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Short communication

Fatty acid profile and nutritive value of quinoa (*Chenopodium quinoa* Willd.) seeds and plants at different growth stages

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ABSTRACT

Quinoa (*Chenopodium quinoa* Willd.) is native to the Andean region and belongs to the group of crops known as pseudocereals. It has great potential for improving food for humans and animals due to its interesting nutritional value. Quinoa was studied to determine the fatty acid (FA) composition, chemical composition, gross energy, *in vitro* dry matter (DM) digestibility (IVDMD) and neutral detergent fibre digestibility (IVNDFD) of the seeds and plant during growth. Herbage samples were collected six times at progressive morphological stages from the early vegetative to the grain fill stage. Effects of plant ageing was analysed by polynomial contrasts. The chemical composition of quinoa is closely connected to development of the plant with the quality of crop decreased with increasing morphological stages. Dry matter, organic matter (OM), and neutral detergent fibre (NDFom) content increased linearly from the mid vegetative to the grain fill stage, while acid detergent fibre (ADFom) content increased linearly from the first to the last stage. The pattern of FA in the seed was characterised by: palmitic acid (PA, $C_{16:0}$), oleic acid (OA, $C_{18:1\ n\text{-}9}$) and linoleic acid (LA, $C_{18:2\ n\text{-}6}$). Among main FA of the plant during growth, α-linolenic acid (ALA, $C_{18:3\ n\text{-}3}$) was the most abundant FA (from 385 to 473 g/kg of total FA), while LA content, which ranged from 146 to 176 g/kg of total FA, decreased with increasing growth until the shoot stage and then increased, while PA, OA and stearidonic acid ($C_{18:4\ n\text{-}3}$) did not show differences in their content during growth. IVDMD and IVNDFD decreased linearly with increasing growth stage. The first summer cut of quinoa, whose lipid fraction is rich in ALA and other polyunsaturated FA, should be before shooting, since its nutritional quality deteriorates when cutting is delayed.

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1. Introduction

Quinoa (*Chenopodium quinoa* Willd.) seed is a staple human food of the South America Andean region which has received attention because of its high nutritional value, due in particular to its fatty acid (FA) composition (Wood et al., 1993) as it has a high proportion of unsaturated FA, particularly oleic (OA, $C_{18:1\ n\text{-}9}$) and linoleic acid (LA, $C_{18:2\ n\text{-}6}$), and its balanced aminoacid spectrum with high methionine (4–10 g/kg DM) and lysine (51–64 g/kg DM) contents (Bhargava et al., 2003).

Abbreviations: ADFom, acid detergent fibre expressed exclusive of residual ash; ALA, α-linolenic acid; CP, crude protein; DM, dry matter; EE, ether extract; FA, fatty acid; FM, fresh matter; GE, gross energy; IVDMD, *in vitro* digestibility; IVNDFD, *in vitro* neutral detergent fibre digestibility; LA, linoleic acid; NDFom, neutral detergent fibre expressed exclusive of residual ash; OA, oleic acid; OM, organic matter; PA, palmitic acid; PUFA, polyunsaturated fatty acids; SA, stearic acid.

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Quinoa seed has also been used as animal feed. Jacobsen et al. (1997) concluded that quinoa seed has potential as a broiler feed, but should not exceed an inclusion level of 150 g/kg of the diet, while they found that dehulling of quinoa slightly improved broiler performance. Horsted and Hermansen (2007) found that nutrient-restricted, high-producing organic layers are capable of finding and utilising considerable amounts of feeds, such as quinoa and other forage crops, from a cultivated foraging area without negative effects on their health and welfare. Improta and Kellens (2001) reported that polishing or washing of quinoa prior to feeding, or diluting the quinoa with an other available feed are viable options which can be considered to improve performance of broilers when quinoa is a major component of the diet.

Quinoa has been evaluated as a new crop outside its original areas of cultivation (Van Schooten and Pinxterhuis, 2003; Jacobsen et al., 2005). The plant's nutritional value is high and the whole plant has been used as animal feed (Galwey, 1989). Harvest residues are also used to feed cattle, sheep, pigs, horses and poultry (FAO, 1994). Rosero et al. (2010) indicated that a high proportion of Colombian livestock farmers know the quinoa crop, but a low proportion of farmers (0.2) used quinoa in animal feed.

Although claims of a nutritionally favourable quality of quinoa seed have been made, only limited information is available on the evolution of the chemical composition in the whole plant at different growth stages. The objective was to determine the FA profile and nutritive value of quinoa seeds and plants during growth.

2. Materials and methods

2.1. Plant material

Quinoa seeds (Ayni variety), harvested in Mantaro Valley (Peru), were kindly furnished by Dr. Aurelio Ciancio (Institute for Plant Protection, National Research Council, Bari, Italy), who obtained them from the Escuela de Nutrición Psicosomática in Lima. The study was conducted in the Western Po Valley near Cuneo, Italy. The quinoa stands were seeded in May 2010. No irrigation or fertilisers were applied after sowing. The herbage samples were collected from 1 m^2 subplots randomly located in $3 \times 6\,m^2$ plots with three replicates. Plants were cut to a 1–2 cm stubble height. Sampling was in the morning after evaporation of dew and was never carried out on rainy days. Herbage samples were collected with edging shears (0.1 m cutting width) at six progressive morphological stages from early vegetative to grain fill stage from the end of June to the end of September 2010.

2.2. Chemical analysis

The herbage samples were immediately dried in a forced draft air oven to a constant weight at 65 °C. Samples were then brought to air temperature, weighed, ground in a Cyclotec mill (Tecator, Herndon, VA, USA) to pass through a 1 mm screen and stored for qualitative analyses.

Whole seed and dried herbage samples were analysed by methods of AOAC (1990) for DM (#925.40), N (#984.13), and ash (#923.03). Neutral detergent fibre (NDFom), acid detergent fibre (ADFom) and lignin(sa) were determined with the Ankom^{200} Fibre Analyser (Ankom Technology Corp., Macedon, NY, USA), following the Ankom Technology Method and corrected for residual ash. The NDF of herbage samples was analyzed without sodium sulfite or α-amylase. The gross energy (GE) was determined using an adiabatic calorimeter bomb (IKA C7000, Staufen, Germany).

Fresh samples (200 g) of the herbage were refrigerated, freeze-dried and ground to pass a 1 mm screen. Lipid content was quantified on freeze-dried samples according to Hara and Radin (1978), while transesterification of FA was performed on the lipid extract according to Christie (1982), with modifications as described by Chouinard et al. (1999).

The FA were analysed as their methyl esters. Analysis was by gas chromatography using a Dani GC 1000 DPC (Dani Instruments S.P.A., Cologno Monzese, Italy), equipped with a Supelcowax-10 fused silica capillary column (60 m × 0.32 mm (i.d.), 0.25 μm). The injector and detector ports were set at 245 °C and 270 °C, respectively. The oven temperature program was initially set at 50 °C for the first min, and then increased at a rate of 15 °C/min to 200 °C, where it remained for 20 min and then increased at a rate of 5 °C/min to 230 °C, where it remained for the last 3 min. The carrier gas was helium. One microlitre of FA methyl esters sample was injected using a Dani ALS 1000 autosampler with a 1:50 split ratio. The peak area was measured using a Dani Data Station DDS 1000, where each peak was identified and quantified according to pure methyl ester standards (Restek Corporation, Bellefonte, PA, USA).

2.3. In vitro digestibility

Ground seed and freeze-dried herbage samples were also analysed to determine their *in vitro* dry matter (DM) digestibility (IVDMD) and NDF digestibility (IVNDFD) using the Daisy^{II} Incubator (Ankom Technology Corp.) according to Robinson et al. (1999). The *in vitro* rumen incubations were in two fermentative runs with different rumen inoculum. Ground (1 mm) samples (250 mg) were inserted into filter bags (Ankom F57 bags) which were then sealed. Jars were divided vertically by using a perforated plastic separator and 2 bags for each sample were inserted on either side of the separator, giving a total of 18 bags. Seed samples were incubated in another jar in the same run. Digestion jars were filled with pre-warmed (39 °C) buffer solutions and placed into the incubator. Rumen liquor was collected from rumen contents obtained at a slaughterhouse from cattle (two run) of the same farm fed a fibre-rich diet (Spanghero et al., 2010). Rumen liquor was filtered through two

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