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PHARMACOGNOSIE

Proximate analysis, fatty acids and mineral composition of processed Moroccan *Chenopodium quinoa Willd.* and antioxidant properties according to the polarity

Analyse approximative et composition en acides gras et minéraux de *Chenopodium quinoa Willd.* Marocain, et propriétés antioxydantes selon la polarité

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Abstract Quinoa is an Andean seed crop of a high nutritional value, recently introduced to Morocco. Quinoa can resist to drought and high salinity, which is important for developing countries in arid regions especially in Africa. This study focuses on the nutritional characteristics of fresh and cooked Moroccan quinoa (proteins, fibres, minerals, fatty acids and phenolic) and the antioxidant properties of its polar and nonpolar extracts, using three different systems (DPPH, β-carotene bleaching, and ferric reducing/antioxidant power (FRAP)). The proximate analysis has shown that quinoa is a good source of proteins (12.51 - 14.50%), fibres (NDF, ADF, ADL and cellulose) and carbohydrates. Moreover, fatty acids composition of quinoa oil demonstrated that quinoa is high in omega 3. Furthermore, mineral analysis by ICP-AES demonstrated that quinoa seeds are rich in potassium, magnesium and other minerals with many health benefits. It was observed that phenolic compounds were more soluble in weak polar solvent than in polar and nonpolar organic solvents. Accordingly the antioxidant activity is correlated to the phenolic content of the extracts.

Keywords Quinoa · Minerals · Fibres · Proteins · Fatty acids · Phenolics · Polarity · Antioxidant

Résumé La quinoa, récemment introduite au Maroc, est une culture de semence andine, avec une haute valeur nutritionnelle. Sa résistante à la sécheresse et à la salinité élevée, lui donne le privilège de constituer une solution pratique pour les alarmes de faim surtout dans les pays d'Afrique. Cette étude se concentre sur les caractéristiques nutritionnelles de la quinoa Marocaine fraiche et cuite (protéines, fibres, minéraux, acides gras et phénolique) et les propriétés antioxydantes de ses extraits polaires et apolaires, en utilisant trois différents systèmes (DPPH, blanchiment du β-carotène, et le pouvoir réducteur du fer). L'analyse a montré que la quinoa est une source riche en protéines (12.51 - 14.50%), en fibres (NDF, ADF, ADL et cellulose) et en sucres. De plus l'analyse des huiles de quinoa a montré que ces grains ont une teneur intéressante d'omega 3. En outre, les taux de minéraux analysés par ICP-AES ont démontré que les graines de quinoa sont riches en potassium, magnésium et autres minéraux. On a observé que les composés phénoliques sont plus solubles dans les solvants faiblement polaires que dans les solvants organiques polaires et apolaires. En conséquence, l'activité anti-oxydante est corrélée à la teneur en composés phénoliques des extraits.

Mots clés Quinoa · Minéraux · Fibres · Protéines · Acides gras · Polyphénoles · Polarité · Antioxydant

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Introduction

Quinoa (*Chenopodium quinoa Willd.* - Amaranthaceous family), a food plant native of Andean region (Peru and Bolivia), has received an increasing attention in recent years, due to its exceptional nutritional value and diverse health benefits. Quinoa is a naturally gluten-free pseudo-cereal that can represent a healthy alternative to frequently used ingredients in gluten-free products [1]. Furthermore, quinoa is with a great technological and commercial interest for human health and animals feeding as well as applications in pharmaceutical industry [2].

Quinoa seeds e.g. white, red and black [3] constitute a rich source of protein, polysaccharide, fatty acids, polyphenols, vitamins and minerals [4,5]. Together, the bioactive secondary metabolites from quinoa have been shown to possess diverse biological properties [6]. Especially antioxidant activity of quinoa might be of particular interest to medical researchers and needs further attention regarding its implication in many physiological processes [7]. Quinoa cultivars are with a high genetic variability in many parts of the world, to be adapted to their climatic properties including drought and high salinity [8]. Accordingly, quinoa cultivars has been introduced in Morocco and shown a good adaptation [9]. Quinoa is a drought-tolerant crop having low water requirements [10], which is very important for countries where economy depends on rainfall. As the consumption of quinoa becomes increasingly popular, there is a need to systematically examine the bioactive components such as phenolic, fibres, proteins, fatty acids and minerals, in order to control and improve the nutritional quality of this interesting food for nutritional therapies. The objectives and results from this study will bring some data about the nutritional characteristics of Moroccan quinoa and help in the development of high quality cultivars.

Material and methods

Plant material

Seeds of quinoa used in this study were locally purchased from the market in Rabat, Morocco (January 2014). The variety tested in our assays was cultivated in Roumani near to Rabat, Zaïr Region (north-western of Morocco).

Cooking regimens

Quinoa seeds were heat-treated by boiling 1% (w/v). After 20 min, seeds were drained and processed for the analyses. Results were expressed on dry matter basis.

Ash, moisture, carbohydrate and protein content

The crude ash, moisture and starch content was determined by methods of the Association of Official Analytical Chemists (AOAC) [11]. The crude protein content was determined using the Kjeldahl method with a conversion factor of 6.25. All methodologies followed the recommendations of AOAC (1990). All measurements were done in triplicate. Crude fat was determined by extracting a known aliquot of sample (250 g) with hexane, using a Soxhlet apparatus. Total carbohydrates were calculated by difference. Results for each parameter were expressed in percentage (%).

Dietary fibre determination

Acid detergent fibre (ADF) and lignin content (ADL) was determined using the method described by Van Soest (1963) [12]. Neutral detergent fibre (NDF) was determined according to Van Soest (1967) [13]. The amount of cellulose in samples was estimated according to AOAC methods [11].

Mineral content

Quinoa mineral composition (Ca, Mg, Mn, Fe, Zn, K, Na, P and Se) was determined using an inductively coupled plasma atomic emission spectroscopy (ICP AES, Jobin Yvon Ultima 2). 150 mg of the quinoa seed powder was ashed with 2 mL HNO_3 acid (70%) mixture in a teflon beaker, before being incinerated at 110 °C. Then, 0.5 mL of hydrofluoric acid (HF) was added and the covered beaker was placed on a sand bath. The sample mixture was heated until a clear solution was obtained. After removing the cover, the mixture was evaporated until drying. Finally, 2 mL of HCl acid was added and the residue was extracted by 25 mL 2.0 M HCl.

Soxhlet extraction procedure

Three different solvents (hexane, ethyl acetate and methanol) were used to fractionate the soluble compounds from quinoa in ascending polarity. Quinoa seeds powders (250 g) were extracted by using a soxhlet extractor for 6 h with 500 mL of extractant under reflux conditions. The organic solvent in the extracts was removed using a rotary evaporator to yield three fractions (hexane (QH), ethyl acetate (QEA) and methanol (QM)).

Quinoa Fatty acid composition

Fatty acid composition was determined following regulation EEC/2568/91. Before analysis, fatty acids (FAs) were converted to fatty acid methyl esters (FAMEs) by shaking for 25 min a solution of 60 mg oil and 3 mL of hexane with 0.3 mL of 2 N methanolic potassium hydroxide. FAMEs were analyzed by gas chromatography using a Varian CP-3800 (Varian Inc.) chromatograph equipped with a FID. A split injector was used and the injected volume was 1 μL. The column used was a CP-Wax 52CB column (30 m × 0.25 mm i.d.; Varian Inc., Middelburg, The Netherlands). The carrier gas was helium and the total gas flow rate was 1 mL/min. The initial and final column temperature was 170 and 230 °C, respectively, and the temperature was increased by steps of 4 °C/min. The injector and detector temperature was 230 °C. Data were processed using a Varian Star Workstation v 6.30 (Varian Inc., Walnut Creek, CA,

USA). Results were expressed as the relative percentage of each individual FA present in the sample.

Phenolic content

The amount of total phenolic contents was determined according to Folin-Ciocalteu method as described by Lister and Wilson (2001) [14]. The total phenolic content was measured as gallic acid equivalents (mg GAE/g dw).

Flavonoids content

The total flavonoids in the extracts were determined using a colorimetric method [15]. The flavonoid content was determined as the rutin equivalent from the calibration curve of rutin standard solutions and expressed as rutin equivalent (mg RE/g dw).

Free radical scavenging activity

The free radical scavenging activity of the quinoa extracts was measured by 1.1-diphenyl-2-picryl-hydrazil (DPPH) [16]. The radical-scavenging activity (RSA) was calculated as a percentage of DPPH discoloration. Using the equation:

$$\%\ \mathrm{RSA} = \frac{\mathrm{AD} - \mathrm{AE} \times 100}{\mathrm{A_D}}$$

Where A_D is the absorbance value of the DPPH blank sample, and A_E is the absorbance value of the test solution. A_E was evaluated as the difference between the absorbance value of the test solution and the absorbance value of its blank.

The EC_{50} was determined graphically using a calibration curve in the linear range by plotting the extract concentration vs the corresponding scavenging effect. The antioxidant activity was expressed as the antioxidant activity index (AAI) [17], and antioxidant efficiency (AE) [18] calculated as follows:

$$\mathrm{AAI} = \frac{\text{final concentration of DPPH in } \mu g/mL}{\mathrm{EC_{50}} \text{ in } \mu g/mL}$$

$$\mathrm{AE} = \frac{1}{\mathrm{EC_{50}}}$$

Ferric reducing/antioxidant power (FRAP)

The ferric ions (Fe^{3+}) reducing antioxidant power (FRAP) method [19] was used to measure the reducing capacity of oat extracts with a slight modification, which involves the presence of extracts to reduce the ferricyanide complex to the ferrous form. The reducing power of the extracts was represented as ascorbic acid equivalent (mg AAE/g dw).

β-carotene bleaching assay

The antioxidant activity of the extracts was evaluated using a β-carotene-linoleic acid (linoleate) model system [20] with slight modifications. Antioxidant activity was calculated by four different methods [21].

Statistical analysis

Data were expressed as the mean values ± standard deviation (SD) for each measurement. The data were also analyzed by one-way analysis of variance (one-way ANOVA). Post Hoc procedure was used for significance of difference ($p < 0.05$). Data analysis was performed using SPSS 13.0 statistical software.

Results and discussion

Quinoa has long been considered as a potential dietary supplement rich in bioactive phenolic compounds. This study focuses on the phytochemical composition e.g. fibre, protein, fatty acids and minerals of fresh and cooked seeds. Additionally, the effect of different extraction solvents in ascending polarity on the antioxidant properties and phenolic content has been examined.

Proximate analysis

Ash, moisture, starch, lipids, carbohydrates, proteins and fibres contents are described in Table 1. The unique benefits of quinoa are related to its high nutritional value. Cereal Proteins is a major concern for a good diet, especially for vegetarians. The protein content of quinoa ranges between 13.81 and 21.9% depending on the variety [22]. Our results (12.51 - 14.50%) are corresponding to this interval. Further, quinoa is high in fibre (Table 1), which makes it an ideal food to detoxify the body, eliminating toxins and waste products that may harm the body.

Mineral content

Mean contents of each mineral found in seeds from fresh and cooked quinoa expressed in mg/kg is shown in Table 2. Quinoa is high in potassium (K) (12398.98 ± 24.20 - 7549.84 ± 5.98) and low in manganese (Mn), iron (Fe) and sodium (Na). This was in close agreement with the observation made by previous studies [4,5,23]. However phosphorus (P) levels in our samples are higher than those reported in the previous studies. Magnesium (Mg), calcium (Ca) and relatively zinc (Zn) are the next highest minerals in quinoa (Table 2). These differences may be linked to differences in

Table 1 Proximate analysis of quinoa seeds [x].

	Composition	Morocco		South America
		Fresh	Cooked	De Bruin[a]
	Moisture	9.25 ± 0.35[a]	13.89 ± 1.80[b]	n.r
	Ash	3.1 ± 0.43[a]	2.89 ± 0.06[a]	3.0
	Protein	12.51 ± 0.18[a]	14.50 ± 0.31[b]	15.6
Fibres	NDF	72.03 ± 0.73[b]	70.21 ± 1.21[a]	n.r
	ADF	27.06 ± 0.07[b]	19.39 ± 1.07[a]	n.r
	ADL	4.44 ± 0.92[a]	3.15 ± 0.76[a]	n.r
	Cellulose	5.5 ± 0.14[b]	4.03 ± 0.45[a]	2.9
	Fat	4.88 ± 0.32[b]	2.21 ± 0.24[a]	7.4
	Starch	54.89 ± 2.50[a]	56.4 ± 1.90[a]	n.r
	Carbohydrates	63.58 ± 1.25[b]	32.38 ± 1.03[a]	69.7

[x] Data are reported to mean (n = 3) ± Standard Error. Values in the same row not sharing a common letter ([a] or [b]) differ significantly at $p < 0.05$; [a] [39] De Bruin A, 1963.

Table 2 Mineral composition of quinoa seeds [x].

Minerals	Morocco		Chile[y]	
	Fresh	Cooked	Fresh	Air dry (80°C)
Ca	937.15 ± 8.30[d]	229.13 ± 2.53[b]	565.10 ± 16.70[c]	108.25 ± 3.10[a]
Fe	3.66 ± 0.20[a]	102.54 ± 2.58[c]	139.60 ± 10.30[d]	57.50 ± 4.80[b]
K	12398.98 ± 24.20[d]	7549.84 ± 5.98[b]	11929.5 ± 176.0[c]	6178.3 ± 22.0[a]
Mg	1804.75 ± 18.32[c]	1200.89 ± 4.29[a]	1760.20 ± 41.80[c]	1684.9 ± 12.0[b]
Mn	3.66 ± 0.12[a]	4.62 ± 2.58[a]	22.9 ± 1.40[c]	17.90 ± 18.00[b]
Na	14.68 ± 1.30[a]	151.29 ± 2.32[b]	265.50 ± 13.0[c]	536.1 ± 19.20[d]
P	6977.40 ± 6.40[d]	2866.53 ± 5.69[b]	4688.7 ± 45.0[c]	419.8 ± 39.57[a]
Se	n.d*	132.11 ± 1.32[b]	n.r	n.r
Zn	384.38 ± 4.90[c]	n.d*	27.7 ± 8.0[a]	25.2 ± 4.0[a]

[x] Data are reported to mean (n = 3) ± Standard Error. Values in the same row not sharing a common letter ([a] to [c]) differ significantly at $p < 0.05$; [y] [4] Margarita Miranda et al., 2010; n.d: not detected; n.r: not reported; *: Content was under limit of detection.

geographic and climatic conditions since they are greater than that which can be accounted for an experimental error.

The Fe and Na content of cooked quinoa increased significantly when compared to the fresh material. Moreover, Mn presented slight increases, while Ca, K, Mg, and P showed an important decrease. Surprisingly, Zn content decreased under limit of detection in cooked seeds, while Se content appeared to be significant. Reduction in minerals contents could be due to interaction of saponins with minerals before processing or diffusion of these micronutrients into intercellular spaces especially at high temperatures [4].

Quinoa oil analysis

The oil content and composition of the major fatty acids of quinoa seeds are shown in Table 3. The oil yield of the fresh and cooked quinoa seeds was 4.88 - 2.21% (w/w), slightly lower than what was reported recently [24], and comparable to content reported by others [25], while the fatty acid composition was relatively similar to reported data [24]. The oil content was highest in fresh quinoa seeds. The majority of the fatty acids in quinoa seeds were unsaturated fatty acids (UFA) (89.45 – 89.57%). UFA were composed mainly by polyunsaturated fatty acids (PUFA) (54.23 – 66.19%), and monounsaturated fatty acids (MUFA) (23.24 – 23.38%). PUFA were composed by two fatty acids, linoleic acid (18:2n-6, an omega-6 fatty acid) and α-linolenic acid (18:3n-3, an omega-3 fatty acid).

Additionally to their energy value, the omega-3 and omega-6 fatty acids provide the essential biological functions that the human body requires. Human beings evolved on a diet with a ratio of omega-6 to omega-3 essential fatty acids (EFA) of nearly 1 whereas in Western diets the ratio is

Table 3 Fatty acids composition of quinoa.

Fatty acids		**Morocco**		**South America**[x]
Carbon	Fatty acids	Fresh	Cooked	White quinoa
Saturated fatty acids				
C 14 : 0	Myristic acid	0.21	0.27	n.r
C 15 : 0	Pentadecanoic acid	0.05	0.07	n.r
C 16 : 0	Palmitic acid	9.38	9.70	9.77
C 20 : 0	Arachidic acid	0.30	0.35	n.r
C 22 : 0	behenic acid	0.44	n.d	n.r
Monounsaturated fatty acids				
C 16 : 1	Palmitoleic acid	0.08	0.14	n.r
18 : 1-9c	Oleic acid	19.70	19.72	27.48
18 : 1-11c	Elaidic acid	2.22	2.39	1.22
20 : 1-11c	Gondoic acid	1.24	1.13	1.39
Polyunsaturated fatty acids				
18 : 2n-6	Linoleic acid	60.31	59.79	47.39
18 : 3n-3	α-Linolenic acid	5.90	6.40	8.44
SFA		10.38	10.39	10.75
MUFA		23.24	23.38	31.54
PUFA		66.21	66.19	56.02
PS Ratio		6,37	6.37	n.r
MS Ratio		2.23	2.25	n.r
ω-6/ω-3 Ratio		10.22	9,34	5.62
Oil yield		4.88	2.21	7.06

SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids. PS Ratio, Polyunsaturated/saturated Ration; MS Ratio, Monounsaturated/saturated Ratio ; [x] [23] Yao Tang et al., 2014.

15:1–16.7:1. Modern diets are deficient in omega-3 fatty acids, and have excessive amounts of omega-6 fatty acids compared with the diet on which human beings evolved and their genetic patterns were established [25,26]. A lower ratio of omega-6/omega-3 fatty acids is more desirable in reducing the risk of many of the chronic diseases of high prevalence in Western societies, as well as in the developing countries. The omega-6/omega-3 ratio in Moroccan quinoa seeds is about (10:1/9:1) (Table 3). While this ratio is slightly less than ideal (4:1), it is much better than the typical Western diets. Incorporating quinoa seeds into diets can therefore help reduce the omega-6/omega-3 ratio, hence lead to reduced health risks [24].

Phenolic and flavonoid content

Phenolic and flavonoid contents are expressed respectively in mg of gallic acid or rutin equivalent per gram of dry weight (mg GAE/g dw - mg RE/g dw) in Table 4. Quinoa seed extracts differ greatly with their phenolic content. Clearly, the highest content was found in QEA (28.19 ± 0.58), followed by QM (20.63 ± 0.51) and finally QH (4.45 ± 0.78) ($p < 0.01$). Besides, flavonoids were only detected in QEA (38.86 ± 1.80) and QM (10.86 ± 1.80). In previous studies [5,27-30], the reported phenolic content of quinoa was lower but comparable to our results. Similarly, the flavonoid content reported here are higher than those reported previously [29,31]. Phenolic content is a convenient indicator of a potential antioxidant activity [28]. However, results reported in literature present many disparencies due to the lack of standardization, genetic make up, storage conditions or extraction methods.

Antioxidant properties

DPPH radical scavenging activity

DPPH is a stable free radical, which has an unpaired valence electron at one atom of nitrogen bridge. Scavenging of DPPH radical is the basis of the popular DPPH antioxidant assay [32]. The antioxidant capacity of the quinoa seed extracts, measured by DPPH assay is described in Figure 1. The parameters EC_{50}, antioxidant activity index (AAI), and antiradical efficiency (AE) estimated for quinoa extracts are presented in Table 4. QEA showed the highest level of antiradical activity with an EC_{50} of (249.9 ± 22.12 μg/mL),

Table 4 Phenolic contents and antioxidant activities of quinoa extracts [x].

Extracts	PC[W]	FC[Y]	DPPH		
			EC_{50}[Z]	*AAI*	*AE*
QH	4.45 ± 0.78[a]	n.d	>1000	n.d	n.d
QAE	28.19 ± 0.58[c]	38.86 ± 1.80[b]	249.9 ± 22.12[a]	7.01	0.0040
QM	20.63 ± 0.51[b]	10.86 ± 1.80[a]	345.89 ± 16.34[b]	3.44	0.0028
Quinoa	7.72 ± 16.70[r]	102.0 ± 11.10[m]	461.89[n]	n.r	n.r

Phenolic content (PC), flavonoid content (FC), quinoa methanolic extract (QM), hexane extract (QH) and ethyl acetate extract (QEA), Not detected (n.d), Not reported (n.r) ; [x] Data are reported to mean (n = 3) ± Standard Error. Values in the same row not sharing a common letter ([a] or [b]) differ significantly at $p < 0.05$: [w] mg GAE/g DW ; [y] mg RE/g DW ; [z] EC_{50} expressed in µg/mL ; r [30] Irene Dini et al., 2010 ; m [37] Shela Gorinstein et al., 2007 ; n [38] Margarita Miranda et al., 2011.

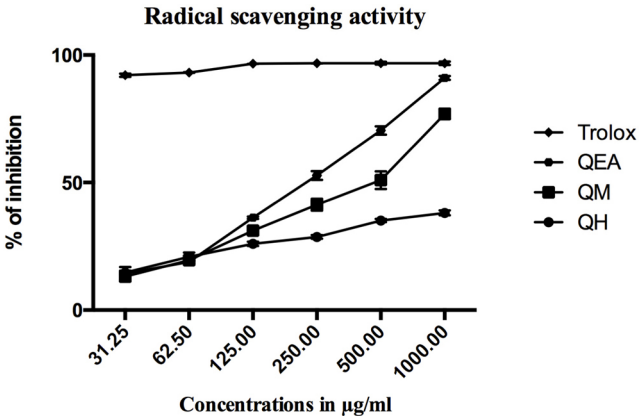

Fig. 1 DPPH radical scavenging activity of Moroccan quinoa extracts

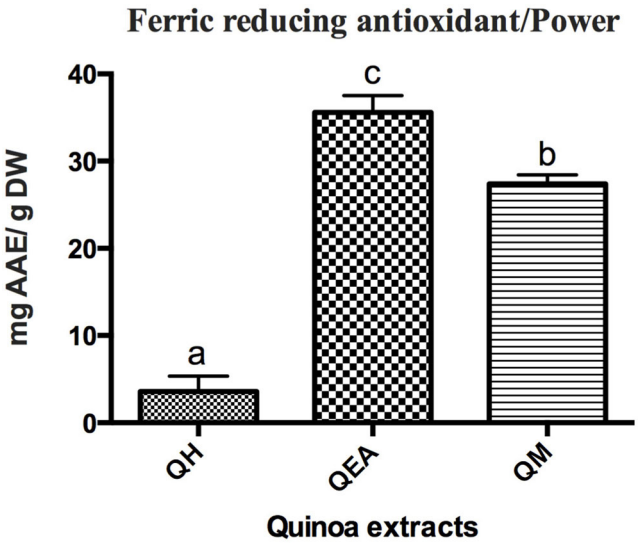

Fig. 2 Ferric reducing antioxidant/power of quinoa extracts, in mg of ascorbic acid equivalent/g of dry weight. Values not sharing a common letter differ significantly at $p < 0.05$

followed by QM (345.89 ± 16.34 µg/mL) and finally QH (>1000 µg/mL). Rodrigo Scherer & Helena Teixeira Godoy (2009) [17] reported AAI index to indicate poor antioxidant activity when AAI < 0.5, moderate antioxidant activity when AAI between 0.5 and 1.0, strong antioxidant activity when AAI between 1.0 and 2.0, and very strong when AAI > 2.0. Quinoa extracts show moderate (QEA) and poor activity (QM and QH) (Table 4). This difference is strongly related to the phenolic content and the active compounds. Comparing with literature data [4], it seems that Moroccan quinoa extracts were more efficient.

Ferric reducing/antioxidant power

Antioxidant compounds reduce Fe^{3+}-ferricyanide complexes to the ferrous (Fe^{2+}) form. In this assay, the yellow colour of the test solution changes to green or blue depending on the reducing power of the antioxidant. A higher absorbance indicates higher ferric reducing power [33]. Ferric reducing antioxidant power (FRAP), in all extracts and fractions was determined as acid ascorbic equivalent from a linear standard curve, as shown in Figure 2. The highest FRAP value expressed in mg AAE/g of dw, was found in QEA (35.6 ± 1.91). The order of antioxidant activity of quinoa extracts based on FRAP method was: QEA > QM > QH, wich is similar and consistent with DPPH results and phenolic content.

β-*carotene bleaching assay*

Free radical scavenging models are valuable methods to assess the potential antioxidant activity of plant extracts. However, no direct information on the protective effects of the plant extracts under those systems can be concluded. Since, those methods, don't use a food or biologically relevant, oxidisable substrate [34]. Therefore, it was important to assess the quinoa extracts in a β-carotene–linoleic acid system: water emulsion assay. In this test, oxidation of linoleic acid produces hydroperoxide-derived free radicals

Table 5 β-carotene bleaching assay of quinoa extracts [x].

Samples[y]	AOX	AA	ORR	AAC
QH	0.0110[c]	23.80[a]	0.71[d]	110.48[a]
QEA	0.0070[b]	47.86[c]	0.54[b]	387.40[c]
QM	0.0080[b]	41.18[b]	0.58[c]	326.17[b]
BHT	0.0029[a]	81.15[d]	0.21[a]	1063.33[d]

[x] Data are reported to mean (n = 3) ± Standard Error. Values in the same column not sharing a common letter differ significantly at $p < 0.05$; [y] Samples concentrations are (quinoa extracts : 1000 µg/mL & BHT : 500 µg/mL).

that attack the eleven pairs of β-carotene double bonds, resulting in a bleaching of the reaction emulsion. An extract capable of retarding or inhibiting the oxidation of β-carotene may be described as a free radical scavenger and primary antioxidant [35]. Antioxidant activity of quinoa extracts followed similar trends based on the inhibition of β-carotene bleaching when expressed as AOX (antioxidant value – sample degradation rate), or ORR (oxidation rate ratio), AAC (antioxidant activity coefficient) and AA (antioxidant activity-percentage of inhibition) (Table 5). As can be seen in Table 5, all of the quinoa extracts inhibited the bleaching of β-carotene by scavenging linoleate-derived free radicals. Ethyl acetate seed extract reduced β-carotene with a bleaching rate of (0.54) which was higher than other extracts but considerably lower than BHT activity ($p < 0.01$). Differences in antioxidant activity of seed extracts reflect clearly their phenolic content (Table 2). It is important to add that β-carotene bleaching assay only provides an indication of the level of lipophilic compounds because the β-carotene bleaching test bleaching test is similar to an oil-in-water emulsion system [36].

Conclusion

The present study revealed that Moroccan quinoa seeds demonstrated high phenolic content and potent antioxidant activities, achieved by DPPH, FRAP and β-carotene bleaching assays. The phytochemical analysis highlight that seeds of fresh and cooked quinoa, are a rich source of minerals, proteins, fatty acids and fibres. The ethyl acetate extract had the highest antioxidant activities, total phenolic and flavonoid contents. These results suggest that the polarity might have a significant influence on the antioxidant activity of quinoa, and that phenolic compounds which are known to be the major contributors in antioxidant activities are much more soluble in weak polar solvents. Quinoa was cultivated for its nutritional value, and after being abandoned in favor of old-world crops. It is now starting to be rediscovered and integrated in many countries by modern scientific approaches for its agricultural, pharmacological and cosmetic industrial uses. Functional properties given by active compounds like minerals, proteins, fibres and phenolic metabolites make of this pseudo-cereal a strong contribution to human nutritional therapy. Data variation in the antioxidant capacity is to be expected, as many factors such as genetics and environmental conditions, which can influence the presence of phenolic compounds. In addition, a comparison of results from different studies can be difficult due to variability in the experimental conditions amongst the used methods. Our results have proved that quinoa seeds show high nutritional value and interesting antioxidant properties, which may suggest that quinoa secondary metabolites may act as potential therapeutic agent in many pathophysiologic processes where oxidative stress is implicated.

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Conflict of interest : the authors declare do not have any conflict of interest

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