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Quinoa Saponins: Concentration and Composition Analysis

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Quinoa (*Chenopodium quinoa* Willd., Chenopodiaceae) is a pseudocereal native to the Andes with high nutritional value, tolerance to drought and frost, and ability to grow in poor soils at high elevations (Ward 2000).

The quinoa grain a traditional food source of the Andes, is rich in essential amino acids. Using the plant as an alternative forage in low rainfall zones has been suggested by Espíndola and Rodríguez (1984). The nutritive differences of sweet and sour quinoa forage cultivars as a function of plant age, have been reported by Capelo (1983), with dry forage yields ranging from 4 to 14 tonnes (t)/ha.

The nutritional value of quinoa is higher than all other cereals. Crude protein content ranges from 10% to 18%, with 4.1% to 8.8% fat, 60.1% starch, 4.2% ash, and 3.4% crude fiber (De Bruin 1964; Tapia 1985; Johnson and Ward 1993). Lorenz and Nyansi (1989) reported a significant high content of alpha-amylose in quinoa, similar to that of rice and wheat.

Several cultivars of quinoa contain saponins that act as antinutrients, frequently associated with lipids (Jenkins 1988). Quinoa saponins are concentrated in the external layers of the pseudo-grain, an achene with a tightly adhering pericarp covering two seed coat layers (Varriano and DeFrancisco 1984). The saponin composition include the sapogenols, oleanolic acid, hederagenin, and phytolaccagenic acid (Ridout et al. 1991; Ruales and Nair 1993; Ng et al. 1994).

The objectives of this study were to evaluate saponin concentration and composition in two quinoa cultivars ‘Sajama’ and ‘Chucara’ during plant development under three soil water deficit treatments.

METHODOLOGY

The experiment was carried out at El Jagüey de Ferniza (25° 02' N latitude, 100° 33' W longitude, at an elevation of 1895 m), Coahuila, México. The annual mean rainfall is 345 mm, and annual mean temperature is 18°C.

Plots were seeded on March 14, 2000 at a density of 12 kg of seed/ha. Two quinoa cultivars ‘Sajama’ and ‘Chucara’, were obtained from the Patacamaya experimental station located at La Paz, Bolivia. The experimental design was a split-split-plot design. The large parcel corresponds to the 3 soil water deficit treatments (TI low, TII medium, and TIII high), the sub-plot to ‘Sajama’ and ‘Chucara’ cultivars, and the sub-sub-plot to sampling stages: branching at 60 days after seeding (DAS), panicle (80 DAS), blooming (100 DAS), and grain fill (120 DAS). Soil water deficit was promoted by the application of different irrigation treatments: TI=33.2 cm, TII=25.7 cm, and TIII=21.3 cm. Before sowing, a compound fertilizer was applied providing 120 kg N/ha and 40 kg P_2O_5/ha.

Shoot samples were collected from an area of 1.8 m^2, transported to the laboratory, cut by means of a chipper, and homogenized. From this material, 500 g were used for the evaluation of plant dry weight. Afterwards the tissue was milled in a laboratory Wiley mill for saponin content, composition analysis, and protein content determination.

Saponin content was determined following successive Soxhlet extractions at 24 and 72 hr. Saponin composition was analyzed by infrared spectroscopy (FTIR) using thin films cast onto sodium chloride crystals. Nitrogen content was measured in a Kjeldahl digester.

RESULTS

Analysis of variance of saponin content showed significant differences only for water deficit treatments, stages, and stage × deficit interaction. The saponin content showed highly significant differences ($p < 0.01$) among the 3 soil water deficit treatments based on analysis of variance. Saponin content for the low soil water deficit plants was 0.456% whereas that for the high water deficit was 0.386%. Highly significant differences ($p < 0.01$) were also observed among the growing stages. The lowest saponin content (0.309%) was found in the branching stage and the highest (0.608%) in blooming. These results are in agreement with those

reported by Ridout et al. 1991, and Ruales and Nair 1993. There were highly significant differences ($p < 0.01$) in soil water deficit × growing stage.

The behavior of saponin content as a function of growing stages for the 3 soil water deficit treatments is shown in Fig. 1 for 'Sajama', and in Fig. 2 for 'Chucara'. The highest soil water deficit treatment (TIII) showed the lowest saponin content during the cycle for the two cultivars.

The infrared spectra showed signals (Table 1) indicating the presence of compounds with chemical groups such as alcohol (3400–3200 cm^{-1}), alcohol or amino groups (3019 cm^{-1}), carboxyl (1725 cm^{-1}), and esters (1730 cm^{-1}), corresponding to the chemical structure reported for saponins (Ridout et al. 1991; Ruales and Nair 1993; Ng et al. 1994).

The FTIR results for the composition of the extracts after 24 and 72 hr showed some differences relative to transmittance (%) of bands, and differences in the signals (Table 1). For example, signals at 1566 cm^{-1} and 1391 cm^{-1} were found in the 72 hr extract but not in the 24 hr extract for 'Sajama' (TI) at the branching stage. These differences may be attributed to solubility characteristics and concentration of the compounds.

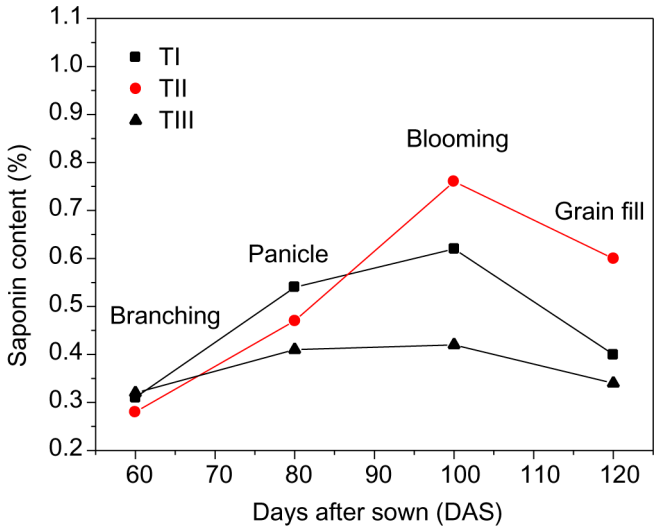

Fig. 1. Saponin content as a function of growing stages for 'Sajama' quinoa grown under 3 soil water deficits.

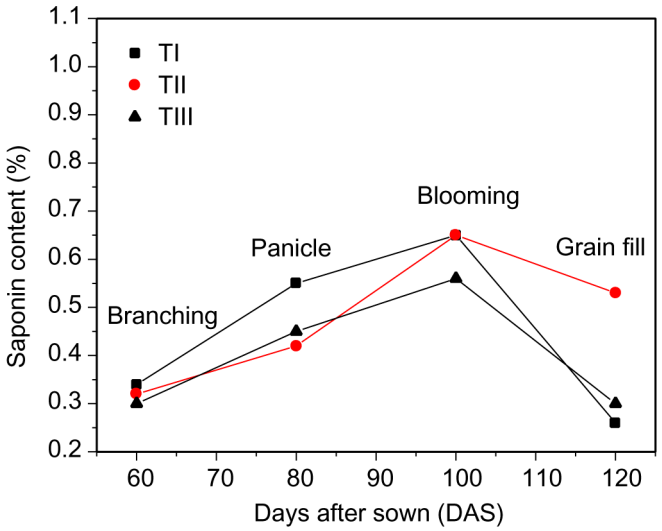

Fig. 2. Saponin content as a function of growing stages for 'Chucara' quinoa grown under 3 soil water deficits.

Table 1. Relevant signals in the FTIR spectra of saponin extracts from 'Sajama' quinoa, at different development stages and extraction times.

Stage[z]	Extr. time (h)	Wave number (cm^{-1})															
S1	24	3373	1720	--	--	--	--	1458	--	1376	--	1155	1104	--	--	--	--
S1	72	3389	1710	--	--	1566	--	1458	1391	1376	--	1155	1104	--	--	--	--
S2	24	3377	1720	--	1622	--	--	1459	1394	--	1333	--	1104	--	--	--	--
S2	72	3377	1720	--	1622	--	--	1459	1394	--	1333	--	1104	--	--	--	--
S3	24	3409	1725	1658	1620	--	--	1459	--	1376	1333	1155	1104	1020	--	--	--
S3	72	3409	1725	1658	1620	--	--	1459	--	1376	1333	1155	1104	1028	--	--	--
S4	24	3379	1720	--	1620	--	1473	1459	1391	--	1335	--	--	--	929	888	600
$	72	3379	1720	--	1620	--	1473	1459	1391	--	1335	--	--	--	929	--	--

[z]S1=Branching, S2=Panicle, S3=Blooming, S4=Grain fill

Spectra of the 72 hr extracts for 'Sajama' showed some differences at the different growing stages (Fig. 3). The following trends were observed: (1) the signals at 888, 934, and 1000 cm^{-1}, became stronger with development, and were more evident at the grain filling stage; (2) a signal at 1622 cm^{-1} appeared in the panicle stage, and became the dominant signal in the following stages; (3) the extract of the branching stage showed a strong signal at 1104 cm^{-1}, but decreased drastically in the other 3 stages; (4) the 3019 cm^{-1} signal (associated with alcohol or amino groups) was not observed in the branching extract; there was a small signal at the panicle stage which was well defined at the blooming and grain filling stages; (5) the signal at 1330 cm^{-1}, was weak at early stages and evolved into a clear medium intensity signal as the plant developed.

In general, no qualitative differences were observed among the cultivars or treatments. However, quantitative differences may exist among the extracts, but separation of the compounds and its identification will be necessary to evaluate these differences.

There were no differences in crude protein content at panicle and blooming stages. Protein content decreased from the panicle to the blooming stages (Table 2). Dry weight accumulation showed differences among treatments for the two cultivars, increasing from panicle to blooming stages.

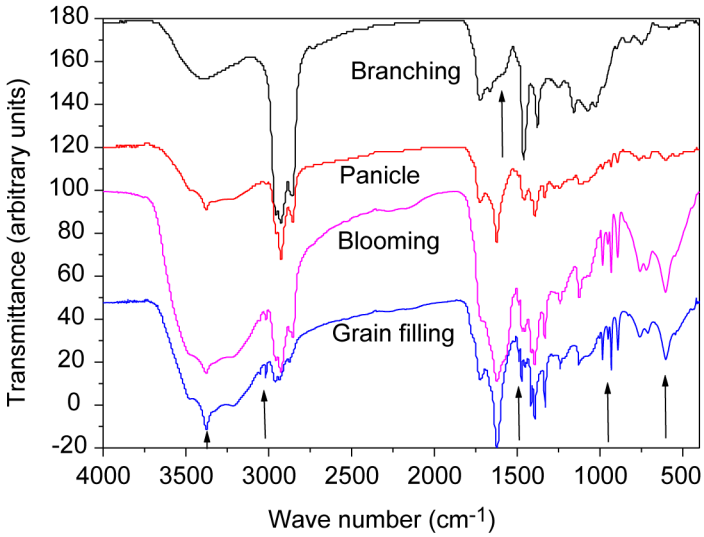

Fig. 3. Quinoa, 'Sajama' (Treatment I). Infrared spectra of the 72 hr extracts obtained at the 4 growing stages.

Table 2. Crude protein content and biomass yield of two quinoa varieties under three soil water deficit treatments.

		Crude protein (%)		Biomass (t/ha)	
Cultivar	Treatment[z]	Panicle	Blooming	Panicle	Blooming
Sajama	TI	17.60	15.01	5.82	10.81
	TII	18.23	15.68	3.45	7.46
	TIII	17.73	16.16	2.71	5.94
Chucara	TI	18.08	15.84	5.89	10.61
	TII	17.72	16.11	3.92	7.70
	TIII	18.55	16.95	2.73	6.54

[z]TI=low soil water deficit, TII=medium soil water deficit, TIII=high soil water deficit

CONCLUSIONS

Soil water deficit treatment affected the saponin content; high deficit promoted low saponin content for the two cultivars. Saponin content depended on the growing stage for all treatments and cultivars. The highest saponin content was found at blooming and decreased at the grain filling stage for treatments and cultivars.

Saponin composition varied qualitatively with growing stages according to FTIR results. Apparently the alcohol content increased from branching to grain filling. No differences were found among soil water deficit treatments.

Crude protein content at panicle and blooming, showed no difference among treatments, but decreased with time. Dry weight increased with time and was higher in the low soil water deficit treatment.

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