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Chemical composition and nutritional value of seeds from new quinoa accessions, cultivated in Egypt

H. Barakat[1], I. Khalifa[1], G. A. Ghazal[1], A. Shams[2], P. N. Denev[3]*

[1] *Department of Food Technology, Faculty of Agriculture, Benha University, Moshtohor, 13736 Qaliuobia, Egypt*

[2] *Crop Intensification Research Department (CIRD), Field Crops Research Institute (FCRI), Agricultural Research Center (ARC), Giza, Egypt.*
[3] *Institute of Organic Chemistry with Centre of Phytochemistry – Bulgarian Academy of Sciences, Laboratory of Biologically Active Substances, 139 "Ruski" blvd., 4000 –Plovdiv, Bulgaria*

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Dedicated to Acad. Ivan Juchnovski on the occasion of his 80th birthday

Quinoa (*Chenopodium quinoa* Willd) is a plant that recently have been successfully grown in Egypt, providing seeds rich in nutrients and bioactive compounds. Present study aimed the characterization of chemical composition, nutritional value, amino acid and fatty acid profiles of selected quinoa accessions (Shams17-2, Shams16 and Shams14) cultivated in Egypt. Moisture, ash, crude protein, crude fat, crude fiber and carbohydrate contents of quinoa seeds were ranged from 10.74 to 11.77%, 3.22 to 3.87%, 11.15 to 17.81%, 4.01 to 6.14%, 6.30 to 8.24 and 56.69 to 66.07%, respectively. Shams17-2 was the richest source of Mg, K and Fe while Shams16 was the richest in Na and Zn. The highest amount of total amino acids was recorded in Shams17-2, whereas the highest content of essential amino acids was found in Shams14. Seeds from Shams17-2 were distinctive with the highest amount of non-essential amino acids. The unsaturated fatty acids content of quinoa oils was 86.60, 87.07 and 85.05% while the saturated fatty acids recorded 10.90, 9.44 and 10.75% for Shams17-2, Shams16 and Shams14, respectively. It could be concluded that quinoa seeds from the new accessions, cultivated in Egypt are a good source of essential nutrients such as minerals, essential amino acids and essential fatty acids.

Key words: Quinoa; chemical composition; nutritional value; fatty acids; amino acids

INTRODUCTION

Quinoa is a grain-like food nowadays referred as a pseudo-cereal. Its use as food is dated back to the Andean civilization and presently it is cultivated in different environmental conditions [1]. Besides their high nutritional value, quinoa seeds (QS) are rich source of different phytochemicals. A recent study reported that a serving portion of quinoa (~40 g) meets a significant part of the daily recommendation intake for essential nutrients - mainly vitamins, minerals and essential amino acids [2]. Quinoa flour is suitable for preparation of different food-stuffs and in particular bakery products (bread, cookies, biscuits, noodles, pasta, pancakes and others) [3], as well as fermented products [4]. In the meanwhile, quinoa has been rapidly gaining recognition as a functional food, thus its chemical constituents and therapeutic properties were recently spotlighted [5]. The Food and Agriculture Organization of the United Nations (FAO) launched the international year of quinoa in 2013 to promote the production and revalorization of this valuable crop [6]. QS are rich in protein, lipids and ash. Their high protein content range from 13.1 to 16.7% and is higher than those of rice, barley, corn and rye, and close to that of wheat [7]. Quinoa protein is referred as a high-quality protein with higher content of lysine, methionine and threonine compared to wheat and maize [8]. Carbohydrate content of QS is similar to that of wheat and starch is the major carbohydrate component constituting 32%-69% of the available carbohydrates. The content of total dietary fiber (7.0–11.7%) and soluble fiber content (1.3–6.1%) in quinoa seeds are close to these in wheat [1]. Lipid content of QS (5.5–7.4%) is higher than wheat (1.7%) and rice (0.7%), making quinoa an adequate source of functional lipids [9]. QS contain more vitamin E, vitamin C, riboflavin (B_2), pyridoxine (B_6) and folic acid than wheat, rice, barley and corn [9, 10], besides its high content of calcium, magnesium, iron, copper and zinc. Moreover, calcium, magnesium, and potassium are found in quinoa in bioavailable forms, thus their contents are considered to be adequate for a

* To whom all correspondence should be sent:
E-mail: *petkodenev@yahoo.com*
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balanced diet [5,11]. QS are gluten-free which is beneficial for the high-risk consumer group with celiac disease. Valuable bioactive compounds exhibiting antifungal, antiviral, anticancer, hypocholesterolemic, hypoglycemic, antithrombotic, diuretic and anti-inflammatory activities such as saponins have been identified in QS [12]. Different polyphenols such as phenolic acids and flavonoids (quercetin, kaempferol and their glycosides) have been found in QS, as well [13-15]. Phytoecdysteroids in QS demonstrated health benefits including anabolic, performance enhancing, anti-osteoporotic, anti-diabetic, anti-obesity and wound healing properties [16].

The high nutritional value of quinoa seeds and their high content of bioactive components encouraged planting of quinoa crop in Egypt. Therefore, the objective of this investigation was to characterize the chemical composition and nutritional value of seeds from new quinoa accessions (QA) from Egypt, selected for their high yield and short cultivation period.

EXPERIMENTAL

Materials and methods

All solvents (HPLC grade) and reagents were purchased from Sigma-Aldrich (Steinheim, Germany).

Plant material

Agronomic, preliminary chemical composition and economic evaluation field trial was carried out at Ismailia Research Station, Agriculture Research Center, to evaluate the new selected quinoa accessions [17].

Characterization of chemical composition

The following A.O.A.C. methods were used for the chemical characterisation of QS: Moisture content (method No. 934.01) was determined by drying appropriate amount of the sample in oven (Tit Axon S.R.L via Canova, Italy) at 105 ºC until constant weight. Method No. 920.39 was applied for determination of crude fat content using Soxhlet apparatus (FRANK, England). Crude fiber content was measured with method No. 978.10, whereas crude protein content (method No. 990.03) was determined by Kjeldahl apparatus (VELP, Italy). Ash content was measured via method No. 923.03 by heating samples in a muffle furnace at 550 ºC until constant weight [18]. Carbohydrate content was calculated according to Merrill and Kunerth [19]. Sodium, potassium and calcium content was determined by flame photometer (PFP 7, Model Jenway 8515, England) applying method No. 956.01, while magnesium, iron and zinc content was determined by atomic absorption spectroscopy (Perkin-ELMER, 2380, England) according to method No. 968.08 of A.O.A.C. [18].

Amino acids determination

The amino acids profile was carried out on the precipitated protein from defatted quinoa after hydrolysis by 6.0 N HCl for 24 h at 110ºC in evacuated ampoules. Quantitative determination of amino acids were carried out by Biochrome 30 instruction manual (Analyzer used), 2005. EZ chrome manual (software for data collection and processing, 2004) according to A.O.A.C. [20].

Determination of fatty acid composition

Extraction procedure: Fatty acids were extracted according to Aldai *et al.* [21]. Approximately 1 g of powdered seeds were accurately weighted into 50 mL conical centrifuge tubes and 1 mg of the internal standard (free heneicosanoic acid, 100 μL of 10 mg mL^{-1} C21:0 in methanol:toluene (1:1, v/v)) was added before saponification. After that, 6 mL of saponification solution (5 M KOH in methanol:water (50:50, v/v)) were added, tubes were flushed with N_2, shaken for 10 min, and transferred into a 60°C water-bath for 60 min for a direct saponification. Reaction mixtures were diluted with 12 mL 0.5% NaCl and 5 mL of a non-polar solvent (i.e. petroleum spirit). Samples were vortexed for 5 min, few drops of absolute ethanol added and centrifuged at 800 × g for 5 min at 20 °C for layer separation. The top layer, containing the non-saponifiable extract was removed and discarded. Then, 3 mL of glacial acetic acid were added to neutralize KOH fraction. After that 5 mL of a non-polar solvent (petroleum spirit) were added and tubes were vortexed for 10 min. Samples were centrifuged again (800 × g for 5 min at 20 °C) and the top layer transferred to clean screw-cap glass tubes. Once again, 5 mL of a non-polar solvent were added for further clearance. Centrifugation and layer transference steps were repeated again and 100 μL of a water scavenger - 2,2-dimethoxypropane were added to each tube and vortexed for 2 min.

Derivatization procedure: Free fatty acids (FFAs) were methylated according to Aldai *et al.*

[21]. For methylation of free FAs, samples were reduced to dryness under N_2 at 40ºC and then re-dissolved in 1mL of methanol: toluene (2:1 vol.) and vortexed for 5 min. Methanol is a catalyst for the (trimethylsilyl) diazomethane (TMS–DM) reaction and drives the reaction in favour of methyl ester formation. At this stage, methylation reagent was added in molar excess of 2 M (trimethylsilyl) diazomethane (TMS–DM) in *n*-hexane (120µL) and the reaction proceeded at 40 ºC for 10 min in open tubes. The samples were dried again under gentle stream of N_2 at 40 ºC for approximately 20 min. Finally, each sample was reconstituted in 2 ml of *n*-hexane (with 50 ppm of BHT), centrifuged at 20.000 *x g* for 5 min at 7ºC then transferred into vials and kept at -20 ºC. Before GLC injection, samples were diluted in 1 µl *n*-hexane, then injected into GLC column and run under an optimized temperature program with optimized gas flow rate.

GLC equipment and program: A Varian Star CX3400 GLC (Varian, Spain) equipped with a FID detector, an automatic sample injector (SPI) in one column mode and a Chrompak CP-SIL 88 for FA methyl esters (FAMEs) (WCOT FUSED SILICA 100m×0.25mm, 0.2 µm film thickness) with retention gap (FUSED SILICA TUBING 4 m×0.25 mm i.d., Methyl deactivated) was used. Helium was used as the carrier gas with a column head pressure of 355 kPa and a flow rate of approximately 2 ml min^{-1} measured at 100 ºC. The GLC conditions were as follows: 100ºC, at 2ºC min^{-1} to 170ºC, hold for 15 min, at 0.5 ºC min^{-1} to 180 ºC, at 10ºC min^{-1} to 200 ºC and hold for 10 min, at 2ºC min^{-1} to 230 ºC then hold for 10 min; injection temperature was 250 ºC; detector temperature was 300 ºC. Peaks were identified in comparison to standards and integrated using a conventional integrator program (Saturn GC Workstation Software ver., 5.51).

Statistical analysis

Statistical analysis was carried out using SPSS program (ver. 19) with multi-function utility regarding to the experimental design and multiple comparisons were carried out applying LSD according to Steel *et al.* [22].

RESULTS AND DISCUSSION

Chemical composition of quinoa seeds

Chemical composition of the investigated quinoa seeds from new quinoa accession cultivated in Egypt and their energy values are presented in Table 1. Moisture, ash, crude protein, crude fat, crude fiber and carbohydrate contents of QS were ranged from 10.74 to 11.77%, 3.22 to 3.87%, 11.15 to 17.81%, 4.01 to 6.14%, 6.30 to 8.24 and 56.69 to 66.07%, respectively. These results are very close to those observed in other studies [1, 7-9]. It was observed that ash, crude protein, crude fat and crude fiber contents in seeds of Shams17-2 are significantly (p<0.05) lower than those in seeds of Shams16 and Shams14. Energy values indicate that seeds from Shams14 had the highest energy values. In general, some of the analyzed parameters in tested quinoa samples differed significantly (p<0.05), which could enlarge their practical uses [5,23,24].

Besides the chemical composition, the content of some minerals in QS was determined, as well. Results presented in Table 2 indicate the high content of the analyzed minerals in the tested QA. From Table 2 it is evident that content of the major minerals Ca, Mg, Na and K varied in the range 1.55, 91.16 and 153.61, 484.26, 338.94 and 200.79, 1.11, 322.97 and 113.21 and 4.11, 3.60 and 3.35 $mg.100g^{-1}$ in seeds of accessions 17-2, 16 and 14, respectively.

Table 1. Chemical composition and energy value of quinoa seeds cultivated in Egypt.

Accession	Chemical composition, [%]						Energy value [kcal.100 g-1]
	Moisture	Ash	Crude protein	Crude fat	Crude fiber	Carbohydrates	
Shams17-2	11.77 ±0.48[b]	3.22 ±0.32a	11.15 ±1.69a	4.01 ±0.36a	6.30 ±0.44a	66.07 ±1.98b	440.85 ±13.00a
Shams16	10.74 ±0.14[a]	3.87 ±0.23a	15.23 ±0.56b	6.14 ±0.63b	8.24 ±0.42b	58.97 ±1.58a	499.30 ±9.16b
Shams14	11.67 ±0.31[b]	3.30 ±0.69a	17.81 ±0.91c	6.09 ±0.47b	8.18 ±0.42b	56.69 ±0.85a	595.76 ±16.69c

Results are presented as means ± standard deviations (SD) from six independent measurements (n=6). Same small letters indicate that values in different accessions are not significantly different (p>0.05).

Table 2. Content of chosen minerals in quinoa seeds from new accessions.

Accession	Minerals content*, [mg.100g^{-1}]					
	Ca	Mg	Na	K	Fe	Zn
Shams17	1.55	484.26	1.11	4.11	12.41	2.12
Shams16	91.16	338.94	322.97	3.60	8.41	3.53
Shams14	153.61	200.79	113.21	3.35	8.10	3.42

* Only one measurement was performed.

Furthermore, Fe and Zn were detected to be 12.41, 8.41 and 8.10, and 2.12, 3.53 and 3.42 mg.100 g^{-1}, for the same sequence, which is in harmony with other studies [1, 3]. It is evident from table 2 that Ca and Na contents in Shams 17-2 are much lower in comparison to the corresponding contents in Shams 14 and 16. It should be noted that Shams 17-2 is a new coloured accession that differs significantly from the non-coloured Shams 14 and 16. It was developed to be rich in anthocyanins rendering a darker colour. It is known that accumulation of minerals and secondary metabolites in plants depends on different factors, such as genetic (cultivar), agro-technique used, climate, etc. The elucidation of this phenomenon will be a subject of our further research on new quinoa cultivars from Egypt.

Amino acid composition of quinoa seeds

The amino acid composition of different QS cultivated in Egypt is given in Table 3. The highest total amino acids were recorded for Shams17-2 followed by Shams14 and Shams16. Interestingly, the highest amount of essential amino acids (EAA) was found in Shams14, while Shams17-2 contains the highest quantities of non-essential amino acids (NEAA). Histidine and Cystine contents were higher in QS in comparison to the referenced egg protein, while among the NEAA Glutamic acid is more than 2-fold higher than in the referenced egg protein. Correspondingly, all essential and non-essential amino acid have been detected in tested quinoa accessions confirming that quinoa protein has balanced amino acid profile, both qualitatively and quantitatively. From the presented results it is evident that total amount of amino acids in the selected quinoa accessions is very close to that in egg (FAO, 1970), which is in agreement with other authors [1,3]. The nutritional evaluation of quinoa protein given in Table 4 indicates its close relativity to the referenced egg protein. In the same context, the essential amino acids index (EAAI%) that is as an indicator for protein quality was in the range 85.21 - 86.92%. As already mentioned, quinoa amino acid profile is considered as better in comparison to wheat protein profile, moreover without Lysine deficiency [1,3,25].

Table 3. Amino acid (AA) composition and content (expressed in g.g^{-1} N) in seeds of three quinoa accessions compared to hen's egg standard protein (FAO, 1970)

Amino acid	Shams17-2	Shams16	Shams14	Hen's egg (FAO 1970)
Essential amino acids (EAA)				
Threonine	0.253	0.238	0.244	0.320
Valine	0.323	0.363	0.335	0.428
Isoleucine	0.275	0.256	0.267	0.393
Leucine	0.431	0.425	0.432	0.551
Tyrosine	0.259	0.250	0.256	0.260
Phenylalanine	0.307	0.300	0.296	0.358
Histidine	0.226	0.213	0.227	0.152
Lysine	0.338	0.388	0.398	0.436
Methionine	0.156	0.181	0.171	0.210
Cystine	0.124	0.144	0.171	0.110
Non-essential amino acid (NEAA)				
Aspartic acid	0.587	0.594	0.567	0.601
Serine	0.266	0.238	0.267	0.796
Glutamic acid	1.084	1.009	1.040	0.478
Proline	0.254	0.244	0.245	0.260
Glycine	0.339	0.356	0.347	0.207
Alanine	0.318	0.338	0.324	0.370
Arginine	0.641	0.581	0.642	0.381
Total amino acids	6.231	6.118	6.219	6.311
Total EAA	2.742	2.758	2.797	3.218
Total NEAA	3.439	3.360	3.422	3.093

As recommended by FAO and WHO, there are two characteristics determining quality. One of them depends on the ratio between individual and total essential amino acids. Scores for tested protein as well as that of FAO pattern [hen's egg FAO 1970] are presented in Table 5. Calculated results indicate that the score of selected quinoa accessions was slightly lower than the score of each EAA of hen's egg standard protein with the exception of Histidine.

Data in Table 6 illustrates the scores of the protein from the selected quinoa accessions in regards to the limiting essential amino acids, compared to FAO pattern. From the results, it could be concluded that Leucine is the first limiting amino acid in Shams17-2 and the second in Shams16. Methionine and Cystine are the first limiting AA in Shams17-2. Threonine is the first limiting AA in Shams16 and Shams14. The second limiting AA in Shams14 is Tyrosine while Isoleucine is the third. These results clearly show that variation of amino acid score may be related to each accession and/or cultivation conditions, which is in accordance with other studies [1,3,25].

Table 4. Nutritional evaluation of quinoa protein from new accessions, in comparison to hen's egg protein.

Seeds	TEAA g / 16 N	TNEAA g / 16 N	EAA: NEAA Ratio	EAA: Protein Ratio	NEAA: Total AA Ratio	EAAI %
Shams17-2	43.87	55.81	0.79	0.44	0.44	85.21
Shams16	44.19	53.76	0.82	0.44	0.45	85.27
Shams14	44.75	54.75	0.88	0.45	0.45	86.92
Egg (FAO, 1970)	51.49	49.49	1.04	0.52	0.51	100.00

EAA: NEAA: Ratio of essential amino acids to nonessential amino acid; EAA: Protein Ratio: Ratio of essential amino acids to 100 g protein;NEAA: Total AA Ratio: Ratio of essential amino acids to total amino acid;EAAI %: Essential amino acids index according to FAO

Table 5. Assessment of individual amino acids of quinoa accessions compared to reference essential amino acids in hen's egg protein [mg individual AA.g^{-1} TEAA].

Amino acids	Shams17-2	Shams16	Shams14	Hen's egg score (FAO 1970)
Threonine	92.27	86.29	87.24	110.42
Valine	117.80	131.62	119.77	147.69
Isoleucine	100.29	92.82	95.46	135.61
Leucine	157.18	154.10	154.45	190.13
Tyrosine	94.46	90.65	91.53	89.72
Phenylalanine	111.96	108.77	105.83	123.53
Histidine	82.42	77.23	81.16	52.45
Lysine	141.50	140.68	142.30	150.45
Methionine + Cystine	102.12	117.84	122.27	151.00

Table 6. Scores of protein from selected quinoa accessions in regards to limiting essential amino acids. Results are expressed in mg.g^{-1} protein.

Amino acid	Shams17-2	Shams16	Shams14	Suggested amino acid pattern (FAO, 1973)*
Threonine	101.29	85.20	97.73	40
Valine	103.45	104.04	107.27	50
Isoleucine	109.91	91.93	106.82	40
Leucine	98.52	87.12	98.70	70
Tyrosine	118.23	102.50	116.88	35
Phenylalanine	102.37	89.69	98.49	48
Histidine	172.41	145.21	173.16	21
Lysine	112.85	101.10	115.70	55
Methionine+ Cystine	99.96	103.64	121.21	45
First limiting amino acid	Leucine	Threonine	Threonine	-
Second limiting amino acid	Methionine + Cystine	Leucine	Tyrosine	-
Third limiting amino acid	---	Phenylalanine	Isoleucine	-

* According to FAO/WHO AD HOC Committee (FAO, 1973).

$$\text{Amino acid score according to FAO (1973)} = \frac{\text{mg amino acid in 1 g protein}}{\text{mg amino acid sugested by FAO/WHO}} \text{ x100}$$

Fatty acid composition in qs oil of selected accessions

Fatty acid composition of extracted oil from QS cultivated in Egypt are shown in Table 7. All together fourteen fatty acids have been identified. The unsaturated fatty acids (USFA) contents of quinoa seed oils were 86.60, 87.07 and 85.05% while the saturated fatty acids (SFA) recorded 10.90, 9.44 and 10.75% for Shams17-2, Shams16 and Shams14, respectively. Linoleic acid was the predominant USFA with content higher than 50% in all samples. For the best of our knowledge and from parallel comparison of QA oils with some edible oils, the analyzed oil samples demonstrated higher USFA and lower SFA than cottonseed, soybean and olive oils. Therefore it can be considered as one of the richest source of Linoleic acid with considerably high ratio of USFA/SFA. The content of omega-3 fatty acids is 7.44%, 5.25% and 5.14% in Shams17-2, Shams16 and Shams14, respectively. These results are in agreement with previous studies [5, 23, 24, 26-28] and open the possibility of using QS oil as a source of omega-3 FA for enhancing the nutritional value of the diet. Saturated fatty acid content is lower in quinoa oil than presented in common vegetable oils but the difference is minor. Erucic acid, which has been implicated as a pathological factor in cardiovascular disease presents in QA oils at levels below the United States Food and Drug Administration (FDA) limit of 2%. This amount is equivalent to the erucic acid content of canola oil [26, 28]. Another study reported Erucic content in QS oil of 0.52% [27].

CONCLUSION

Quinoa is a pseudo-cereal with remarkable nutritional and health-promoting values, and results obtained in the current study prove that. The content of essential amino acids and essential fatty acids varied within the different accession. The results for the chemical composition of the selected QA cultivated in Egypt are base for scaling up the production of these promising accessions in the country. Further research on biological properties of quinoa phytochemicals, their bioavailability, mechanisms of action and health promoting benefits is needed for a full integration of this plant in Egyptians' diet.

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Table 7. Fatty acid profile of three selected quinoa accessions planted in Egypt

Fatty acid	Fatty acid, %			Fatty acids in reference oils*, %		
	Shams 17-2	Shams 16	Shams 14	Cotton seeds oil	Soybean oil	Olive oil
Myristic acid (C14:0)	0.21	0.17	0.17	0.6-1.0	0.05-0.2	0.0-0.05
Palmitic acid (C16:0)	9.29	8.07	9.01	21.4-26.4	8.0-13.5	7.5-20
Palmitoleic acid (C16:1)	0.14	0.10	0.08	0.05-1.2	0.05-0.2	3.0-3.5
Margaric acid (C17:0)	0.05	0.04	0.04	0.05-0.1	0.05-0.1	0.0-0.3
Heptadecenoic acid (C17:1)	0.05	0.04	0.04	0.05-0.1	0.05-0.1	0.0-0.3
Stearic acid (C18:0)	0.52	0.39	0.47	2.1-3.3	2.0-5.4	0.5-5.0
Oleic acid (C18:1)	19.74	19.36	19.59	14.7-21.7	17.0-30.0	55.0-83.0
Linoleic acid (C18:2)	55.75	58.75	56.85	46.7-58.2	48.0-59.0	3.5-21
γ-Linolenic acid (C18:3n6)	0.52	0.39	0.07	0.05-0.4	4.5-11.0	0.0-1.0
α-Linolenic acid (C18:3n3)	7.44	5.25	5.14			
Arachidic acid (C20:0)	0.34	0.30	0.42	0.2-0.5	0.1-0.6	0.0-0.6
Gadoleic acid (C20:1)	1.43	1.50	1.58	0.05-0.1	0.05-0.5	0.0-0.4
Behenic acid (C22:0)	0.49	0.47	0.64	0.05-0.6	0.05-0.7	0.0-0.2
Erucic acid (C22:1)	1.53	1.68	1.67	0.05-0.3	0.05-0.3	--
Unknown	2.49	3.48	4.19	--	--	--
Total SFA	10.90	9.44	10.75	24.4-31.9	10.3-20.5	8.0-26.2
Total USFA	86.60	87.07	85.05	61.7-82.0	69.7-88.7	61.5-92.1
USFA/SFA	7.94	9.22	7.91	2.5-2.6	4.9-6.8	4.2-7.7

* Results according to Egyptian Standard [29], Egyptian Standard [30] and, Egyptian Standard [31].

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ХИМИЧЕН СЪСТАВ И ХРАНИТЕЛНА СТОЙНОСТ НА СЕМЕНА ОТ НОВИ ГЕНОТИПОВЕ КИНОА, КУЛТИВИРАНИ В ЕГИПЕТ

Х. Баракат[1], И. Халифа[1], Г. А. Газал[1], А. Шамс[2], П. Н. Денев[3]*

[1] *Катедра по хранителна технология, Земеделски факултет, Университет на Банха, 13736 - Калюбия, Египет.*
[2] *Институт по полски култури, Земеделски изследователски център, Гиза, Египет.*
[3] *Институт по органична химия с Център по фитохимия - Българска академия на науките, Лаборатория по биологично активни вещества, бул. „Руски" 139, 4000 Пловдив, България*

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(Резюме)

Киноата (*Chenopodium quinoa* Willd) е растение, което от скоро се отглежда успешно в Египет, осигурявайки семена, богати на хранителни вещества и биоактивни съединения. Настоящото изследване е насочено към охарактеризиране на химичния състав, хранителната стойност, аминокиселинния и мастнокиселинния състав на избрани генотипове киноа (Shams17-2, Shams16 и Shams14), култивирани в Египет. Съдържанието на влага, пепел, белтък, мазнини, хранителни влакнини и въглехидрати в семената от киноа варира съответно в границите от 10.74 до 11.77%, 3.22 до 3.387%, 11.15 до 17.81%, 4.01 до 6.14%, 6.30 до 8.24 и 56.69 до 66.07%. Shams17-2 е най-богатият генотип на Mg, K и Fe, докато Shams16 е най-богат на Na и Zn. Най-голямо количество общи аминокиселини е отчетено в генотип Shams17-2, докато най-високо съдържание на есенциални аминокиселини е намерено в Shams14. Shams17-2 се отличава с най-голямо количество не-есенциални аминокиселини. Съдържанието на ненаситени мастни киселини в маслата от семена на киноа е 86.60, 87.07 и 85.05%, докато наситените мастни киселини са 10.90, 9.44 и 10.75%, съответно за генотипове Shams17-2, Shams16 и Shams14. От направеното изследване може да се заключи, че семената от киноа от новите Египетски генотипове са добър източник на основни хранителни вещества като минерали, есенциални аминокиселини и есенциални мастни киселини.

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