Evaluation of quinoa (*Chenopodium quinoa* Willd.) flour fortification on the quality of pasta production

Mona Y. Mostafa

ABSTRACT

The aim of the present investigation was to formulate a pasta product with increased levels of protein and nutritive value by adding quinoa flour to traditional durum wheat semolina. And studying the effects of fortification on farinograph parameters, color characteristics, cooking quality, consumer acceptance, texture profile and chemical composition, and the most desirable ratio of quinoa flour is to be determined. Pasta was fortified with 10, 20 and 30% quinoa flour (QF) and evaluated against a control made of 100% semolina flour (control) for farinograph parameters, color characteristics, cooking quality, consumer acceptance, texture profile and chemical composition. Fortification pasta dough with QF at 10, 20 and 30% gradually increased water absorption, mixing tolerance index and dough weakening, meanwhile decreased the arrival time, dough development time and dough stability scores gradually comparing with those of pasta control sample. Pasta was darker and more brown in color (L* and b* values decreased while a* values increased) with the increased addition of quinoa flour. Pasta products containing quinoa flour had an increased weight and volume than control gradually by increasing QF. Cooking loss of fortified pastas was significantly (p<0.05) greater than the control, but were within the acceptable range of 7-8%. The untrained consumer panel significantly (p<0.05) preferred the control pasta over those fortified with quinoa flour. All pasta variations were deemed acceptable in sensory study. Hardness of pasta increased as the percentage of quinoa fortification increased. Quinoa flour had adverse effects on protein, fat, ash and fiber content when compared to control. It can be recommended that fortification with different percentages of quinoa flour produces high nutritional value and high protein pasta.

Keywords: Pasta, Quinoa, Farinograph, Cooking quality, Hardness.
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**INTRODUCTION**

Quinoa, or *chenopodium quinoa*, is a member of the *Amaranthaceae* plant family. Although it is a flowering plant, quinoa’s grass-like uses and qualities cause it to be considered a pseudo-cereal. Quinoa grains can be used for many things. They can be toasted, ground into flour, boiled and added to soup, or cooked and served similar to rice. Quinoa flour can be used to make pasta or breads. Unlike cereals, quinoa has a soft outer layer that does not need to be removed before milling. This allows quinoa to yield roughly 100% flour (*Fleming and Galwey*, 1995; *Jacobsen*, 2011; *James*, 2009 and *Alvez et al.*, 2010).

Studies have shown that quinoa is a good source of quality protein (10.4-17.0%), dietary fiber, polyunsaturated fats, and minerals (*FAO*, 2014). It has been found to contain between 10-21% protein, with most products averaging around 13% (*Fleming and Galwey*, 1995; *Bhargava et al.*, 2005). These fats are shown to maintain their quality due to the prevalence of vitamin E, a natural antioxidant (*Su-Chuen et al.*, 2007; *Abugoch*, 2009).

Quinoa content is rich in vitamin A, B2, E and minerals such as calcium, iron, zinc, magnesium and manganese, which give the grains high value for different target populations: for instance, adults and children benefit from calcium for bones and from iron for blood functions (*Kozioł*, 1992 and *Repo-Carrasco et al.*, 2003).

Quinoa has some functional (technological) properties like solubility, water-holding capacity (WHC), gelation, emulsifying, and foaming that allow diversified uses (*Gorinstein et al.*, 2008). Quinoa starch has physicochemical properties (such as viscosity, freeze...
stability) which give it functional properties with novel uses (James 2009). There are several developments with quinoa flour at a smaller scale, like bread, cookies, muffins, pasta, snacks, drinks, flakes, breakfast cereals, baby foods, beer, diet supplements, and extrudates (Linnemann and Dijkstra, 2002; Dogan and Karwe, 2003 and Bhargava et al., 2006). Nsimba et al. (2008) used quinoa and amaranth in products such as bread, pastas and baby foods. The seeds are small and have been used as flour, toasted, added to soups, or made into bread. Quinoa is highly nutritive and is being used to make flour, soup, breakfast and alcohol. It is sold either as whole grain that is cooked as rice or in combination dishes (Galwey, 1989).

Due to its low price, ease of preparation, stable shelf life, and overall versatility, pasta is consumed by many people worldwide. Having originated in Asia and the Mediterranean, Italy is still most well-known for its pasta making and leads in national consumer consumption per capita. The versatility of pasta allows it to be formed into almost any shape and size. It comes in varieties such as spaghetti, fettuccine, macaroni, rotini, and farfalle. It can even be stuffed with meats or cheeses to make ravioli. Pasta is prepared in two styles, fresh or dried. Fresh pasta eliminates the drying step and allows for a much quicker product to be made, but has only a portion of the shelf life of dried pasta (Marconi and Carcea 2001; International Pasta Organization 2012; Savita et al., 2013).

Pasta is a source of carbohydrates (74–77%, dry basis) with low glycaemic index (GI) (Monge et al. 1990). Pasta also contains 11–15% proteins but is deficient in lysine and threonine (the first and second limiting amino acids),
common to most cereal products (Abdel-Aal and Hucl, 2002). This provides an opportunity for the use of non-traditional raw materials to increase the nutritional quality of pasta (Del Nobile et al., 2005). Consequently, legumes and cereals are nutritionally complementary (Duranti 2006).

**Aim of work:** Therefore the present investigation was carried out to assess the pasta quality by enriching with quinoa seeds as a protein source.

**MATERIALS & METHODS**

**Materials**

Semolina (Triticum durum) was procured from the local market. Quinoa seeds (Chenopodium quinoa Willd.) were obtained from National Research Center, Giza, Egypt. The quinoa seeds were treated by washing and polishing to remove an outer coat containing bitter saponins (Dini et al., 2002). Then, seeds grinded until become soft powder.

**Methods**

**Pasta preparation:** Pasta samples were produced by hand in a homemade style. The control sample was made from 100% semolina flour (SF), while three different samples were made by replacing 10, 20 and 30% SF with quinoa flour (QF) as follow:

- **Control:** Pasta control prepared with 100% SF.
- **10% QFP:** Pasta prepared with 90% SF and 10% QF.
- **20% QFP:** Pasta prepared with 80% SF and 20% QF.
- **30% QFP:** Pasta prepared with 70% SF and 30% QF.

The dry ingredients were combined into a homogenous mixture and poured onto a clean, smooth work area. Warm water at approximately 32-49° Celsius was slowly poured into a well formed in the center of the mounded flour. The water
was incorporated by pulling flour from the inside wall using a fork. Once all the water was added and mixing with a fork became difficult, the remaining flour was blended in by hand. The crumbly dough mass was then kneaded for approximately 10 minutes, forming a smooth, elastic dough. Kneading was done by the repeated action of flattening the dough with the palm of the hand, rotating the dough, and folding over. The kneaded dough was wrapped in plastic film and set to rest at room temperature for one hour. Once rested, the dough ball was divided into two pieces for processing. Each dough piece was flattened and sent through the pasta machine (Imperia Tipo Lusso SP150, Torino, Italy) starting on the thickest setting (number 1). The dough was folded into thirds and sent through again. It was then folded in half, run through, and cut into manageable lengths. Sheets of dough were fed through the pasta machine at decreasing thicknesses (numbers 2, 3, and 4, respectively). The thin, flattened sheets were laid to dry for 10 minutes before being passed through the fettuccine cutter. The cut strands were laid on wire racks and covered with a towel to dry overnight. The dried pasta was stored in bags at room temperature until further use.

**Analytical Methods:**

**Chemical composition:** Moisture, ash, crude protein, fat and crude fiber contents were determined according to the methods outlined in *AOAC (2000).* Carbohydrates were calculated by difference as mentioned as follows: Carbohydrates = 100 − (% protein + % fat + % ash + % crude fiber).

**Rheological properties:** Rheological properties of dough were evaluated using Farinograph according to *AACC (2000).*
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**Color measurement:** Objective evaluation of color of pasta samples was measured in the National Research Center, Giza, Egypt. Hunter L*(luminosity), a*(red intensity), and b*(yellow intensity).

**Sensory evaluation:** Sensory evaluation of cooked pasta was evaluated as described by Hussein *et al.* (2006).

**Cooking quality of pasta:** Cooking quality of pasta were carried out by measuring the increases in weight, volume and cooking loss after cooking according the methods of AACC (2000).

**Texture profile analysis of Pasta:** Hardness, Deformation at hardness, Peak Stress and Fracturability with 1% of load sensitivity analysis of uncooked and cooked pasta samples was conducted using The TVT Texture Analyzer (Perten instruments) according to TVT Method 10.0 following the method described by Tang *et al.* (1999). Data was obtained, calculated, and graphed using the texture analyzer PC software program Texture Expert Exceed (Version 2.62, Texture Technologies Corp., and Scarsdale, NY) to assess the effect of quinoa flour on textural attributes.

**Statistical evaluation:** The obtained results were evaluated statistically using analysis of variance as reported by McClave & Benson (1991).

**RESULTS & DISCUSSION**

Data in Table 1 show a comparison between Chemical composition contents of semolina flour (SF) and quinoa flour (QF). SF recorded 10.81 ±0.70, 13.10 ±0.50, 3.36 ±0.07, 5.43 ±0.01, 67.29 ±1.25 and 6.31 ±0.15% for moisture, crude protein, total fats, total ash, total carbohydrates and crude fiber, respectively. Meanwhile, QF recorded 10.78 ±0.07, 13.99 ±0.14,
3.87 ±0.01, 6.08 ±0.02, 65.44 ±0.39 and 7.14 ±0.08% for the same previous parameters, respectively. It could be observed from results that QF had the higher contents of protein, fat, ash and fiber as compared to those of SF. These results were with accordance with USDA (2013) which stated that quinoa flour contained (13.28 g moisture, 368 kcal energy, 14.12 g protein, 6.07 g total lipid, 2.38 g ash, 64.16 g carbohydrate, 7.0g fiber) g per 100g. While semolina flour contained (12.67 g moisture, 360 kcal energy, 12.68 g protein, 1.05 g fat, 0.77 g ash and 72.83 g carbohydrates) g per 100g.

Quinoa flour contained 11.2% moisture, 13.5% crude protein, 6.3% ether extract, 9.5% crude fibre, 1.2% total ash and 58.3% carbohydrate (Ogunbnewle, 2003). The protein content of quinoa is higher than in cereals and ranges from 14 to 18 % of the seed, as compared to maize (10%), rice (8%) and wheat (14%) (Koziol, 1992).

Farinograph parameters of four different pasta dough formulas (semolina flour, semolina flour with 10, 20 and 30% quinoa flour) were represented in Table 2. These pasta formulas regarding were evaluated for water absorption, arrival time, dough development time, dough stability, mixing tolerance index and dough weakening. Data show that fortification pasta dough with QF at 10, 20 and 30% caused a gradually increasing in mixing tolerance index and dough weakening comparing to pasta control. Meanwhile, the arrival time, dough development time and dough stability values were decreased gradually by the increasing of quinoa flour in pasta dough. 20 and 30% QF increased water absorption compared to control pasta.

Svec et al. (2011) investigated dough rheological properties and bread quality from
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wheat/quinoa composite flour made at rates from 0 to 30% supplements. Quinoa wholemeal incorporation in wheat flour did not influenced water absorption, but dough stability decreased dependently to basic flour quality and quinoa additions similarly to Jancurová et al. (2009). During dough kneading, up to 33% shorter development time and 50% dough stability with twofold breakdown were recorded for Q30. Contrary to that, Jancurová et al. (2009) described independence of development time on quinoa level and also dough stability prolongation.

Color characteristics were measured in pasta samples at four stages (the flour mixture before processing, pasta after processing before drying, dried pasta and pasta after cooking) and the obtained data were tabulated in Table 3.

Generally, the fortification of pasta with quinoa flour caused a significant decreasing (p<0.05) in brightness (*L*\(^*\) value) at all previous stages of pasta processing comparing with the control pasta which was significantly lighter than other samples. This decrease in brightness of pastas containing legume flours is in accordance with many researchers who have experimented with legumes such as chickpea, green pea, yellow pea, split pea, faba bean, soy, and lentil, as well as pseudo-cereals like quinoa (Lorenz et al., 1993, Ugarcic-Hardi et al., 2003, Zhao et al., 2005, Wood 2009, Petitot et al., 2010b). Ugarcic-Hardi et al. (2003) attributed the decrease in brightness to a higher ash content in legume flours. It is known that consumers prefer bright yellow translucent bright yellow translucent pasta products, but the limit of acceptable brightness is undefined.

Similar to lightness decreasing, redness increased (*a*\(^*\) value increased) as more
quinoa flour was added. It can be concluded that the amount of quinoa flour added to pasta significantly affects redness of the product. The control pasta was found to be the most yellow (highest $b^*$ value), with yellowness significantly ($p<0.05$) decreasing as more quinoa flour was added. This is in accordance with other researchers who have seen a decrease in yellowness of pastas containing chickpea, green pea, yellow pea, lentil, and quinoa flours (Lorenz et al., 1993, Zhao et al., 2005, Wood 2009). This decrease in yellowness may be due to the leaching and/or degradation of color pigments, such as carotenoids and xanthophyll (Wood, 2009).

Similar results were found by Petitot et al., (2010b) where pasta fortified with faba bean flour saw a significant increase in redness. Petitot et al., (2010b) also noted that yellowness ($b^*$ values) was not affected in this change. This is important to note because according to Ugarcic-Hardi et al., (2003), bright yellow pasta is achieved by having both high $b^*$ values and low $a^*$ values.

The effect of quinoa flour (QF) fortification of pasta weight increase, volume increase and cooking loss percentage were studied and the obtained data was tabulated in Table 4. A significant increase ($p<0.05$) were observed in weight and volume increase values gradually by increasing QF percentage in pasta. Weight increase percentage recorded 235±3.00, 255±4.32 and 275±5.33% for pasta with 10, 20 and 30% QF, respectively. On the other hand, while volume increase percentage recorded 180±3.20, 195±5.60 and 210±3.55 for pasta with 10, 20 and 30% QF, respectively, meanwhile control pasta made with 100% SF recorded 220±2.80 and 165±4.42 for weight and volume increase percentage,
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respectively. Cooking loss was significantly (p<0.05) affected by the addition of QF. The control pasta made with 100% SF recorded significant (p<0.05) less cooking loss (3.5±0.14) comparing with pasta containing QF. It could be noticed that the cooking loss values increase gradually by the increasing of QF percentage as recorded 5.00±0.21, 6.5±0.28 and 7.5±0.42 for pasta samples with 10, 20 and 30% QF. This is in accordance with Bahnassey and Khan (1986) and Lorenz et al. (1993), who found that cooking loss increased as the level of fortification increased. Fortifying pasta with legume flours (pea, lupin, chickpea, lentil, split pea, or faba bean) increases cooking loss (Nielson et al., 1980, Rayas-Duarte et al., 1996, Zhao et al., 2005 and Petitot et al., 2010b). Also, Lorenz et al. (1993) also found that adding quinoa flour to pasta resulted in a higher cooking loss than the control made from wheat flour. Duszkiewicz et al. (1988) observed higher water absorption and cooking loss in spaghetti blended with legume flour and concentrates. Legume supplementation of pasta resulted in greater cooking loss when compared to control (Bahnassey and Khan, 1986)

The addition of quinoa flour was significantly (p<0.05) affected consumer acceptance of the pasta products. The average scores given by panelists in color, flavor, mouthfeel, elasticity and overall acceptability can be seen in Table 5. The control pasta was significantly (p<0.05) more liked than pastas containing quinoa flour. The least favored pasta was 30% quinoa flour pasta. This may be due to the poor textural properties of the samples. Of the fortified pastas, 10% quinoa flour pasta was found to be the most favored.

These results are in accordance with other
Researchers who found that pasta made from 100% semolina flour received the highest overall acceptability when compared to pastas supplemented with legume and pseudo-cereal flours (Bahnassey and Khan 1986, Zhao et al., 2005; Mastromatteo et al., 2011). Quinoa has been incorporated into wheat noodles (Lorenz et al., 1993). No statistically significant difference was found between noodles made with 10% and 30% quinoa. Noodles with 50% quinoa content were ranked least acceptable. Quinoa flour was extruded with corn grits to produce expanded snack products. Addition of quinoa produced a darker, less yellow extruded product. The products were rated as moderately acceptable (Coulter & Lorenz, 1991a, 1991b; Lorenz et al., 1995).

Texture profile of dried and cooked pasta was represented in Table 6. Hardness of the pastas was affected by the fortification of pasta with quinoa flour. Hardness is the height of the force peak of the first compression cycle (Bourne 2002). In this study, it is the maximum force required to compress the dried pasta samples recorded 17.55, 32.30, 34.32 and 48.32N for control sample, 10, 20 and 30% quinoa flour pasta, respectively. Meanwhile, the maximum force required to compress the cooked pasta samples recorded 3.02, 3.47, 3.86 and 4.09 for control sample, 10, 20 and 30% quinoa flour pasta, respectively.

The control pasta (dried or cooked) was found to be less hard than the fortified pasta products. Pasta formula fortified with 30% quinoa flour was harder than pastas with 10 and 20% quinoa flours. The addition of quinoa flour has a greater effect on cooked and dried pasta hardness. These results are similar to those found by Petitot et al., (2010b) where pasta fortified with 35%...
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legume flours (split pea or faba bean) significantly increased the hardness of pasta, which they attributed to increased protein content and decreased water uptake. In 1993, Lorenz et al. experimented with adding 10, 30, and 50% quinoa flour to wheat pasta. The addition of quinoa required more water for mixing, made the pasta darker in color, and increased cooking loss. Pasta made with 50% quinoa flour was shown to be poor in flavor and texture and was deemed unacceptable (Lorenz et al., 1993).

Data in Table 7 show the effect of substitution of 10, 20 and 30% of semolina flour (SF) by quinoa flour (QF) on the chemical composition of processed pasta comparing with the control sample. Results show that the fortification pasta with QF increased significantly (p<0.05) the protein, fat, ash and fiber contents of pasta comparing with control pasta sample. On the other hand, the addition of QF caused a significant decreasing (p<0.05) in moisture and carbohydrates contents of processed pasta. These results due to the higher contents of protein, fat and ash of quinoa flour comparing with semolina flour. In quinoa flour pasta (QFP), protein contents recorded 10.07±0.07, 11.19±0.22 and 12.36±0.01%, while fat contents recorded 1.71±0.07, 2.23±0.07 and 2.80±0.10% for 10, 20 and 30% QFP, respectively comparing with semolina flour pasta which recorded 9.13±0.07 and 1.19±0.03% for protein and fat, respectively.

It could be noticed that the pasta sample with 30% QF caused an obvious increasing in protein, ash, fat and fiber contents comparing with other pasta samples. The results agreed with other research workers, Gurpreet et al. (2011); Young-Soo-Kim (1998); Osorio et al. (2008); Bahnassey and
Khan (1986) who reported the incorporation of plant proteins flour increased the protein, fibre and ash contents of the final products.

CONCLUSION

The pasta product with the most beneficial ratio of quinoa flour is that containing 30% quinoa flour. It had the highest protein, fat, ash and fiber contents. Pasta samples cooking loss was found to be in an acceptable range, and besides the texture attributes were not adversely affected by fortification. The color characteristics of pasta 10% QF were also nearly to that of the control, leading to a high level of visual acceptability.

REFERENCES

AACC (2000):

AOAC (2000):

Abdel-Aal ESM and Hucl P (2002):

Abugoch LE (2009):
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Del Nobile M A; Baiano A; Conte A and Mocci G (2005):

Dick JW and Youngs VL (1988):

Dini I; Tenore GC and Dini, A (2002):

Dogan H and Karwe M (2003):

Duranti M (2006):


FAO STAT (2014):
Evaluation of quinoa (*Chenopodium quinoa* Willd.) flour fortification on the quality of pasta production

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**Fleming FE and Galwey NW (1995):**


**Galwey NW (1989):**


**Gorinstein S; Lojek A; Ciż M; Pawelzik E; Delgado-Licon E; Medina O; Moreno M; Salas I and Goshev I (2008):**


**Gurpreet Kour; Savita Sharma S and Nagi HPS (2011):**

Enrichment of pasta with different plant proteins.

**Hussein AMS; Mustafa BE and Moharrum HA(2006):**


**International Pasta Organization [Internet] Oct (2012):**


**Jacobsen SE (2011):**

The Situation for quinoa and its production in Southern Bolivia: from Economic Success to environmental Disaster. *Journal of Agronomy and Crop Science,*
Evaluation of quinoa (*Chenopodium quinoa* Willd.) flour fortification on the quality of pasta production

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**James L E A (2009):**  

**Jancurová M; Minaroviová L and Dandár A (2009):**  

**Koziol MJ (1992):**  
Chemical composition and nutritional evaluation of quinoa (*Chenopodium quinoa* Willd.). *Journal of Food Composition and Analyses, 5*:35-68.

**Linnemann A and Dijkstra D (2002):**  

**Lorenz K; Gifford H and Johnson, D L (1993):**  
Quinoa in pasta products. *Developments in Food Science, 37*: 1031–1041.

**Lorenz K; Coulter L and Johnson D (1995):**  
Functional and sensory characteristics of quinoa in foods. *Developments in Food Science, 37*:1031–1041.

**Marconi E and Carcea M (2001):**  

**Mastromatteo M; Chillo S; Iannetti M; Civica V and Del Nobile MA (2011):**
Evaluation of quinoa (Chenopodium quinoa Willd.) flour fortification on the quality of pasta production

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Osorio DP; Acevedo AE and Vinalay MM (2008): Pasta added with chickpea flour: Chemical composition, In vitro starch digestibility and
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predicted glycemic index.

Petitot M; Boyer L; Minier C and Micard V (2010b):
Fortification of pasta with split pea and faba bean flours: pasta processing and quality evaluation. *Food Res Int.*, **43**:634-641.

Rayas-Duarte P; Mock CM and Satterlee LD (1996):

Repo-Carrasco R; Espinoza C and Jacobsen SE (2003):
Nutritional value and use of the Andean crops quinoa (*Chenopodium quinoa*) and kañiwa (*Chenopodium pallidicaule*). *Food Rev Int.*, **19**:179–189.

Savita S; Arshwinder K; Gurkirat K and Vikas N (2013):

Su-Chuen N; Anderson A; Coker J and Ondrus M (2007):

Svec M; Hrušková T; Hofmanová M and Vítová (2011):
Evaluation of quinoa (*Chenopodium quinoa* Willd.) flour fortification on the quality of pasta production

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Tang C; Hsieh F; Heymann H and Huff HE (1999):

Ugarcic-Hardi Z; Hackenberger D; Subaric D and Hardi J (2003):

USDA (United States Department of Agriculture) (2013):

Wood JA (2009):

Young-Soo- Kim (1998):

Zhao YH; Manthey FA; Chang SK; Hou H and Yuan SH (2005):
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Table (1): Chemical composition of raw materials:

<table>
<thead>
<tr>
<th>Samples</th>
<th>Parameters</th>
<th>Moisture %</th>
<th>Protein %</th>
<th>T. fat %</th>
<th>T. ash %</th>
<th>Carbohydrates %</th>
<th>Fiber %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semolina flour</td>
<td></td>
<td>10.81±0.70</td>
<td>13.10±0.50</td>
<td>3.36±0.07</td>
<td>5.43±0.01</td>
<td>67.29±1.25</td>
<td>6.31±0.15</td>
</tr>
<tr>
<td>Quinoa flour</td>
<td></td>
<td>10.78±0.07</td>
<td>13.99±0.14</td>
<td>3.87±0.01</td>
<td>6.08±0.02</td>
<td>65.44±0.39</td>
<td>7.14±0.08</td>
</tr>
</tbody>
</table>

Table (2): Effect of quinoa flour fortification on farinograph parameters of pasta dough

<table>
<thead>
<tr>
<th>Samples</th>
<th>Water absorption (%)</th>
<th>Arrival time (min)</th>
<th>Dough development time (min)</th>
<th>Dough stability (min)</th>
<th>Mixing tolerance index (BU)</th>
<th>Dough weakening (BU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>57.5</td>
<td>7.0</td>
<td>11.0</td>
<td>11</td>
<td>20</td>
<td>60</td>
</tr>
<tr>
<td>10% QFP</td>
<td>57.5</td>
<td>4.5</td>
<td>8.0</td>
<td>10.0</td>
<td>25</td>
<td>70</td>
</tr>
<tr>
<td>20% QFP</td>
<td>60.5</td>
<td>5.5</td>
<td>7.5</td>
<td>9.0</td>
<td>35</td>
<td>80</td>
</tr>
<tr>
<td>30% QFP</td>
<td>62.5</td>
<td>5.0</td>
<td>7.0</td>
<td>7.5</td>
<td>60</td>
<td>100</td>
</tr>
</tbody>
</table>

*QFP: Quinoa flour pasta*
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Table (3): Effect of quinoa flour fortification on color characteristics of pasta

<table>
<thead>
<tr>
<th>Samples</th>
<th>L*</th>
<th>a*</th>
<th>b*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>85.40±0.21a</td>
<td>2.25±0.03a</td>
<td>20.85±0.10a</td>
</tr>
<tr>
<td>10% quinoa flour pasta</td>
<td>83.81±0.11b</td>
<td>1.95±0.05b</td>
<td>19.15±0.07b</td>
</tr>
<tr>
<td>20% quinoa flour pasta</td>
<td>82.47±0.07b</td>
<td>1.70±0.03c</td>
<td>17.88±0.09c</td>
</tr>
<tr>
<td>30% quinoa flour pasta</td>
<td>81.55±0.04c</td>
<td>1.41±0.04d</td>
<td>16.80±0.09d</td>
</tr>
<tr>
<td>LSD at 0.05</td>
<td>2.150</td>
<td>0.244</td>
<td>0.522</td>
</tr>
</tbody>
</table>

Color parameters of Processed pasta before drying

<table>
<thead>
<tr>
<th>Samples</th>
<th>L*</th>
<th>a*</th>
<th>b*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>77.61±0.28a</td>
<td>1.89±0.035c</td>
<td>20.05±0.05b</td>
</tr>
<tr>
<td>10% QFP</td>
<td>73.22±0.45b</td>
<td>1.80±0.02c</td>
<td>19.26±0.02c</td>
</tr>
<tr>
<td>20% QFP</td>
<td>62.49±0.09c</td>
<td>2.43±0.06b</td>
<td>20.83±0.07a</td>
</tr>
<tr>
<td>30% QFP</td>
<td>62.02±0.07c</td>
<td>2.57±0.07a</td>
<td>21.35±0.07a</td>
</tr>
<tr>
<td>LSD at 0.05</td>
<td>0.775</td>
<td>0.274</td>
<td>0.547</td>
</tr>
</tbody>
</table>

Color parameters of Processed pasta after drying

<table>
<thead>
<tr>
<th>Samples</th>
<th>L*</th>
<th>a*</th>
<th>b*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>77.01±0.381a</td>
<td>2.16±0.07c</td>
<td>19.55±0.14c</td>
</tr>
<tr>
<td>10% QFP</td>
<td>70.11±0.139b</td>
<td>3.07±0.120b</td>
<td>22.97±0.56b</td>
</tr>
<tr>
<td>20% QFP</td>
<td>66.15±0.302c</td>
<td>3.42±0.124a</td>
<td>23.57±0.03b</td>
</tr>
<tr>
<td>30% QFP</td>
<td>63.55±1.53d</td>
<td>3.45±0.07a</td>
<td>24.09±0.07a</td>
</tr>
<tr>
<td>LSD at 0.05</td>
<td>2.071</td>
<td>0.290</td>
<td>1.107</td>
</tr>
</tbody>
</table>

Color parameters of Cooked pasta

<table>
<thead>
<tr>
<th>Samples</th>
<th>L*</th>
<th>a*</th>
<th>b*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>71.17±0.55a</td>
<td>0.66±0.01d</td>
<td>17.19±0.07c</td>
</tr>
<tr>
<td>10% QFP</td>
<td>62.17±0.23b</td>
<td>1.62±0.02c</td>
<td>18.40±0.07a</td>
</tr>
<tr>
<td>20% QFP</td>
<td>59.38±0.35c</td>
<td>2.31±0.02b</td>
<td>17.66±0.05b</td>
</tr>
<tr>
<td>30% QFP</td>
<td>53.67±0.32d</td>
<td>2.53±0.04a</td>
<td>17.16±0.07c</td>
</tr>
<tr>
<td>LSD at 0.05</td>
<td>2.574</td>
<td>0.192</td>
<td>0.421</td>
</tr>
</tbody>
</table>

QFP: Quinoa flour pasta, L*: luminosity, a*: red intensity, and b*: yellow intensity
Evaluation of quinoa (Chenopodium quinoa Willd.) flour fortification on the quality of pasta production

Mona Y. Mostafa

Table (4): Effect of quinoa flour fortification on cooking quality of pasta

<table>
<thead>
<tr>
<th>Samples</th>
<th>Weight increase (%)</th>
<th>Volume increase (%)</th>
<th>Cooking loss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>220±2.82d</td>
<td>165±4.42d</td>
<td>3.5±0.14d</td>
</tr>
<tr>
<td>10% QFP</td>
<td>235±3.00c</td>
<td>180±3.20c</td>
<td>5.00±0.21c</td>
</tr>
<tr>
<td>20% QFP</td>
<td>255±4.32b</td>
<td>195±5.60b</td>
<td>6.5±0.28b</td>
</tr>
<tr>
<td>30% QFP</td>
<td>275±5.33a</td>
<td>210±3.55a</td>
<td>7.5±0.42a</td>
</tr>
<tr>
<td>LSD at 0.05</td>
<td>12.801</td>
<td>12.453</td>
<td>0.791</td>
</tr>
</tbody>
</table>

QFP: Quinoa flour pasta

Table (5): Effect of quinoa flour fortification on organolyptic characteristics of pasta

<table>
<thead>
<tr>
<th>Samples</th>
<th>Color (10)</th>
<th>Flavor (10)</th>
<th>Mouthfeel (10)</th>
<th>Elasticity (10)</th>
<th>Overall acceptability (10)</th>
<th>Total (50)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>9.75 ± 0.35a</td>
<td>9.83 ± 0.28a</td>
<td>9.70 ± 0.23a</td>
<td>9.81 ± 0.25 a</td>
<td>9.55 ± 0.52 a</td>
<td>47.81 ± 1.02 a</td>
</tr>
<tr>
<td>10% QFP</td>
<td>8.9 ± 0.42a</td>
<td>9.33 ± 0.57a</td>
<td>9.01 ± 0.42a</td>
<td>8.50 ± 0.35b</td>
<td>8.95 ± 0.46 a</td>
<td>44.18 ± 1.25b</td>
</tr>
<tr>
<td>20% QFP</td>
<td>7.65 ± 0.35b</td>
<td>9.11 ± 0.28a</td>
<td>8.10 ± 0.35b</td>
<td>7.13 ± 0.41c</td>
<td>7.13 ± 0.37b</td>
<td>42.25 ± 0.88c</td>
</tr>
<tr>
<td>30% QFP</td>
<td>7.20 ± 1.41b</td>
<td>8.26 ± 0.64b</td>
<td>6.70 ± 0.32c</td>
<td>6.50 ± 0.62d</td>
<td>6.04 ± 0.35c</td>
<td>38.66 ± 1.52d</td>
</tr>
<tr>
<td>LSD at 0.05</td>
<td>0.9311</td>
<td>0.8996</td>
<td>0.9211</td>
<td>0.9621</td>
<td>0.8621</td>
<td>2.207</td>
</tr>
</tbody>
</table>

QFP: Quinoa flour pasta
Table (6): Effect of quinoa flour fortification on texture profile of dried and cooked pasta

<table>
<thead>
<tr>
<th>Samples</th>
<th>Hardness (N)</th>
<th>Deformation at hardness (mm)</th>
<th>Hardness work (mJ)</th>
<th>Peak Stress Dyn/cm²</th>
<th>Fracturability with 1% of load sensetivity (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Control</strong></td>
<td>17.55</td>
<td>0.23</td>
<td>0.80</td>
<td>55904152</td>
<td>17.55</td>
</tr>
<tr>
<td><strong>10% QFP</strong></td>
<td>32.30</td>
<td>2.15</td>
<td>3.20</td>
<td>102876128</td>
<td>1.93</td>
</tr>
<tr>
<td><strong>20% QFP</strong></td>
<td>34.32</td>
<td>1.87</td>
<td>4.70</td>
<td>109309792</td>
<td>1.13</td>
</tr>
<tr>
<td><strong>30% QFP</strong></td>
<td>48.32</td>
<td>0.49</td>
<td>3.00</td>
<td>153876960</td>
<td>48.32</td>
</tr>
</tbody>
</table>

**Cooked pasta**

<table>
<thead>
<tr>
<th>Samples</th>
<th>Hardness (N)</th>
<th>Deformation at hardness (mm)</th>
<th>Hardness work (mJ)</th>
<th>Peak Stress Dyn/cm²</th>
<th>Fracturability with 1% of load sensetivity (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Control</strong></td>
<td>3.02</td>
<td>1.61</td>
<td>3.40</td>
<td>9619262</td>
<td>3.02</td>
</tr>
<tr>
<td><strong>10% QFP</strong></td>
<td>3.47</td>
<td>1.62</td>
<td>1.10</td>
<td>11055905</td>
<td>3.47</td>
</tr>
<tr>
<td><strong>20% QFP</strong></td>
<td>3.86</td>
<td>1.98</td>
<td>1.30</td>
<td>12305160</td>
<td>0.07</td>
</tr>
<tr>
<td><strong>30% QFP</strong></td>
<td>4.09</td>
<td>1.73</td>
<td>1.30</td>
<td>13023481</td>
<td>4.09</td>
</tr>
</tbody>
</table>

*QFP: Quinoa flour pasta  Hardness = The maximum force of the 1st compression*
Evaluation of quinoa (*Chenopodium quinoa* Willd.) flour fortification on the quality of pasta production

Mona Y. Mostafa

Table (7): Effect of quinoa flour fortification on chemical composition of pasta

<table>
<thead>
<tr>
<th>Samples</th>
<th>Moisture %</th>
<th>C. protein %</th>
<th>T.fat %</th>
<th>T.ash %</th>
<th>T. carbohydrates %</th>
<th>C. fiber %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>12.81±0.19a</td>
<td>9.13±0.07d</td>
<td>1.19±0.03d</td>
<td>2.97±0.12d</td>
<td>73.88±0.35a</td>
<td>2.04±0.01d</td>
</tr>
<tr>
<td>10% QFP</td>
<td>12.43±0.03b</td>
<td>10.07±0.07c</td>
<td>1.71±0.07c</td>
<td>3.54±0.09c</td>
<td>72.23±0.29b</td>
<td>3.10±0.02c</td>
</tr>
<tr>
<td>20% QFP</td>
<td>12.06±0.3c</td>
<td>11.19±0.22b</td>
<td>2.23±0.07b</td>
<td>4.13±0.01b</td>
<td>70.36±0.33c</td>
<td>4.17±0.07b</td>
</tr>
<tr>
<td>30% QFP</td>
<td>11.47±0.02d</td>
<td>12.36±0.01a</td>
<td>2.80±0.10a</td>
<td>4.78±0.05a</td>
<td>68.57±0.14d</td>
<td>5.27±0.08a</td>
</tr>
</tbody>
</table>

*QFP: Quinoa flour pasta*
Evaluation of quinoa (*Chenopodium quinoa* Willd.) flour fortification on the quality of pasta production

Mona Y. Mostafa

**Abstract**

The study aimed to assess the effect of different levels of quinoa flour fortification on the quality of pasta production. The study was carried out by fortifying pasta flour with 10, 20, and 30% quinoa flour, then comparing it with control (100% durum wheat flour pasta) in terms of farinograph properties, color characteristics, cooking quality, consumer acceptance, and sensory analysis. The results showed that fortification of pasta flour with quinoa flour led to a gradual increase in water absorption capacity of the dough and weak gluten, while the addition of quinoa flour led to a gradual decrease in gluten stability compared to the control. Fortification of pasta flour also led to an increase in darkening of its color compared to durum wheat flour pasta gradually with increasing fortification level. Furthermore, the study investigated the effect of adding quinoa flour on the cooking quality, observing an increase in weight and size with an increase in cooking loss as the fortification increased compared to the control, but within acceptable limits. All samples of fortified pasta flour were generally accepted by the sensory panel. Additionally, it was observed that the hardness, protein content, fat content, ash, and fiber content of quinoa flour increased gradually with increasing fortification level compared to the control. The study recommends the production of high-quality pasta fortified with different levels of quinoa flour.

**Keywords:** Pasta – Quinoa – Farinograph – Cooking quality – Sensory analysis.