Food Chemistry **48** (1993) 131–136

Content of fat, vitamins and minerals in quinoa (*Chenopodium quinoa*, Willd) seeds

Jenny Ruales[a,b] **& Baboo M. Nair**[a]

[a]*Department of Applied Nutrition and Food Chemistry, Chemical Center, University of Lund, PO Box 124, S-221 00 Lund, Sweden.*,
[b]*Instituto de Investigaciones Tecnológicas, Escuela Politécnica Nacional, Apartado Postal 17 01 2759, Quito, Ecuador*

(Received 1 July 1992; revised version received 5 January 1993; accepted 5 January 1993)

The seed of an important food crop, indigenous to the Andean region of Latin America, called quinoa (*Chenopdium quinoa*, Willd) is a good source of thiamin (0·4 mg/100 g), folic acid (78·1 mg/100 g), and vitamin C (16·4 mg/100 g). The seeds contain twice as much γ-tocopherol (5·3 mg/100 g) as α-tocopherol (2·6 mg/100 g) and larger amounts of calcium (874 mg/kg), phosphorus (5·3 g/kg), magnesium (2·6 mg/100 g), iron (81 mg/kg), zinc (36 mg/kg), potassium (12 g/kg), and copper (10 mg/kg) than most of the common cereal grains. The amounts of mercury, lead, and cadmium found in these samples were low in relation to the values of tolerable intake for these elements. All values are expressed on a dry-weight basis. The fat content of raw quinoa seeds was 9·7% on a dry-weight basis with high amounts of oleic acid (24·8%) and linoleic acid (52·3%). The level of linolenic acid was 3·9%. The process of removing saponins from the seeds reduces the vitamin and mineral contents to some extent. The loss is significant ($p < 0{\cdot}001$) in the case of potassium, and considerable also in the case of iron and manganese ($p < 0{\cdot}01$).

INTRODUCTION

Quinoa (*Chenopodium quinoa*, Willd) is an indigenous food crop of the Andean region of South America. It grows well at high altitudes (2000 and 4000 m above sea level), and the yield ranges from 2000 to 4000 kg/ha depending on the variety and conditions of farming. Quinoa is resistant to frost and is able to grow in poor soils with low annual rainfall, between 300 and 400 mm (Weber, 1978; Risi and Galwey, 1984). The quinoa seeds, which are small, round, and flattened, measure about 1·5 mm in diameter, and about 350 seeds weigh 1 g (Varriano-Marston & DeFrancisco, 1984; Ruales & Nair, 1992*a*). The protein content is about 15%, and the starch content is about 60%. Quinoa also contains about 9% fat and about 11% dietary fibre. The nutritional quality of its protein compared with that of common cereals is also very high (Mahoney *et al.*, 1975; Ruales & Nair, 1992*b*). A process for manufacturing infant food on an industrial scale that uses quinoa as the main raw material is being developed. In this connection, information about the content of vitamins and minerals in quinoa is of great importance. According to Freire (1988), 55·4% of the children under 5 years of age in Ecuador showed signs of malnutrition. That same study reports a deficiency of vitamin A among 5% of the children, presenting retinol content in serum lower than 100 μg/litre and deficiency (measured as activation coefficient for glutathione reductase > 1·4) of riboflavin among 31% of the children. The deficiency of riboflavin is most common in the rural areas. Deficiency of zinc is found among 25% of the infant population below 5 years, when the cut-off point was 60 μg/dl of zinc in the serum and the deficiency of iron is observed in 22% of the children when the cut-off limit of haemoglobin in the blood was at 110 g/litre. Micronutrient deficiency, especially that of iron and zinc, is frequent, not only in developing countries, but also to some degree in developed countries. Children and women in the fertile ages are found to be the most affected groups regarding iron deficiency. Hallberg (1984) reported that the main cause of widespread iron deficiency is to a great extent nutritional, because the amount of iron absorbed may not always satisfy the nutritional requirements of the individuals owing to poor availability. Some antinutritients, such as saponins and phytic acid, are known to lower the bioavailability of zinc and iron (Sandberg, 1987; Southon *et al.*, 1988; Brune, 1989; Price *et al.*, 1989; Rossander-Hulthén *et al.*, 1990; Sandberg, 1990) Quinoa seeds contain saponins and phytic acid Ruales & Nair, 1993). A major part of the saponins is easily removed by polishing the seeds and washing them with water. However, the amount of phytic acid that remains after removal of the outer layers of the seeds is relatively high, probably because it is evenly distributed in the endosperm.

Food Chemistry 0308-8146/93/$06.00

The present paper deals with the content of fat, fatty acids, vitamins, and minerals in quinoa seeds. The effect of the process of scrubbing and washing used for removing the saponins from the seeds on their content of minerals and vitamins was also investigated, and the nutritional density of quinoa for some vitamins and minerals is calculated.

MATERIALS AND METHODS

Samples

Quinoa seeds (*Chenopodium quinoa*, Willd), variety 40057 Latinreco, produced under controlled conditions of farming, harvesting and storage, were obtained from Latinreco SA, Quito, Ecuador.

Sample preparation

Raw quinoa seeds were scrubbed and polished by using a pulper (model 5707, Langsenkamp, Indianapolis, IN, USA), equipped with a sieve with holes of 0·8-mm diameter. The seeds were then cleaned from dust and other contaminants by using an air-vibrator grain separator (Model 100, The Hance Corporation, Westville, OH, USA). The seeds were washed for 20 min with tap water in a tank equipped with a mixer. They were then rinsed and dried in an oven at 50°C overnight. Finally, the seeds were ground with a sample mill (Cyclotec 1093, Tecator AB, Höganäs, Sweden) to a particle size of 40–60 mesh, packed in polyethylene bags, and stored at 4°C until used for analysis.

Fat and fatty acids

The fat analysis was performed gravimetrically after extraction with petroleum ether, according to the method of Croon and Fuchs (1980). Fat was then hydrolysed with 3% concentrated sulfuric acid in methanol, and the methyl esters of the fatty acids were produced with a mixture of 50% dimethyl carbamate in hexane and 1% metallic sodium in methanol. The methyl esters were separated on a gas chromatograph (Varian, Model 3700, Varian Associates, Humboldt Ct., Sunnyvale, USA) equipped with a fused-silica capillary column (30 m × 0·25 mm), having OV-351 as the stationary phase and helium as the carrier gas (Ruales *et al.*, 1988).

Vitamin A

Vitamin A was assayed as retinol (Söderhjelm & Andersson, 1978). Ascorbic acid was added as antioxidant prior to saponification with potassium hydroxide in ethanol and water. The ethanol–water phase was extracted with n-hexane, and the hexane phase was washed twice with a saturated solution of sodium chloride in water. The extract was evaporated to dryness in a rotary evaporator, and the residue was dissolved in 5 ml methanol. A volume of about 10 μl was injected into the HPLC (LDC, Model 1204 A, Laboratory Data Control, Milton Roy Division Company, FL, USA), equipped with an RP C18 (Nucleosil particle size of 5 μm) column (25 cm × 4·6 mm i.d.) and separated with methanol as the mobile phase. The UV absorbance was monitored at 325 nm.

Vitamin E

Vitamin E was analysed as tocopherols and tocotrienols (Piironen *et al.*, 1983). The samples were saponified with potassium hydroxide solution and then extracted with *n*-hexane. For the separation of the samples, a liquid chromatograph (Varian 5000, Liquid Chromatograph, Varian Associates, Humboldt Ct., Sunnyvale, USA), equipped with a spectrofluorometer (Model RF-540 Shimadzu) and an integrator (Chromatopac C-R3A Shimadzu), was used.

The column was a Lichrospher Si 100 II (Hibar Cat. 50316). The injected sample (20 μl) was eluted with *n*-hexane : di-isopropylether (96 : 4) at a flow rate of 2·2 ml/min. The fluorescence was measured at an excitation wavelength of 330 nm.

Vitamin B1 (thiamin)

The assay of thiamin was carried out spectrofluorimetrically as thiochrome (Freed 1966; Strohecker & Henning, 1965). The thiamin was released from the sample first by acid hydrolysis (0·1 M HCl) and then by enzymatic hydrolysis by using Clara-diastase (Clarase 300) (Fluka 27540, Fluka Chemie AG, Buchs, Switzerland). Thiamin was separated by filtration and then oxidised to thiochrome by using NaOH and $K_3Fe(CN)_6$. The detection was performed with a spectrofluorometer (RF-540 Shimadzu, Shimadzu Corporation, Kyoto, Japan) at an excitation wavelength of 365 nm and an emission wavelength of 435 nm.

Vitamin B2 (riboflavin)

Riboflavin was assayed spectrofluorimetrically (Johnsson & Branzell, 1986) after the sample had been hydrolysed with HCl and digested with acid phosphatase (Type I, from Wheat germ, SIGMA P-3627, Sigma Company, St. Louis, MO, USA) to release the riboflavin. The sample was analysed by HPLC (Varian 500 Liquid Chromatograph, Varian Associates, Humboldt Ct., Sunnyvale, USA) equipped with a spectrofluorometric detector (RF-540 Shimadzu). An RP C18 analytical column (Shadom ODS Hypersil, 5 μm, 25 cm × 4·6 mm i.d.) and an RP C18 pre-column (Shadom ODS Hypersil, 5 μm, 3 cm × 3 mm i.d.) were used to separate riboflavin. The sample (100 μl) was eluted with methanol:water (33:67), the pH of which was adjusted to 4·5 with acetic acid, at a flow rate of 0·5 ml/min. The fluorescence was measured at an excitation wavelength of 440 nm and an emission wavelength of 520 nm.

Folic acid

A microbiological method (Hansen, 1964; Jägerstad, 1987; Jägerstad & Westesson, 1979), with *Lactobacillus*

casei (ATCC 7469) as the test organism, was used for the determination of folic acid. Bacto Micro Assay Culture Agar (B 319 Difco, Difco Laboratories, Detroit, MI, USA) was used to store the culture, and, for the sub-cultivation and cultivation, Bacto Micro Inoculum Broth (B320 Difco). The basal medium was prepared with Folic Acid Casein Medium (BBL-Dano Folic Acid Casein Medium, Cat. No. 11267, BBL Microbiology Systems, A/S Ferrosan, Copenhagen, Denmark).

Vitamin C

Ascorbic acid was assayed by a colorimetric method as L-ascorbic acid by using a kit purchased from Boehringer Mannheim, Cat. No 409677 (Boehringer Mannheim GmbH, Germany).

Minerals

The analysis of minerals was performed with an atomic-absorption spectrophotometer (Varian AA 1275) equipped with a graphite tube atomiser (GTA 95) after dry ashing. The homogenised samples (15–70 g) were dried and then ashed at 450°C. Hydrochloric acid was added, and the solution was evaporated to dryness. The residue was dissolved in 0·1 N nitric acid, and the mineral contents were determined as described by the Nordic Committee on Food Analysis (1991).

Phosphorus was analysed as described by the Nordic Committee on Food Analysis (1965), with spectrophotometric detection. Lead and cadmium were also determined by atomic-absorption spectrophotometry after the samples had been ashed by the method described by Jorhem *et al.*, (1984). For the determination of mercury (Varian, 1989) the samples were digested with 6N HCl. The mercury was released by adding stannous chloride 25% w/v $SnCl_2$ in 20% v/v HCl).

Selenium and arsenic were analysed by using a method (Siemer & Hagemann, 1975) described by Saari (1980). The quinoa sample (1 g) was oxidised with a saturated solution of $MgNO_3$. The sample was then evaporated and pre-ashed on a hotplate, and the final ashing was performed in a furnace at 500°C for 6 h. Hydrochloric acid (25 ml, 6N) was carefully added to the ash in the beaker. The Se and As determinations were done after 1–4 ml samples had been injected into the hydride generator, followed by HCl (6N) to give a total volume of 4 ml. $NaBH_4$ solution (1 ml) was then injected, whereupon a selenium peak was recorded immediately and the peak area measured. The same procedure was followed for As analysis.

Nutrient density

The nutrient density was calculated as described by Hansen (1973). As a reference for the number of calories a figure of 1300 kcal/day was taken, which corresponds to the recommended dietary allowances for children between one and three years (FAO/WHO, 1985; National Research Council, 1989).

RESULTS AND DISCUSSION

The results of the fat analysis are presented in Table 1. The seeds of quinoa contain 9·7% ± 0·2 fat on a dry-weight basis. Quinoa fat has a high content of oleic acid (24·1%) and linoleic acid (52·3%). The level of linolenic acid was 3·8%. The polishing and washing did not cause any loss of fat from the seeds. The PS-ratio (the relationship between all polyunsaturated fatty acids and the saturated fatty acids) of the quinoa oil (4·90) is higher than the PS-ratio of most of the edible oils, such as soy-bean oil (3·92), corn oil (4·65), and olive oil (0·65). The percentage of energy delivered by linoleic acid in quinoa seeds is 10, which is higher than the recommendation by the American Academy of Pediatricians that infant foods should contain at least 2·7% of energy in the form of linoleic acid (National Research Council, 1989).

The amounts of certain vitamins in quinoa seeds are presented in Table 2.

Although quinoa is not a cereal, it is often used for consumption in place of cereals and contains more riboflavin and folic acid than common cereals such as wheat, barley, oats, rye, rice, and maize (Kent, 1984). The amount of α-tocopherol in quinoa is higher than that of wheat. Thus , quinoa seeds can be a source of vitamin E. The amount of γ-tocopherol is twice that of α-tocopherol in quinoa.

The mineral content of quinoa seeds is presented in Table 3. The data obtained for mineral composition in this study are in the range of values reported by Koziol (1992) and González *et al.* (1989).

The contents of copper and sodium in processed quinoa were found to be higher. This is difficult to explain, but it could be caused by contamination from water used for washing.

Potassium and phosphorus are present in high concentrations in quinoa seeds. The ratio of calcium : magnesium is 1 : 3 and that of calcium : phosphorus is 1 : 6, which is far from the recommended Ca : P ratio of 1 : 1·5. The dietary-intake ratio of Ca : P is reported to

Table 1. Fatty acid composition of fat in quinoa seeds (g/100g fat)

Fatty acid		Raw whole quinoa	Polished and washed quinoa
Myristic acid	C 14	0·1	0·1
Palmitic acid	C 16	9·7	9·9
Palmitoleic acid	C 16:1	0·2	0·2
Stearic acid	C 18	0·6	0·6
Oleic acid	C 18:1	24·8	24·5
Linoleic acid	C 18:2	52·3	52·3
Linolenic acid	C 18:3	3·9	3·8
Arachidic acid	C 20	0·4	0·4
Eicosenic acid	C 20:1	1·4	1·4
Eicosadienoic acid	C 20:2	0·2	0·1
Behenic acid	C 22	0·5	0·6
9-Docosenoic acid	C 22:1w9	1·4	1·5
Tetracosanoic acid	C 24	0·2	0·2
Tetracosenoic acid	C 24:1	2·4	2·6

Table 2. The content of certain vitamins in Quinoa seeds* (mg/100 g dry basis)

Vitamins	Raw whole quinoa	Polished and washed quinoa
Thiamin	0·4 ± 0·01[a]	0·3 ± 0·08[b]
Riboflavin	0·2 ± 0·01[a]	0·2 ± 0·01[a]
Vitamin A (mg RE/100 g)	0·2 ± 0·05[a]	0·2 ± 0·05[a]
Tocopherols:		
α-tocopherols	2·6 ± 0·50[a]	2·4 ± 0·5[a]
α-tocotrienols	ND†	ND†
β-tocopherols	0·2 ± 0·08[a]	0·2 ± 0·03[a]
β-tocotrienols	0·3 ± 0·05[a]	0·3 ± 0·01[a]
γ-tocopherols	5·3 ± 0·25[a]	4·9 ± 0·40[a]
γ-tocotrienols	0·01 ± 0·00[a]	0·01 ± 0·00[a]
δ-tocopherols	0·3 ± 0·01[a]	0·3 ± 0·02[a]
Vitamin C	16·4 ± 0·55[b]	19·2 ± 0·50[a]
Folic acid (μg/100 g)	78·1 ± 2·80[a]	66·3 ± 2·10[b]

* Means ± SE; $n = 3$. Means followed by the same letter are not significantly different at 95% confidence limits.
† ND. Not detected (detection limit of 50 ng)

Table 3. Content of certain minerals in quinoa seeds* (mg/100 g dry basis)*

Vitamins	Raw whole quinoa	Polished and washed quinoa
Calcium	874 ± 26[b]	1 231 ± 37[a]
Magnesium	2 620 ± 55[a]	2 463 ± 99[a]
Zinc	36 ± 2[a]	45 ± 2[a]
Iron	81 ± 0·9[a]	59 ± 0·7[b]
Manganese	33 ± 1·2[a]	25 ± 0·9[b]
Copper	10 ± 0·4[a]	21 ± 0·8[b]
Sodium	22 ± 0·6[a]	76 ± 2·1[b]
Potassium	1 201 ± 9[a]	571 ± 10[b]
Phosphorus	5 350 ± 34[b]	5 709 ± 50[a]
Cobalt	0·5 ± 0·02[a]	0·4 ± 0·02[a]
Molybdenum	2·8 ± 0·08[a]	2·3 ± 0·14[a]
Nickel	0·8 ± 0·04[a]	0·8 ± 0·04[a]
Lead	0·3 ± 0·05[a]	0·2 ± 0·03[a]
Chromium	0·2 ± 0·01[a]	0·2 ± 0·01[a]
Cadmium (μg/kg)	39 ± 3·5[a]	28 ± 2·4[a]
Arsenic	0·1 ± 0·01[a]	0·1 ± 0·01[a]
Mercury (μg/kg)	5·4 ± 0·3[a]	5·5 ± 0·3[a]
Selenium (μg/kg)	36 ± 1·8[a]	39 ± 2·2[a]

* Means ± SE; $n = 3$. Means followed by the same letter are not significantly different at 95% confidence limits.

have some effect on the level of calcium in the blood of many animals (National Research Council, 1989).

Quinoa contains 35 μg of Se per kg quinoa on a dry basis. The National Research Council (1989) recommended dietary-selenium allowances of 0·87 μg/kg body weight for adults, and for children it is usually extrapolated from the values for adults on the basis of body weight and a factor for growth.

Mercury, lead, and cadmium have been found in quinoa seeds, and the amounts are low compared with the tolerable intake according to FAO/WHO (1972), which is 0·43 mg/day for lead, 0·04 mg/day for mercury, and between 0·06 and 0·07 mg/day for cadmium. However, the current Swedish limits (Jorhem *et al.*, 1984) for lead in foods especially intended for children under three years of age are 0·2 mg per kg of product, which is only slightly higher than the amount of lead found in quinoa seeds (0·18 mg lead/kg processed quinoa).

Table 4 shows the nutrient density of quinoa for some vitamins and minerals.

The calculation is based on the amount of quinoa necessary to satisfy the daily requirement of energy (1300 kcal) recommended for children one and three years of age (FAO/WHO, 1985; National Research Council, 1989).

Quinoa could satisfy the requirement of most vitamins recommended by the Committee on Dietary Allowances (National Research Council, 1989).

The biological activities of different forms of tocopherols found in foods vary. If the activity of α-tocopherol is set to 100%, that of β-tocopherol is between 25% and 50%; that of γ-tocopherol between 10% and 35%; and that of α-tocotrienol 30%. In this

Table 4. Nutrient density for some vitamins and minerals in Quinoa seeds

Nutrients	RDA[a]	Nutrient density[b]				
	Children between one and three years of age	Quinoa (332 g)	Wheat (351 g)	Rice (361 g)	Oat (333 g)	Maize (356 g)
Energy	1 300 kcal	1·0	1·0	1·0	1·0	1·0
Vitamin A	400 μg RE	1·4	0	0	0	0·2
Vitamin E	5 mg α-TE	2·1	1·2	0·5	0·5	0·8
Vitamin C	45 mg	1·4	0	0	0	—
Thiamin	0·7 mg	1·2	2·1	1·7	2·9	2·0
Riboflavin	0·8 mg	0·9	0·6	0·3	0·6	0·4
Folic acid	100 μg	2·2	1·7	1·6	1·7	1·4
Calcium (Ca)	800 mg	0·4	0·2	0·1	0·4	0·1
Phosphorus (P)	800 mg	2·1	1·5	1·3	1·4	1·2
Magnesium (Mg)	150 mg	4·9	3·2	4·0	2·8	3·0
Iron (Fe)	15 mg	1·1	1·0	0·4	1·2	1·1
Zinc (Zn)	10 mg	1·3	1·1	0·6	1·0	0·6
Copper (Cu)	1 mg	6·3	1·9	1·3	1·5	1·3

[a] RDA, Recommended dietary allowances (1989).
[b] Nutrient density: ratio between the amount of nutrients present in the material that is enough to provide 1300 kcal and the amount of nutrients recommended for children between one and three years based on the values for washed quinoa from Table 2 and Table 3, and the values for wheat, brown rice, oats, and maize from Kent (1984) and Statens Livsmedeksverk (1986).

study, β-tocopherol was assumed to have 50%, γ-tocopherol 10%, and α-tocotrienol 30%, respectively, of the activity of α-tocopherol. The activities of the other forms have been assumed to be 5% of that of α-tocopherol (National Research Council, 1989).

The data on the mineral content are in agreement with the data reported by INIAP (1987). In general, the amounts of minerals in quinoa seeds are enough to satisfy the nutritional recommendations. However, calcium needs to be supplemented through other sources.

It is reported that quinoa is a poor extractor of soil phosphorus. The soil of the Andes region, where quinoa is grown, is of volcanic origin, with poor phosphorus content. This can be a reason for the natural adaptation of quinoa to this region. The relation N:P:K in the quinoa plant was 8:1:13. By using the traditional method of harvesting (pulling out the whole plant), the amount of N : P : K removed from the soil was equivalent to 160:20:260 kg/ha (Blasco, 1979). The ratio sodium : potassium in processed quinoa in this experiment was 1:7:5.

Quinoa contains more iron than common cereals; however, its availability may be affected to some extent by saponins (1% in quinoa flour) and phytic acid (10 mg/g in quinoa flour) in the seeds (Ruales & Nair, 1993).

The amount of phytic acid after the washing process used for the removal of saponins remained high, about 8 mg/g quinoa flour (Ruales & Nair, 1993). Excessive amounts of phytate in the diet have a negative effect on the mineral balance because it binds multivalent minerals such as Fe^{3+}, Zn^{2+}, Ca^{2+}, and Mg^{2+} and makes them less available for absorption in the intestinal tract (Hallberg, 1984; Larson & Sandberg, 1990). The maximum amounts of phytic acid not having any negative effect on the Zn and Fe availability were reported to be 50 mg and 10 mg per meal, respectively (Sandberg, 1990).

However, Allred *et al.* (1976) reported animal-feeding experiments showing that the availability of iron from the diets based on quinoa (Sajama variety) is at least as good as the availability of iron from iron sulphate. The amount of dietary iron gained as haemoglobin per mg of iron intake by rats fed on diets with 30% quinoa was 0·74. However, the mineral bioavailability from quinoa in man needs further evaluation.

Some varieties of quinoa exhibit a bitter taste, owing to the presence of saponins, which are located mainly in the outer layer of the seeds. In order to increase the acceptability of the finished product, quinoa seeds have to be polished and washed before being processed. The traces of saponins that remained in the seeds were not detected by an informal taste panel, and the content was determined to be about 0·33% of the dry weight of the seeds. The content of phytic acid in quinoa was reduced by 29% as a result of polishing and washing (Ruales & Nair, 1993). The process of removing saponins seems to affect the vitamin composition of quinoa to a minor degree. Thiamin was reduced by 30% ($p < 0.001$), α-tocopherol by 5%, and folic acid by 15% ($p < 0.001$). The content of ascorbic acid seems to increase. West *et al.* (1978) studied the possibility that certain saponins could form complexes with minerals and that such complexes could reduce the availability of minerals and inhibit growth. However, they did not find any evidence (West & Greger, 1978) for the complexing of fat-soluble vitamins (A, D_3, or E) by saponins. Saponins vary in chemical nature, and further studies are necessary to establish whether the quinoa saponins have any effect on the availability of the fat-soluble vitamins.

The procedure of scrubbing and washing with water used in this work to remove saponins seems to affect the mineral content. A significant ($p < 0.001$) decrease in potassium content (46%) was observed after scrubbing and washing. This is in agreement with the data reported by Varriano-Marston and DeFrancisco (1984), who also reported the presence of high contents of potassium and chloride. Furthermore, data from a research carried out on 20 varieties of Ecuadorian quinoa (INIAP, 1987) show a decrease in the potassium content of about 47% while saponins are removed by this method. The quantities of the other minerals also decreased after scrubbing and washing: iron by 28%, manganese by 27%, and magnesium by 8%.

CONCLUSIONS

The seeds of quinoa contain about 10% fat on a dry-weight basis. The PS-ratio of the quinoa oil (4·90) is higher than that of most edible oils. Quinoa seeds seem to satisfy the nutritional requirements of many vitamins and minerals for children (1300 kcal) between one and three years of age. The process of scrubbing and washing the seeds to remove the saponins modified to some extent the content of vitamins and minerals. A significant decrease in potassium content was observed after removing the outer layers.

ACKNOWLEDGEMENT

We thank Marie Moschos and Ulla Lindquist for technical assistance and Professor N.-G. Asp, Department of Applied Nutrition and Food Chemistry, Chemical Centre, University of Lund, for providing facilities to work on this project. This work was financed by the International Science Programs, Uppsala University, Uppsala, Sweden.

REFERENCES

Allred, L., Mahoney, A. W. & Hendricks, D. G. (1976). The availability of iron in quinoa. *Nutr. Rep. Int.* **14**, 575–9.

Blasco, M. (1979). Composition de la quinua cultivada en el Altiplano de Puno, Perú, *Turrialba*, **29**, 219–21.

Brune, M. (1989). The inhibitory effect of phytic, calcium, and phenolic compounds on non-heme iron absorption. Ph.D. thesis. Department of Medicine II, University of Gothenberg, Sweden.

Croon, L. B. & Fuchs, G. (1980). Fetthaltbestämming i mjöl och mjölprodukter. *Vår Föda*, **32**, 425–7.

FAO/WHO/UNU (1972). Sixteenth Report of the Joint FAO/WHO Expert Committee on Food Additives. Technical Report, Series 617.

FAO/WHO/UNU Expert Consultation (1985). Energy and protein requirements. Technical Report, Series 724.

Freed, M. (1966). Methods of vitamin assay. In *Vitamin Chemists Association*. ed. M. Freed. Interscience Publishers, New York, NY, USA, pp. 123–45.

Freire, W., Dirren, H., Mora, J. O., Arenales, P., Granda, E., Breilh, J., Campaña, A., Páez, P., Darque, L. & Molina, E. (1988). Diagnostico de la Situación Alimentaria Nutricional y de Salud de la Población Ecuatoriana Menor de 5 Años. DANS, CONADE, MSP. Quito, Ecuador.

González, J. A., Roldán, A., Gallardo, M., Escudero, T. & Prado, F. E. (1989). Quantitative determination of chemical compounds with nutritional value from Inca crops: *Chenopodium quinoa* ('quinoa'). *Plant Foods Hum. Nutr.* **39**, 331–7.

Hallberg, L. (1984). Iron. In *Nutrition Reviews: Present Knowledge in Nutrition*, 5th edition. The Nutritional Foundation, Washington, DC, USA, pp. 459–8.

Hansen, H. (1964). On the diagnosis of folic acid deficiency. Orstadius Broktryvkeri AB, Gothenberg, Sweden.

Hansen, R. G. (1973). An index of food quality. *Nutr. Rev.*, **37**, 1–7.

INIAP (1987). Valores promedio de efecto de los tratamientos en el contenido de minerales en 20 lineas de quinoa ecuatorianas (*Chenopodium quinoa W.*). Internal report.

Jägerstad, M. (1987). Microbiological assay of folacin. Internal document, Industriell Näringslära, Kemicentrum, Box 124, S-221 00 Lund, Sweden.

Jägerstad, M. & Westesson, A.-K. (1979). Folate. In: Nutrition and old age. chemical analyses of what old people eat and their states of health during years of follow-up. *Scand. J. Gastroenterol.* **14**, 196–202.

Johnsson, H. & Branzell, C. (1986). High-performance liquid chromatographic determination of riboflavin in food—a comparison with a microbiological method. *Int. J. Vit. Nutri. Res.*, **57**, 53–8.

Jorhem, L., Mattsson, P. & Slorach, S. (1984). Lead, cadmium, zinc and certain other metals in foods on the Swedish market. *VårFöda*, **36**, 135–208.

Kent, N. L. (1984). Chemical composition of cereals. In *Technology of Cereals*, 3rd edition. Pergamon Press, Oxford, pp. 27–48.

Koziol, M. J. (1992). Chemical composition and nutritional evaluation of quinoa (*Chenopium quinoa* Willd.). *J. Food Compos. & Anal.*, **5**, 35–68.

Larsson, M. & Sandberg, A.-S. (1990). Phytate degradation in oats during sourdough fermentation and malting. Annual Report. Proceedings from 24th Nordic Cereal Congress, Stockholm, Sweden.

Mahoney, A. W., López, J. G. & Hendricks, D. G. (1975). An evaluation of the protein quality of quinoa. *J. Agric. Food Chem.*, **23**, 190–3.

National Research Council (1989). *Recommended Dietary Allowances*, 10th edition. National Academy Press, Washington, D.C., USA.

Nordic Committee on Food Analysis (1965). Determination of the total content of phosphorus in foods. No. 57, UDC 543.847.

Nordic Committee on Food Analysis. (1991). Metals: determination by atomic absorption spectrophotometry in foodstuffs. No 139. UDC 546.4/.8:543.422.

Price, K. R., Southon, S. & Fenwick, G. R. (1989). The effect of saponins on iron and zinc availability. In *Nutrient Availability. Chemical and Biological Aspects*, ed. D. Southrate, I. Johnson & G. R. Fenwick. AFRC. Institute of Food Research, Norwich, and Royal Society of Chemistry, London, pp. 155–7.

Piironen, V., Varo, P., Syväoja, E-L., Salminen, K. & Koivistoinen, P. (1983). High-performance liquid chromatographic determination of tocopherols and tocotrienols and its application to diets and plasma on Finnish men. *Int. J. Nutr. Res.*, **53**, 41–6.

Risi, J. & Galwey, W. (1984). The chenopodium grains of the Andes: In: Inca crops for modern agriculture. *Adv. Appl. Biol.*, **10**, 145–216.

Rossander-Hulthén, L, Gleerup, A. & Hallberg, L. (1990). Inhibitor effect of oat on non-haem iron absorption in man. *Europ. J. Clin. Nutr.*, **44**, 783–91.

Ruales, J., Pólit, P. & Nair, B. M. (1988). Nutritional quality of blended foods of rice, soy and lupins processed by extrusion. *Food Chem.*, **29**, 309–21.

Ruales, J. & Nair, B. (1992*a*). Properties of starch and dietary fibre in raw and processed quinoa (*Chenopodium quinoa*, Willd). *Plant Foods Hum. Nutr.*, in press.

Ruales, J. & Nair, B. (1992*b*). Nutritional quality of the proteins in quinoa (*Chenopodium quinoa*, Willd). *Plant Foods Hum. Nutr.*, **42**, 1–11.

Ruales, J. & Nair, B. (1993). Saponins, phytic acid, tannins and protease inhibitors in quinoa (*Chenopodium quinoa*, Willd) seeds. *Food Chem.*, **48**, 137–43.

Sandberg, A.-S. (1987). Digestion of phytate in the human gut: its relevance for mineral absorption. Paper presented at *International Symposium on Complex polysaccharides—Challenges for future research on dietary fibre*. London, 27–28 Nov., 1986.

Sandberg, A.-S. (1990). Effekt av olika havrefraktioner med avssende på fytinsyranedbrytning och mineralsbsorption. Slutrapport SJFR.

Saari, E. (1980). Modified atomic absorption spectrophotometric determination of selenium in foodstuffs by hydride generation. Kemira Oy, Ouly Research Laboratory, pp. 1–4.

Siemer, D. & Gagemann, L. (1975). A method for the determination of selenium in animal feeds baed on hydride method. *Anal. Lett.* **8**, 323–37.

Southon, S., Wright, A. J. A., Price, K. R., Fairweather-Tait, S. J. and Fenwick, G. R. (1988). The effect of three types of saponin on iron and zinc absorption from a single meal in the rat. *Br. J. Nutr.*, **59**, 589–90.

Statens Livsmedelsverk (1986). *Livsmedelstabeller*. Energi och Näringämmen. Uppsala, Sweden.

Statens Livsmedelsverk (1989). Ät rät och må bra. In *Våga äta*, pp. 10.

Strohecker, G. & Henning, H. M. (1965). *Vitamin Assay: Tested Methods*. CRS Press, Cleveland, OH, USA, pp. 65–71.

Söderhjelm, P. & Andersson, B. (1978). Simultaneous determination of vitamin A and E in feeds and foods by reversed phase high-pressure liquid chromatography. *J. Sci. Food Agric.*, **29**, 697–702.

Varian (1989). Operation Manual: VGA-76 (Vapor generation accessory). Varian Techtron Pty. Ltd, Mulgrave, Victoria, Australia.

Varriano-Marston, E. & DeFrancisco, A. (1984). Ultrastructure of quinoa fruit (*Chenopodium quinoa*, Willd). *Food Microstruct.*, **3**, 165–73.

Weber, E. J. (1978). The Inca's ancient answer to food shortage. *Nature*, **272**, 486.

West, L. G. & Greger, J. L. (1978). *In vitro* studies on saponin–vitamin complexation: a research note. *J. Food Sci.*, **43**, 1340–1, 1343.

West, L. G., Greger, J. L., White, A., & Nonnamaker, B. J. (1978). *In vitro* studies on saponin–mineral complexation: a research note. *J. Food Sci.*, **43**, 1342–3.