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UTILIZATION OF QUINOA FLOUR (*CHENOPODIUM QUINOA*) IN FUNCTIONAL FOOD PRODUCTION

Mohamed M.M. Aly-Aldin[*] and Sara M.S. Awad [**]

**Food Science and Technology Department,Faculty of Agricultural,Menoufia University Shibin El–kom,Egypt.*
***Food Science and Technology, Agricultural Industrialization Unit ,Desert Research Center , Cairo , Egypt.*

ABSTRACT

The aim of this study was to substitute of corn flour by quinoa flour to produce gluten free (bakery) as cake for people who have celiac disease, as well as by those who are allergic to wheat. Corn flour was replaced by quinoa meal with ratios of 10, 20 and 30%. The prepared cake were accessed for their (functional) nutritional properties. The farinograph and extinsograph properties of flour dough and product quality properties (physical, chemical, protein content, color and sensory evaluation of gluten free cake) resulted from corn flour and quinoa meal were examined in cake. The obtained results showed that protein, fat, fiber and ash contents were increased with increasing level of addition of quinoa flour, thus improved the nutritional. In addition, results showed that the water absorption, dough development time (DDT) and dough weakening increments and dough stability decrements. All the prepared cakes were highly acceptable for the panelists. Generally, replacement levels of 10 and 20% of quinoa flour showed acceptable results in the sensory and physical properties in cake with a significant increased in the nutritional qualities.

Key words: Corn flour, gluten free cakes, Quinoa flour, physical, farinograph, Sensory evaluation.

INTRODUCTION

Quinoa flat, oval-shaped seeds that are typically yellow however will zero in color from pink to black **(Karyotis *et al*., 2003)**. (*Chenopodium sp*.) is plant of the South America, happiness to pseudo cereals. Three thousand years ago, quinoa was planted by the Incas WHO referred it 'mother of all grains' **(Taylor and Parker, 2002)**. And therefore the international organization has recently named 2013 the 'International Year of Quinoa' **(United Nations, 2012)**.

Quinoa (*Chenopodium quinoa* Willd.) could be a seed crop, that has some healthy properties like straightforward to digest and a decent sources of protein, dietary fiber, minerals and essential amino acids e.g. lysine, methionine and histidine **(Ramos Diaz *et al*., 2015)**. Additionally, the quinoa seed contains antioxidant compounds like carotenoids and flavonoids **(Dini *et al*., 2010 and Maradini *et al*., 2017)**. Attributable to these necessary options, the enrichment of food products with quinoa became the interest of food trade to development of functional foods. Some studies have indicated that quinoa is also used as a diet supplement and binder attributable to its carbohydrate, fiber and protein content **(Ramos Diaz *et al*., 2015, 2016)**. Additionally, it has some practical (technological) properties like solubility, water-holding capacity (WHC), gelation, emulsifying and foaming that permit heterogeneous uses **(Abou-Zaid *et al*.,2014).**

Beside, it has been considered an oil crop, with a stimulating proportion of omega-6-fatty acid. Quinoa starch has physicochemical properties like viscousness and freeze stability that provides it functional properties with novel uses .Quinoa includes a high nutritional value and has recently been used as a unique functional food attributable to of these properties; it is a promising alternative cultivar **(Jancurová *et al*., 2009 and Vega-Gálvez *et al*., 2010)**. Moreover, quinoa is promoted as a very healthy food of the long run (gluten free). It is a food of the twenty-first century **(Valencia-Chamorro, 2003)**.

In recent years, the demand for gluten-free products has been on the increase so interest in gluten-free bread production is growing. Several analysis used gluten-free flour like rice and/or corn flour to provide a gluten-free it may be eaten by people who have celiac disease as well as by those who are allergic to wheat **Ylimaki *et al*., (1991) and Moore *et al*., (2006)**. Corn flour is helpful since it lacks gluten and contains high quantity of simply digestible carbohydrates, making it desirable in celiac diets. Quinoa flour could be a smart various to be utilized in gluten free baked products since it contains high quality proteins (about 15%), and its essential amino acid balance is great attributable to a wider amino acid spectrum than cereals and legumes **(Ruales and Nair,1992)**, with higher lysine (5.1-6.4%) and methionine (0.4-1.0%) contents **(Bhargava *et al.*, 2003)**.

Presently the gluten-free food makers are investment within the use of whole grains as well as corn, rice, sorghum, buckwheat, amaranth and quinoa, since the majority of these are excellent fiber, iron and vitamin B sources **.** The pseudo cereals are thought-about as probably gluten free grains with a wonderful nutrient profile, capable of diversifying this rising market **(Natalia *et al.*,2015)**.

Although there are several studies regarding exploitation quinoa and quinoa flour in several food producing technologies like bread, baby foods, flakes and beer, studies about using quinoa and quinoa flour in meat and meat products technology are restricted within the literature **(James, 2009; Wang and Zhu, 2016 and Maradini *et al.*, 2017)**. Additionally, the total seeds contains an oversized kind of antioxidant compounds, like carotenoids **(Eberhardt *et al.*, 2000 and Dini *et al.*, 2010)** and flavonoids **(Dini *et al.*, 2004)**, all of that are protecting against a spread of diseases, significantly cancer, allergy, inflammatory diseases; and reduce the risk of cardiovascular diseases **(Scalbert *et al.*, 2005 and Alvarez-Jubetea *et al.*, 2010)**, Alzheimer's disease and diabetes **(Rimm *et al.*, 1996 and Nsimba *et al.*, 2008)**.

Sadly, quinoa seeds contain bitter-tasting constituents (chiefly water-soluble saponins) situated within the outer layers of the reproductive structure, creating it primarily tasteless. Therefore, most industrial quinoa seeds, are processed to get rid of their coating by washing or milling so to eliminate bitter compounds before consumption **(Popenoe *et al.*, 1989)**.

The aim of this study was to assess the influence of quinoa flour addition on corn gluten-free bakery (cake) targeting a good sensory acceptance and highly nutritional value. Also, evaluation of the quality parameters of the bakery product was studied.

MATERIALS AND METHODS

The quinoa seeds were obtained from Khmisa Farm, Siwa Research Station, Desert Research Center-Egypt. The seeds were washed with cold water for several time in order to remove possible saponin residues then dried in an electric oven at 50°C. The quinoa seeds were ground into powder using a high-speed blender mill (25000/min), (WK-1000A; Qing Zhou Machinery Co., Ltd.), and then stored in polyethylene bags at 4°C until analysis. Flour (72% extraction), whole fresh egg, sugar, shortening, dry milk, baking powder, vanilla , cinnamon and salt (sodium chloride) were purchased from local market.

Processing of cake:

Cake samples were prepared according to the modified method of **Bennion and BamFord, (1997)**. The control cake formula (C) was formulated from 100 g flour, 85 g whole fresh egg, 85 g sucrose, 55 g shortening, 3 g dry milk, 3.8 g baking powder and 0.6 g vanilla , (added 0.5 gram of cinnamon). Quinoa flour was substituted by corn flour at 10, 20 and 30%. To prepare the cake, sugar and shortening were creamed together using a kitchen machine (Mighty Setter-Electric Portable Hand Mixer – with stand and stainless steel mixing bowl instructions, made in Japan). Flour, dry whole milk and baking powder were mixed together, then the mixture was added gradually to shortening, sucrose, egg, vanilla and beaten for 3 min using the mixing machine at low speed, then baked at $180C^0$ for 30 min. Baked cakes were left to cool for 1 hour at room temperature.

Analytical methods:

The quinoa flour cake were analyzed for total ash, moisture, crude fiber, crude protein and ether extract, according to **A.O.A.C. (2000)**. Total carbohydrate was determined by the difference. Total phenolic contents in cake samples were determined according to **Singleton and Rossi, (1965)**.

Farinograph and extinsograph measurements:

Farinograph measurements for fine wheat flour and various flour formulae with quinoa flour were conducted using a Brabender Farinograph (Duisburg, Germany). The following parameters were determined: water absorption capacity (WA), dough development time (DDT), dough stability (DS), mixing tolerance index (MTI) and degree of softening (DOS) after mixing dough for 12 min after reaching the optimum. Extinsograph was used to record the following measurements ;

Elasticity (BU), extensibility (mm), proportional numbe(BU/mm) and energy of dough(cm^2) according to the method described by **A.A.C.C.(2002)**.

Determination of physical parameter of cake samples:

The weight and volume of prepared cake samples were measured after 1 hour of baking according to **A.A.C.C. (2002)**. The ratio of volume to weight was also calculated to obtain the specific volume.

Determination of color of cake samples:

The crust and crumb color of cake samples were determined using Chroma meter (Konica Minolta, model CR 410, Japan) that calibrated with a white plate and light trap supplied by the manufacturer at Cairo University Research Park (CURP), Faculty of Agriculture, Cairo University. Color was expressed using the CIE L, a, and b color system **(CIE, 1976)**. Three spectral readings were taken for each sample, Lightness (L*) (dark to light), redness (a*) values (reddish to greenish) and yellowness (b*) values (yellowish to bluish) was estimated.

Sensory evaluation of cake samples:

Sensory properties of cake samples were evaluated after cooling by 10 trained panelists from stuff members of Dessert Research Centre. Appearance, taste, odor, crust color, crumb color, crumb, texture and overall acceptability of prepared cake samples were evaluated according to the method described by **A.A.C.C. (2000)**.

Statistical analysis:

Statistical analysis was performed using one way analysis of variance (ANOVA). All tests were conducted at the 5% significant level**."SPSS"** Statistics, **(1998)**, version 20.

RESULTS AND DISCUSSION

Chemical analysis of corn flour and quinoa flour:

The result of the proximate composition of the flour samples is shown in **Table (1).** The ash was 1.96%, moisture 12.53%, fiber 5.87%, protein 15.26% and fat 5.29% content of quinoa flour which were higher than that of corn flour. The Carbohydrate was found to be 59.18% in quinoa flour which was lower than that of corn flour.

Table (1): Chemical composition of corn flour and quinoa flour (g/100g).

Flour type Constituent	Corn flour	Quinoa flour
Ash(%)	0.68	1.96
Moisture(%)	10.02	12.53
Fiber(%)	3.31	5.87
Protein(%)	6.74	15.26
Fat(%)	2.45	5.29
Total Carbohydrate(%)	79.20	59.18

Chemical composition of cake

Chemical composition of prepared cake formulae supplemented by quinoa flour with different ratio 10, 20 and 30% was illustrated in **Table (2).**

Table (2): Chemical composition of prepared cake formulae fortified by quinoa flour.

Proximate analysis	Control	QF10%	QF20%	QF30%	LSD
Moisture(%)	5.7 ^{a}±0.6	5.9 ^{a}±0.8	6.4 ^{a}±0.6	7.1 ^{a}±0.8	1.33
Crude Protein(%)	10.99 ^{d}±0.17	12.81 ^{c}±0.12	13.55 ^{b}±0.14	14.62 ^{a}±0.19	0.29
Ether Extract(%)	25.56 ^{c}±0.15	27.13 ^{b}±0.12	27.28 ^{ab}±013	27.56 ^{a}±0.15	0.26
Crude Fiber(%)	6.55 ^{d}±0.12	8.79 ^{c}±0.17	10.47 ^{b}±0.14	12.26 ^{a}±0.13	0.27
Total carbohydrate(%)	49.99 ^{a}±1.1	44.12 ^{b}±0.85	40.91 ^{c}±0.69	37.01 ^{d}±0.94	1.71
Ash (%)	1.21 ^{b}±0.06	1.25 ^{ab}±0.12	1.39 ^{ab}±0.06	1.45 ^{a}±0.07	0.153
Total calories(K.cal/100g)	473.96	471.89	463.36	454.56	

(C) is control cake, (QF10) is the cake treatment with 10% quinoa flour, (QF20) is the cake treatment with 20% quinoa flour, (QF30) is the cake treatment with 30% quinoa flour. Means sharing the same letter in a row are not significantly different at ($p \leq 0.05$). *results as expressed as gl100 g dry weight basis.*

Chemical composition of moisture content was ranged from 5.7 to 7.1, protein 10.99 to 14.62, Ether Extract 25.56 to 27.56, Crude Fiber 6.55 to 12.26, Total carbohydrate 37.01 to 49.99, and Ash 1.21 to 1.45. It is evident from the results that total protein, fat, crude fiber, ash and moisture increased as the level of quinoa flour increased. This increase may be due to that quinoa flour is a rich source of protein, fats, fiber and ash.Similar results were obtainted by **(Koziol, 1992 and Alvarez-Jubete *et al*., (2009 and 2010)**. On the other hand, a slight decrease in total carbohydrates content was noticed in the same samples and reached 37.01% in flour containing 30% QF, against 49.99% of corn flour sample. These findings are in agreement with the results of **Rosell *et al*., (2010) ; Yamani and Lannes, (2012)**.

Effect of quinoa flour on farinograph parameters:

Table (3) show the Influence of prepared cake formulae by quinoa addition with different ratio 10, 20 and 30% to corn flour on Farinograph properties of dough.

Table (3): Farinograph parameters of prepared cake containing quinoa flour at different levels.

Cake Samples	Water absorption (%)	Arrival Time (min)	Dough Development time (min)	Dough stability (min)	Degree of softening (BU)
Control	64.0 ^{d}	1.0 ^{c}	1.5 ^{c}	8.0 ^{b}	80 ^{b}
Q F 10%	65.1 ^{c}	1.0 ^{c}	1.5 ^{c}	9.0 ^{a}	70 ^{c}
Q F 20%	66.0 ^{b}	2.5 ^{b}	4.5 ^{b}	9.0 ^{a}	70 ^{c}
Q F 30%	67.5 ^{a}	4.5 ^{a}	5.5 ^{a}	6.5 ^{c}	90 ^{a}

(C) is control cake, (QF10) is the cake treatment with 10% quinoa flour, (QF20) is the cake treatment with 20% quinoa flour, (QF30) is the cake treatment with 30% quinoa flour. Means sharing the same letter in a column are not significantly different at ($p \leq 0.05$).

Addition of quinoa meal mainly increased the water absorption. By increasing the sample level from 0% to 30% the highest increase in water absorption was found by the addition of 30% quinoa flour was 67.5% as compared to control samples 64.0%. The increase in the water absorption in the case of quinoa meal was marginal. Similar effects on water absorption were observed by **Abou-Zaid *et al*., (2012)** when matter was protein rich was added. **Abou-Zaid *et al*., (2011)** reported that the differences in water absorption are mainly caused by addition rich matter in fiber, protein and/or starch, which exist in the higher protein content which retain more water.

Arrival time which increased by quinoa meal ratio increasing in the formulae, it was increased from 1.0 min at 10% to 4.5 min in 30% quinoa meal formula as compared to 1.0 min in control. The extent of increase in dough development time (DDT) and dough stability were increased by quinoa meal increasing from 8.0 min at 0% quinoa meal to 9.0 min at 10 and 20% quinoa meal after that the increasing in quinoa meal cusses decreased in arrival time to 6.5 min for 30% quinoa meal, respectively.

On the other hand, results showed the weakening of dough was increased with the increasing level from 0% to 30% of quinoa meal. This increase may be due to that with quinoa meal increased, the network proteins was diluted and cussed an increase in weakening values, as reported by **Abou-Zaid *et al*., (2011)** by increasing legumes flour, the weakening value was increased.

Effect of quinoa flour on Extinsograph parameters:

Extinsograph of prepared cake formulae supplemented by quinoa flour with different ratio 10, 20 and 30% were illustrated in **Table (4).** extensograph measurments, i.e. extensibility (mm), elasticity (BU), proportional number (BU/mm) and energy of dough (cm^2).

Table (4): Extinsograph parameters of prepared cake containing quinoa flour at different levels.

Cake Samples	Elasticity (B.U)	Extensibility (mm)	Proportional number(BU/mm)	Energy (Cm^2)
Control	360	85	4.24	62
Q F 10%	310	95	3.26	48
Q F 20%	280	85	3.50	37
Q F 30%	230	80	2.71	35

(C) is control cake, (QF10) is the cake treatment with 10% quinoa flour, (QF20) is the cake treatment with 20% quinoa flour, (QF30) is the cake treatment with 30% quinoa flour. Means sharing the same letter in a column are not significantly different at ($p \leq 0.05$).

The obtained results showed that elasticity of prepared cake was ranged from 230 to 360 BU. The highest value was found in control samples and the lowest was found in formula which contained 30% QF. Elasticity was decreased as the level of QF increased . On the other hand extensibility was ranged between 80 and 95. The highest value was found in formula which contained 10% QF and the lowest was found in formula which contained 30% QF. The proportional number was ranged from 2.71 to 4.24 BU/mm. The highest value was found in control samples and the lowest was found in formula which contained 30% QF. The energy of dough cm^2 was ranged from 62 to 35 cm^2. The highest value was found in control samples and the lowest was found in formula which contained 30% QF. These results are in agreement with **Hamaker, (2001)** mentioned that, the decrease in energy and elasticity of dough affected by increasing the percentage of fiber, may be due to the reduction of gluten as the percentage. It could be concluded that the addition of QF to prepared cake improved the extinsograph. Moreover, formula contained 10% of QF was the best results.

Physical properties of cake:

Physical properties Weight (g), Volume (cm^3) and Specific volume (cm^3/g)) of prepared cake formulae supplemented by quinoa flour with different ratio 10, 20 and 30% was shown in **Table (5).**

Table (5): Physical properties of prepared cakes supplemented by quinoa flour.

Cake samples	Weight (g)	Volume (cm^3)	Specific volume(cm^3/g)
Control	43.33 ^{a} ± 1.53	82.67 ^{a} ± 4.51	1.91 ^{a} ± 0.09
Q F 10%	45.67 ^{a} ± 3.22	80.33 ^{ab} ± 5.86	1.76 ^{ab} ± 0.16
Q F 20%	46.33 ^{a} ± 1.53	75.33 ^{ab} ± 2.52	1.62 ^{b} ± 0.07
Q F 30%	47.33 ^{a} ± 1.16	71.67 ^{b} ± 3.06	1.51 ^{b} ± 0.06
LSD	3.81	7.89	0.19

(C) is control cake, (QF10) is the cake treatment with 10% quinoa flour, (QF20) is the cake treatment with 20% quinoa flour and (QF30) is the cake treatment with 30% quinoa flour. Means sharing the same letter in a column are not significantly different at ($p \leq 0.05$).

Weight of prepared cakes was ranged from 3.33 to 47.33, the higher value was found in formula which contained 30% and lowest value was found in control samples. i.e. the higher weight of cakes, the higher levels of addition quinoa flour. Volume (cm^3) was ranged from 71.67 to 82.67 and specific volume was ranged from 1.51 to 1.91(cm^3/g). Results revealed that weight of cake was increased as the level of quinoa flour increased. In contrast, both volume and specific volume were decreased as the level of quinoa flour increased. The same results are in agreement with those obtained by **El-Hadidi, (2006);Sukhcharn Singh, *et al.*, (2010) and Abou-Zaid *et al*., (2011).**

Color characteristics:

Table (6) illustrated the Mean value score of color of cake formulae fortified by quinoa flour with different ratio 10.0, 20.0 and 30.0 %. Color characteristic is a major criterion that affects the quality of the final product.

Table (6): Color characteristics of prepared cakes supplemented by quinoa flour.

Cake samples	Crust color			Crumb color		
	L*	a*	b*	L*	a*	b*
C	53.39a±0.06	16.75a±0.19	33.04c±0.16	63.37a±0.16	4.3a± .04	28.49b±0.16
QF10%	52.11b±0.49	16.48a±0.15	33.79bc±0.5	63.32a±0.29	3.89b± .1	29.23a±0.1
QF 0%	51.24b±0.19	15.75b±0.04	34.31ab±0.13	61.56b±0.08	3.83b± .04	29.37a±0.23
QF30%	51.12b±0.69	14.61c±0.19	34.99a±0.39	61.12b±0.28	3.78b±.034	29.5a ±0.23

(C) is control cake, (QF10) is the cake treatment with 10% quinoa flour, (QF20) is the cake treatment with 20% quinoa flour, (QF30) is the cake treatment with 30% quinoa flour. Means sharing the same letter in a column are not significantly different at ($p \leq 0.05$).*L*,brightness/darkness. a*,greeness/redness. b*,yellowness/blueness.*

The fortified flours blends showed a difference in color as compared to the control (100% corn flour). Color is slight improvement that was interpreted as an intense color and it was dependent on the Fortification level. That shows Hunter values of whiteness (L*), redness (a*) and Yellow (b*) measured for crust and crumb color. All fortified samples had slightly lower L* values for crust than the control. All cake incorporating by quinoa flour, had lower crust L* values than the control, indicating darker color, it was due to dietary fiber level increased and the color of quinoa meal was yellowish white. The results are in coincidence and confirmed with that obtained by **Abou-Zaid *et al*., (2012) and Pizarro *et al* ., (2013)**. Increasing the percentage of added quinoa meal to corn flour, led the values of whiteness (L*), redness (a*) and Yellow (b*), to be slightly increased in all fortified samples. Subjective evaluations confirmed that the quinoa meal cakes samples were darker, more red (a-values) than control samples. The results showed that the a-values (redness) were increased in the fortified cakes samples with the increasing of quinoa meal level from 0% to 30%. The results are consistent with that obtained by **Abou-Zaid *et al*., (2012).**

Sensory evaluation of quinoa cake:

Organoleptic evaluation of appearance, taste, odor, texture, crust color,crumb color and overall acceptability of prepared cake formulae supplemented with 10, 20 and 30 % was illustrated in **Table (7) and fig.(1).**

Table (7): sensory evaluation of prepared cake using different levels of quinoa.

Cake samples	Appearance	Taste	Odor	Texture	Crust color	Crumb color	Overall acceptability
Control	9.5±0.47	9.6±0.46	9.5±0.47	9.5±0.53	9.3±0.42	9.4±0.52	9.5±0.10
QF10%	9.3±0.67	9.5±0.53	9.3±0.48	9. 3±0.48	9.2±0.59	9.3±0.48	9.3±0.10
QF20%	9.1±0.52	9.2±0.42	9.1±0.32	9. 1±0.32	9.1±0.39	9.1±0.32	9.1±0.04
QF30%	8.7±0.54	7.8±0.95	9.0±0.00	8.4±0.84	8.8±0.63	8.5±0.97	8.5±0.42

The results showed that appearance score was ranged from 9.5 to 8.7, taste 9.6 to 7.8, odor 9.5 to 9.0, texture 9.5 to 8.4, crust color 9.3 to 8.8, crumb color 9.4 to 8.5 and overall acceptability 9.5 to 8.5, respectively. It is worthy to mention that all parameters of sensory evaluation were recorded highly score. Moreover, all prepared cake formulae were highly acceptable by the panelists and suitable for human consumption. These results are in agreement with those found by **Hassan, (2002).**

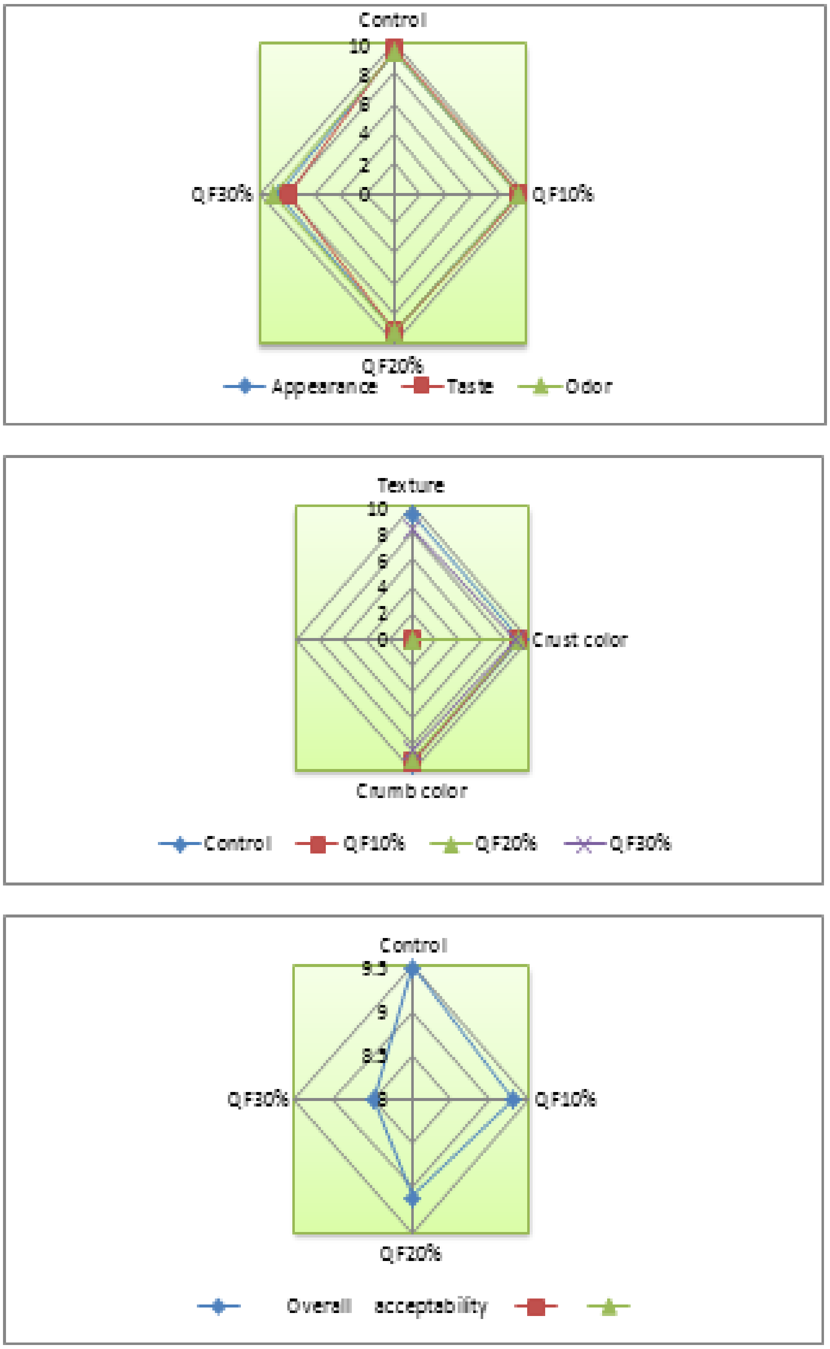

Fig. 1: sensory evaluation of prepared cake using different levels of quinoa.

Conclusion:

Quinoa flour and corn flour were successfully incorporated in gluten free cake. The usage of Quinoa flour increased the ash, protein, fat and fiber, that improve the nutritional characteristics of the product with improved functional properties. All the cakes were highly acceptable for the panelists. Generally, replacement levels of 10 and 20% of quinoa flour showed acceptable results in the sensory and physical properties in cake with a significant improvement in the nutritional qualities. These studies shown the potential of corn flour and quinoa flour for produce gluten free cake and could be useful in the manufacture of highly nutritious cakes.

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الاستفادة من دقيق الكينوا في انتاج غذاء وظيفي

محمد محمد محمد علي الدين* و سارة محمد صلاح عواد سالم**

* كلية الزراعة - جامعة المنوفية - قسم الصناعات الغذائية - شبين الكوم – مصر
** مركز بحوث الصحراء - قسم الانتاج النباتي- وحدة التصنيع الزراعي - القاهرة - مصر

يهدف البحث الي احلال مسحوق الكينوا بنسب 10، 20 ،30% محل دقيق الذرة لانتاج كيك خالي من الجلوتين. و تم تقييم القيمة الغذائية و الخواص الاكستنسوجراف والفارينوجراف للعجين . وتم تقييم التركيب الكيميائي و الطبيعي ومحتوي الكيك من البروتين، كما تم دراسة اللون في الكيك. و قد دلت النتائج المتحصل عليها :- بالنسبة للتركيب الكيميائي فقد حدثت زيادة في كل من البروتين ، الليبيدات ، الالياف و المعادن بزيادة اضافة مسحوق الكينوا مما ادي الي تحسين القيمة الغذائية في المنتج النهائي ، بالاضافة الي تحسين خواص العجين الريولوجية .و اظهرت المعاملات بانها مقبولة حسيا بدرجة عالية و اظهر التقييم الحسي و الخواص الطبيعية زيادة معنوية عند مستوي معنوية 0.05 % في القيمة الغذائية .

الكلمات الدالة: دقيق الكينوا – دقيق الذرة - كيك - التركيب الكيميائي والخواص الطبيعية - كيك خالي من الجلوتين – التقييم الحسي