



BIOCHEMICAL AND BIOTECHNOLOGY STUDIES ON QUINOA SEEDS

By

GHADA TAWFIK AHMED ABDEL- MAKSOUH

**B.Sc. (Food Science), Fac. Agric., Ain Shams Univ., (1994)
M.Sc. Agric. Sci. (Biochemistry), Fac. of Agric., Cairo Univ. (2011)**

**Submitted in Partial Fulfillment of
The Requirements for the Degree of**

DOCTOR OF PHILOSOPHY

**In
AGRICULTURAL SCIENCE
(Agric. Biochemistry)**

**Department of Agric. Biochemistry
Faculty of Agriculture
Benha University**

2017

CONTENTS

Subject	Page
1. INTRODUCTION	1
2. REVIEW OF LITERATURE	5
2.1. General Characteristics of Quinoa (<i>Chenopodium quinoa</i> Willd).....	6
2.2. Physical Properties of Quinoa Seeds	9
2.3. Functional properties of quinoa flour.....	11
2.4. Proximate chemical composition of quinoa flour	12
2.4.1. Protein.....	16
2.4.2. Carbohydrates	22
2.4.3. Lipid	26
2.4.4. Minerals	29
2.4.5. Vitamins	32
2.4.6. Polyphenols and flavonoids.....	35
2.4.7. Antioxidant.....	37
2.4.8. Antinutritional factors	39
2.4.8.1.Saponins.....	39
2.5. Utilization and Applications.....	46
2.5.1. Utilization of quinoa seed flour in food applications.....	46
2.5.2. Free gluten products (Coeliac disease).....	49

3. MATERIALS AND METHODS.....	51
3.1. Materials.....	51
3.2. Methods.....	51
3.2.1. Physical Properties of Quinoa Seeds.....	51
3.2.2. Preparation of quinoa seeds flour (QF).....	52
3.2.2.1. Processing of quinoa seeds.....	52
3.2.3. Analytical methods.....	53
3.2.3.1. Chemical composition.....	53
3.2.3.2. Amino acid analysis.....	53
3.2.3.2.1. Nutritional quality parameters.....	54
3.2.3.2.2. Amino acid score.....	54
3.2.3.2.3. Protein efficiency ratio.....	54
3.2.3.2.4. Biological value.....	54
3.2.3.2.5. Protein digestibility (<i>in vitro</i>).....	55
3.2.3.3. Fatty acids.....	56
3.2.3.4. Minerals content.....	57
3.2.3.5. Vitamins content.....	57
3.2.3.6. Determination of saponin content.....	58
3.2.3.7. Determination of Phenolic compounds.....	59
3.2.3.8. Antioxidant activity (DPPH radical scavenging activity).....	59
3.2.4. Functional properties.....	60

3.2.4.1. The water absorption index, water solubility Index.....	60
3.2.4.2. Swelling power	62
3.2.4.3. Bulk density.....	62
3.2.4.4. Oil absorption capacity.....	62
3.2.5. Utilization of quinoa flour in free gluten products.....	62
3.2.5.1. Free gluten biscuits.....	62
3.2.5.1.1. Physical properties of biscuits.....	64
3.2.5.1.2. Hardness.....	64
3.2.5.1.3. Sensory evaluation of biscuits.....	64
3.2.5.2. Free gluten crackers.....	65
3.2.5.2.1. Physical properties of crackers.....	66
3.2.5.2.2. Sensory evaluation of crackers	67
3.2.6. Shelf-life study	67
3.2.6.1. Microbiological analysis	67
3.2.6.2. Acid value	68
3.2.6.3. Peroxide value	68
3.2.7. Statistical Analysis	68
4. RESULTS AND DISCUSSION	69
4.1. Physical Properties of quinoa seeds.....	69
4.2. Effect of different treatments on fractions and saponin content in quinoa seeds	70
4.3. Functional properties of quinoa flour.....	72

4.4. Proximate chemical composition of quinoa flour.....	73
4.4.1. Amino acid content of quinoa flour.....	75
4.4.1.1 Nutritional values of quinoa flour	78
4.4.2. Fatty acids composition of quinoa flour.....	79
4.4.3. Minerals in quinoa flour.....	81
4.4.4. Vitamins in quinoa flour	83
4.4.5. Phenolic and antioxidants compounds	84
4.5. Free gluten products from quinoa flour.....	87
4.5.1. Biscuits.....	87
4.5.1.1. Sensory characters of free gluten biscuits	87
4.5.1.2. Physical properties of biscuits.....	89
4.5.1.3. Chemical analysis and caloric values of free gluten biscuits..	91
4.5.1.4. Acid value, peroxide value and antioxidant activity of free gluten biscuits	93
4.5.1.5. Effect of storage period on free gluten biscuits.....	94
4.5.1.5.1. Effect of storage on sensory characters of free gluten biscuits	94
4.5.1.5.2. Effect of storage on acid values, peroxide values and antioxidant activity of free gluten biscuits 96	
4.5.1.5.3. Effect of storage on moisture content and hardness of free gluten biscuits	99
4.5.1.5.4. Effect of storage on the microbial quality of free gluten biscuits	100

4.5.2. Free gluten crackers.....	101
4.5.2.1. Sensory characters of free gluten crackers.....	101
4.5.2.2. Physical properties and hardness of free gluten crackers	103
4.5.2.3. Chemical analysis and caloric values of free gluten crackers	104
4.5.2.4. Acid value, peroxide value and antioxidant activity of free gluten crackers	106
4.5.2.5. Effect of storage period on free gluten crackers.....	107
4.5.2.5.1. Effect of storage on sensory characters of free gluten crackersa	107
4.5.2.5.2. Effect of storage on acid value, peroxide value and antioxidant activity of free gluten crackers	108
4.5.2.5.3. Effect of storage on moisture content and hardness of free gluten crackers	109
4.5.2.5.4. Effect of storage period on the microbial quality (cfu/g) of free gluten crackers	111
5. SUMMARY AND CONCLUSION	113
6. REFERENCES	121
7. ARABIC SUMMARY	

LIST OF TABLES

No	Title	Page
1	Biscuits formulation.....	63
2	Score card of biscuits.....	65
3	Crackers formulation	66
4	Score card of crackers	67
5	Physical Properties of quinoa seeds	70
6	Milling properties and saponin content of different treatments of quinoa seeds	72
7	Functional properties of quinoa flour	73
8	Proximate composition (%) of quinoa seed flour (on dry weight basis)	75
9	Amino acid content of quinoa seed flour (gm/100g protein)	77
10	Nutritional values of amino acids of quinoa seed flour	79
11	Fatty acids composition of quinoa seeds flour	81
12	Minerals content of quinoa seed flour (mg/kg).	83
13	Vitamins content of quinoa seed flour (mg/100g).	84
14	Total contents (mg/100 g) of phenolic acids and flavonoids in quinoa seeds	86

15	Sensory evaluation of biscuits	88
16	Physical properties of biscuits	90
17	Chemical analysis and caloric values of biscuits	93
18	Acid value, peroxide value and antioxidant values of biscuits	94
19	Effect of storage at room temperature on sensory evaluation of biscuits.....	96
20	Effect of storage at room temperature on acid value (mg KOH/g fat), peroxide values (meq/kg fat) and antioxidant (%) of biscuits	98
21	Effect of storage at room temperature on moisture content (%) and hardness of biscuits	100
22	Effect of storage period on the microbial quality (cfu/g) of biscuits	101
23	Sensory evaluation of crackers	103
24	Physical properties of crackers.	104
25	Chemical analysis and caloric values of crackers	105
26	Acid value, peroxide value and antioxidant values of crackers	106
27	Effect of storage at room temperature on sensory evaluation of crackers.	107
28	Effect of storage at room temperature on moisture content (%), acid value (mg KOH/g fat), peroxide values (meq/kg fat) and antioxidant (%) of crackers.	109
29	Effect of storage at room temperature on moisture content (%) and hardness of crackers	111

30	Effect of storage period on the microbial quality (cfu/g) of crackers.	112
----	--	------------

ABSTRACT

Present study was carried out to evaluate the physical, chemical, nutritional and functional properties of quinoa seeds flour. Results showed that, the 1000-seed weight and the bulk density values of quinoa seeds were 2.71g and 0.80 g/m³, respectively. The chemical composition obtained data indicated that quinoa seeds flour contained 13.55, 7.30, 2.69, 3.45 and 63.56% for crude protein, crude fibers, ash, fat and total carbohydrates, respectively. Amino acids compositions of quinoa flour had a well-balanced amino acids composition especially lysine (4.67g/100 g protein). Also, quinoa flour oil was rich in unsaturated fatty acids, with ratio to saturated acids in quinoa was about 87:13.

On the other hand, biscuits prepared with replacing either of 50% of quinoa seeds flour or 75% of rice had overall acceptability which was not significant ($P \leq 0.05$) different comparing with to that of control biscuits. Also, physical properties, such as volume, weight, diameter and thickness of biscuits from different blends of rice and quinoa seeds flours showed that as the level of quinoa flour increased, the volume of biscuits decreased gradually. On the other side, chemical analysis and caloric values of biscuits from different blends of rice flour and quinoa flour showed that protein, fat, ash and crud fiber contents of flour-replaced biscuits were higher than that of the control biscuits.

On the other hand, crackers prepared with replacing of 100% of quinoa seeds flour of corn had overall acceptability which was not significant ($P \leq 0.05$) different comparing with to that of control crackers. Also, physical properties, such as volume, weight and thickness of crackers from different blends of corn and quinoa seeds

flours showed that as the level of quinoa flour increased, the volume of crackers decreased gradually. On the other side, chemical analysis and caloric values of crackers from different blends of corn flour and quinoa flour showed that protein, fat, ash and crud fiber contents of flour-replaced crackers were higher than that of the control crackers.

Key words: Quinoa flour - *Chenopodium* quinoa – Nutritional and functional properties- Biscuits-Crackers.