Quinoa Crop Biodiversity in Chile: An Ancient Plant Cultivated With Sustainable Agricultural Practices and Producing Grains of Outstanding and Diverse Nutritional Values.

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***Abstract*. .**

Quinoa crop (Chenopodium quinoa) has been cultivated since the last seven thousand years in Latin America. However the nutritional and functional properties have been diffused only since the last decade. The exportation market to Northern countries is increasing at levels not seen previously for an organic product. Its ancient cultivation practices were normally sustainable even in Chile. However strong isolation of today' small farmers in Chile has provoked less access to international markets and also great genetic distances among cultivars from the long latitudinal and ecological gradient where this crop is cultivated (4000 m.a.s.l. at 19ºS to coastal areas at sea level between 18ºS to 40ºS). The nutritional diversity along this gradient has not been previously studied.

This study focuses on the nutritional properties of five distinctive local land races found along Chile, belonging to different genetic pools, but collected from farmers that have not developed formal crop improvement, with the exemption of a single hybrid variety, also included in this study.

Results showed that genetic variability of quinoa ecotypes plus the environmental diversity allow an also great nutritional diversity. Protein content had significant lower levels (12%) for northern ecotypes while higher values (16%) were found among the less known southern seed origins, cultivated by Mapuche people. While other properties like Vitamin B2 showed higher values in northern ecotypes, supporting the idea that genetic richness or diversity of quinoa ecotypes hide an also rich nutritional diversity. All the cultivars are managed under sustainable ecological practices, unique possibility among small-scale farmers.

Keywords. Quinua, land races diversity, nutritional properties, agroecological diversity.

Introduction

Quinoa crop is well known to be an exceptional and outstanding food due to a set of nutritional properties like high quality proteins containing the whole set of 20 amino acids, plus vitamins like Complex B, E, minerals like Fe, K, Ca, P and others, good quality lipids and also Isoflavons plus interesting antioxidant functional properties (Schlick and Bubenheim 1996 and see recent review by Vega-Gálvez et al. 2010). In Chile, although cultivated along the whole country (through 3,000 km) it remains as an almost extinct agricultural practice (Tagle and Planella 2002), highly restricted to three biogeographic and ecologically different areas: the North-Altiplano around 19°S; at 3,500 m.a.s.l. the central-coastal area around 35°S, and in the south area around 39°S. Its rich genetic biodiversity (Fuentes et al., 2009), allows quinoa landraces suitable for very different environments, even very extreme ones (Alfonso-Bécares and Bazile, 2009). Farmers normally do not add chemical fertilizers and most of the water comes from rainfall. The crop is highly tolerant to extreme low irrigation (Martínez et al., 2009) and it exists only one official variety, named La Regalona, an hybrid obtained after a long selection program for higher yields (Von Baer et al. 2009). The rest of ecotypes present in the country are recognized as different local cultivars or ecotypes, not submitted to formal selection programs and serving mostly for self-consumption. The three different biogeographic regions or genetic pools of quinoa show very different photoperiods from the North to the South corresponding to farms distributed between 19 ºS to 39 ºS (Bazile & Negrete, 2009) where day-length show sharp differences (Fig. 1). The associated genetic differences are also very strong (Fig.2). The main purpose of the present study was to evaluate if the long geographic-genetic distances also affected nutritional properties like protein and vitamin content of the harvested quinoa seeds cultivated in the three genetic zones from north, centre and southern Chile. Two ecotypes were obtained from each region, including La Regalona variety from the South of the country. Other properties were also evaluated and they are shown here and also in a parallel work of this symposium (Vega-Galvez et al 2011).

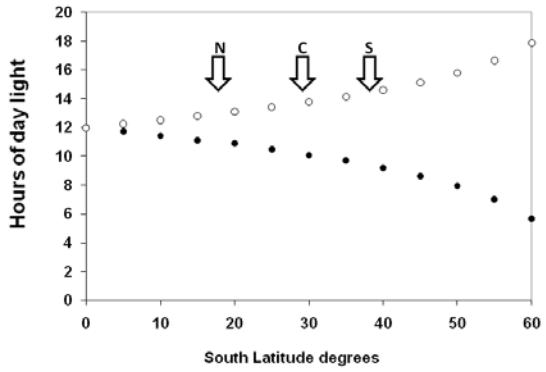

Figure 1. Photperiodic differences along a latitudinal gradient in the southern hemisphere as given by light-day hours in summer (open circles on January 1st) and in winter time (closed circles on June 1st) and the sites where Chilean quinoa ecotypes survived extinction (N: North-Altiplano, C: Center of the country and S: southern latitudes), and where samples for this study were taken from.

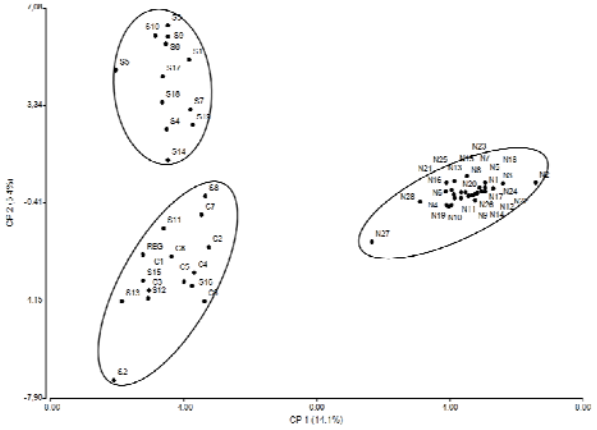

Figure 2. Genetic diversity of Chilean quinoa ecotypes separated in three zones or genetic pools as revealed by Principal Component Analysis with 20 polymorphic microsatellite loci (modified from Fuentes et al. 2009). Some ecotypes of the center (C) and south (S) appear mixed, suggesting closer genetic distances among them but farther away from the northern ones (N). REG stands for La Regalona hybrid variety from south of Chile.

Material and methods

Origin of quinoa seed and preparation of samples. The quinoa seeds were harvested from the three ancestral production areas of Chile including samples from the three genetic pools (Fig. 1). A total de 6 ecotypes of quinoa were provided: Ancovinto and Cancosa (around 19 ºS), Cahuil and Faro (around 34 ºS) and La Regalona (official variety) and Villarrica (around 39 ºS). The samples were analyzed without a dehusking treatment. Ground quinoa grains were used and all the analyses were done in triplicate

Determination of proteins and basic nutritional properties. The moisture content was determined by A.O.A.C. method nº 934.06 (A.O.A.C., 1990) employing a vacuum oven (Gallenkamp, OVL570, Leicester, UK) and an analytical balance with an accuracy of ±0.0001 g (CHYO, Jex120, Japan). The crude protein content, the lipid content, the crude fibre and ash content were all determined using the methodologies following the recommendations of the Association of Official Analytical Chemists (AOAC, 1990). **Determination of vitamins**. Analysis of vitamins B1, B2, B3 and E (α-tocopherol) were done by HPLC. Samples were extracted with methanol-BHT (1 mg mL−1) solution as described by Miranda et al. (2010). All analysis of vitamins were expressed in mg100 g−1 dry matter, and followed the protocols of AOAC (1995). ***Statistical analysis*** Analysis of data was performed using Statgraphics® Plus 5 (Statistical Graphics Corp., Herndon, VA, USA). One-way ANOVA with five levels, three replicates was performed. Differences among the media were analyzed using the least significant difference (LSD) test with a significance level of 0.05 and a confidence interval of 95%. In addition, the multiple range test (MRT) included in the statistical program was used to demonstrate the existence of homogeneous groups within each of the parameters.

Results and discussion

All nutritional evaluations were found to be within ranges of previously published for quinoa from other South American latitudes (Vega-Galvez et al., 2010). However the three genetic regions of Chile showed significant differences for almost all parameters of the proximal analysis and for vitamins content. Some values, like proteins are higher in the southern ecotypes (Table 1), while others like vitamin B2 are higher for Altiplano ecotypes (Table 2). These results are important to support local land races improvement as well as for designing crosses to create improved varieties. These seeds came mostly from farms were agricultural practices are healthy and sustainable for the environment.

Conclusions. This study of six ecotypes quinoa from Chile revealed that the great genetic diversity holds also great nutritional diversity that gives additional values to local races and allows identification of target ecotypes to start farther improvement of nutritional values among local land races.

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Table 1. Proximal analysis of six quinoa ecotypes from the three genetic zones (mean ± standard deviation). All data are expressed as mg 100g-1 of dry matter. Different superscript letters on the same row indicate significant differences ($P < 0.05$). N: nitrogen. Values as mean ± standard deviation (n=3).

	North		Centre		South	
	Ancovinto	Cancosa	Cáhuil	Faro	Regalona	Villarrica
Moisture	7.74 ± 0,07^{a}	9.29 ± 0,06^{b}	13.17 ± 0,02^{c}	13.17 ± 0,10^{c}	14.27 ± 0,03^{d}	15.18 ± 0,02^{e}
Ash	3.36 ± 0,06^{a}	3.46 ± 0,10^{a,b}	3.15 ± 0,07^{c}	3.53 ± 0,04^{b,d}	3.61 ± 0,09^{d}	3.65 ± 0,09^{d}
Protein (N x 6,25)	12.85 ± 0,28^{a}	13.59 ± 0,08^{b}	11.41 ± 0,54^{c}	11.32 ± 0,19^{c}	14.66 ± 0,38^{d}	16.10 ± 0,14^{e}
Fat	6.24 ± 0,06^{a}	5.88 ± 0,13^{b}	7.15 ± 0,16^{c}	6.59 ± 0,10^{d}	6.42 ± 0,09^{a,d}	5.97 ± 0,07^{e}
Crude Fiber	1.45 ± 0,06^{a}	1.91 ± 0,28^{b}	1.33 ± 0,46^{a}	1.50 ± 0,14^{a}	1.90 ± 0,23^{b}	2.81 ± 0,07^{c}
Total carbohydrates	68.36 ± 0,42^{a}	65.88 ± 0,08^{b}	63.80 ± 0,68^{c}	63.89 ± 0,17^{c}	59.14 ± 0,27^{d}	56.73 ± 0,19^{e}
Available Carbohydrates	66.91 ± 0,54^{a}	63.97 ± 0,15^{b}	62.47 ± 0,87^{c}	62.39 ± 0,16^{c}	57.24 ± 0,32^{d}	53.93 ± 0,17^{e}

Table 2. Content vitamin (mg 100g-1) for quinoa Ecotypes from the three genetic zones. Different superscript letters on the same row indicate significant differences ($P < 0.05$).

	Genetic Zones					
	North		Centre		South	
	Ancovinto	Cancosa	Cáhuil	Faro	Regalona	Villarrica
Vitam B1	0,452 ± 0.018^{a}	0,485 ± 0.006^{b}	0,562 ± 0.017^{c}	0,558 ± 0.027^{c}	0,648 ± 0.006^{d}	0,349 ± 0.006^{e}
Vitam B2	0,081 ± 0.002^{a}	0,073 ± 0.002^{b}	0,067 ± 0.002^{c}	0,060 ± 0.005^{d}	0,056 ± 0.002^{e}	0,074 ± 0.001^{b}
Vitam B3	0,994 ± 0.046^{a}	0,562 ± 0.013^{b}	1,303 ± 0.051^{c}	1,226 ± 0.056^{d}	1,569 ± 0.026^{e}	1,418 ± 0.005^{f}
Vitam E	2,465 ± 0.184^{a}	2,587 ± 0.108^{a}	2,613 ± 0.039^{a}	3,051 ± 0.079^{b}	2,445 ± 0.082^{a}	4,644 ± 0.240^{c}