 0.29 |
| Riboflavin | 0.30 |
| Niacin | 1.24 |

[a] Per 100 g.

TABLE III
Amino Acid Composition of Dehulled Quinoa Flour

| Amino Acid | Amount (g/100 g protein) |
|---|---|
| Threonine | 4.41 |
| Half cystine | 1.39 |
| Valine | 3.67 |
| Methionine | 2.27 |
| Isoleucine | 3.02 |
| Leucine | 6.88 |
| Tyrosine | 3.66 |
| Phenylalanine | 4.52 |
| Lysine | 6.30 |
| Tryptophan | ND[a] |
| Aspartic acid | 10.54 |
| Serine | 5.62 |
| Glutamic acid | 17.29 |
| Proline | 3.54 |
| Glycine | 6.26 |
| Alanine | 5.53 |
| Histidine | 4.09 |
| Ammonia | 1.28 |
| Arginine | 9.71 |

[a] Not determined.

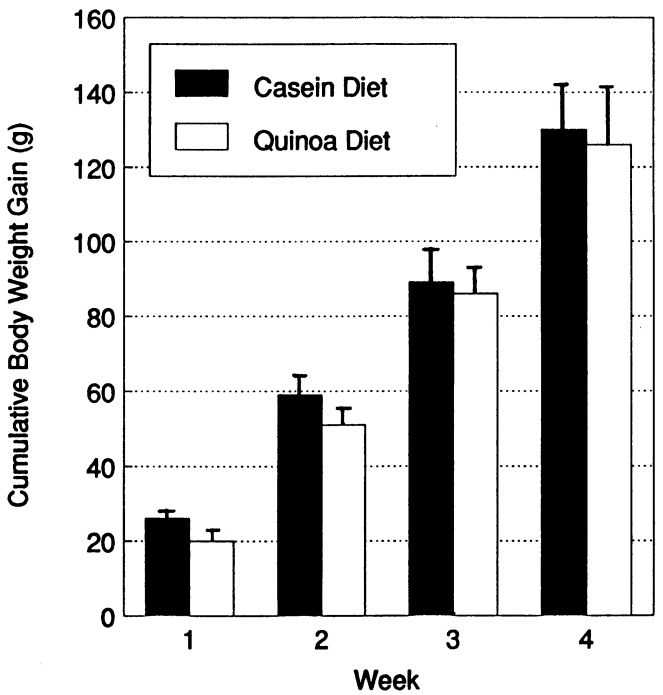


Fig. 1. Growth response of rats fed casein or quinoa diet.

TABLE IV
Protein Quality of Dehulled Quinoa Flour[a,b]

| Parameter | Protein Source | |
|---|---|---|
| | Casein | Quinoa |
| Protein efficiency ratio (PER) | | |
| Protein intake, g | 36.8 ± 2.0 a | 33.1 ± 3.1 b |
| Body weight gain, g | 130 ± 12 a | 126 ± 15 a |
| PER (determined) | 3.5 ± 0.2 b | 3.8 ± 0.2 a |
| PER (corrected) | 2.5 ± 0.1 b | 2.7 ± 0.1 a |
| Apparent protein digestibility | | |
| Protein intake, g | 36.8 ± 2.0 a | 33.1 ± 3.1 b |
| Protein digested, % | 88.9 ± 0.5 a | 84.3 ± 0.8 b |
| Nitrogen balance | | |
| Nitrogen intake, g | 5.89 ± 0.33 a | 5.30 ± 0.50 b |
| Fecal nitrogen, g | 0.65 ± 0.05 b | 0.83 ± 0.09 a |
| Urinary nitrogen, g | 1.25 ± 0.12 a | 1.02 ± 0.16 b |
| Nitrogen balance, % | 67.8 ± 3.0 a | 65.0 ± 2.2 b |

[a] Values are averages (10 rats per diet) ± standard deviations.
[b] Within a row, averages not sharing a common letter are significantly different ($P < 0.05$).

1975). Methionine in the quinoa flour tested was 2.27 g per 100 g of protein. Thus, it provided only 38% (methionine alone) or 46% (cystine's contribution considered) of the rat's need for methionine (NRC 1987) (Table III). Other essential amino acids (tryptophan not determined) provided greater proportions of the rat's requirements than did methionine.

### Protein Quality

Protein quality of quinoa was assessed by three different methods. The growth responses (cumulative bodyweight gain) obtained during the PER study are presented in Figure 1. By the third week, there was no significant difference in weight gain of the rats fed quinoa or casein. Determined and corrected PER values were a little higher for quinoa than for casein (Table IV). This occurred even though lysine concentration in quinoa (Table III) was somewhat lower than in casein (7.2 g per 100 g protein). Both sources probably adequately met the lysine requirement (NRC 1987) of rats, but both apparently failed to meet the need for methionine, the first limiting amino acid in quinoa as well as in casein.

Grain-derived foods are usually less well-digested than animal-derived foods. This could be the reason for the small, but significant, difference observed in protein digestibilities between quinoa and casein (Table IV). Apparent protein digestibility is based on fecal protein losses. The simultaneous consideration of urinary protein losses (as nitrogenous end products) provided a more precise estimate of protein quality and revealed that urinary nitrogen losses were lower in rats fed quinoa than in rats fed casein. However, the overall nitrogen balance was still slightly lower in rats fed quinoa than in those fed casein.

Viewing amino acid profile and animal studies collectively, it may be concluded, as observed also by Mahoney et al (1975), that the quality of protein in quinoa equals that of casein. This means that supplementation of cereal grains with quinoa can effectively enhance the protein quality of the resultant product. However, quinoa is of limited value in raising the protein level in cereal-based diets because its protein content is only a little higher than that of most cereals.


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