J Food Sci Technol (October 2020) 57(10):3884–3892
https://doi.org/10.1007/s13197-020-04420-7

ORIGINAL ARTICLE

Changes in chemical and anti-nutritional properties of pasta enriched with raw and germinated quinoa (*Chenopodium quinoa* Willd.) flours

Berat Demir[1] · **Nermin Bilgiçli**[2]

Revised: 11 January 2020 / Accepted: 3 April 2020 / Published online: 11 April 2020

Abstract In this study, quinoa seeds were processed to flour in ungerminated (raw) and germinated forms. Raw quinoa flour (RQF) and germinated quinoa flour (GQF) were replaced (0, 10, 20 and 30%) with wheat semolina in pasta formulation to improve nutritional and functional properties of pasta. Some chemical (ash, crude fat, crude protein, total phenolic content (TPC), antioxidant activity (AA) and mineral matter), anti-nutritional (phytic acid), physical and sensory properties of pasta samples were determined. With germination of quinoa seed, ash, protein, TPC and AA amount of GQF increased by 51%, 37%, 111%, 123% and 17%, respectively, while phytic acid amount decreased by 77%, in comparison to RQF. As the RQF or GQF ratio increased in pasta formulation, ash, crude protein, TPC, AA and mineral matter amounts significantly ($p < 0.05$) increased. Such parameters linearly increased with the elevated ratio of quinoa flour. Compared to RQF, GQF at high utilization ratios displayed higher negative effects on cooking quality of pasta, but it showed great performance on increasing nutritional and functional properties.

Keywords Germination · Pasta · Phenolic · Phytic acid · Quinoa

✉ Nermin Bilgiçli
nerminbil2003@hotmail.com

[1] Bahri Dağdaş International Agricultural Research Institue, Karatay, Konya, Turkey

[2] Department of Food Engineering, Engineering and Architecture Faculty, Necmettin Erbakan University, Köyceğiz Campus, Konya 42050, Turkey

Introduction

Quinoa (*Chenopodium quinoa* Willd), a cereal-like and stress-tolerant food crop, has been cultivated in South America for 5000 years. Quinoa (pseudocereal) seed is an important source of fiber and protein. Therefore, the food researchers have shown particular interest in this pseudocereal for the last few years due to its great potential as gluten-free component. Besides its nutritional advantages, the quinoa plant has a rich genetic diversity and highly resilient to agro-ecological extremes (Repo-Carrasco-Valencia et al. 2010). A lot of studies have been conducted on utilization of quinoa in human and animal nutrition, recently. It has become a very popular raw material in the diet of vegan/vegetarian and individuals with allergic risks caused by cereals (Paśko et al. 2009). Quinoa seeds contain vitamins E (tocopherols), C and B complex, and minerals such as Ca, K, Mg, Fe, Mn, P, high-quality lipids and isoflavones. It is also known that quinoa has some anti-nutritional factors, especially saponins and phytic acid. Saponins have a strongly bitter taste, surface active compounds with a structure consisting of a triterpenoid aglycone or steroid and one or more sugar chains, which are present in quinoa seeds at significant levels. Saponin levels in different quinoa varieties range between 0.01% and 4.65% and average 0.65% (Koziol 1992). Phytic acid is found especially in cereals, legumes, nuts and oilseeds. It has ability to bind minerals, proteins and starch. Thus, the phytic acid reduces absorption, digestion, solubility and functionality of these components (Oatway et al. 2001). Due to precious nutritional and functional advantages of quinoa, the year 2013 was announced as the 'Year of Quinoa' by the FAO (Food and Agriculture Organization).

In recent years, consumption of germinated/sprouted seeds has been preferred by individuals who want to

change their eating habits and want to live healthier. The germinated seeds can be shown among the best examples of functional foods used to reduce the risk factors of many diseases and improve human health (Paśko et al. 2009). With the germination process, especially vitamins, amino acids, phenolic compounds and minerals increase while the amount of some anti-nutritional factors such as oligosaccharides, phytic acid, cyanogenic glycosides and trypsin inhibitors decrease. Among industrial foods, pasta is widely consumed because of its ease of preparation, transporting, cooking and storage. In addition to adults, especially children love to consume pasta. There are many experimental studies on improvement nutritional and functional properties of pasta (Herken 2005; Torres et al. 2007; Ha and Park 2011; Lorusso et al. 2017). Surprisingly, literature knowledge on the use of GQF in pasta is insufficient. Soel and Sim (2017) conducted a study on quality characteristic of noodles with added germinated black quinoa powder. Therefore, the prime aims of this study were (1) to increase some nutrient elements and reduce phytic acid by germination of quinoa, (2) to enrich the pasta in terms of functional and nutritional properties with acceptable textural and sensory properties by different ratios of RQF and GQF addition.

Materials and methods

Materials

Wheat semolina was obtained from Selva Gıda San. A.Ş., Konya, Turkey and quinoa seeds were purchased from Yayla Agro Bakliyat A.Ş., Mersin, Turkey. Untreated quinoa seeds, obtained after the harvest were washed with water at room temperature to remove the dust, dirt and foreign material. This stage continued until the bubble from the saponin was removed and clear washing water was obtained. Washed seeds were kept in 2.5% Sodium hypochlorite (NaClO) solution for 10 min for disinfection and drained. Raw quinoa flour (RQF) was obtained after drying and milling of seeds described as below.

Germination of seed

To prepare germinated quinoa flour (GQF), quinoa seed was washed, disinfected and drained as above. Seeds to be germinated were soaked in water for 3 h. The soaked seeds were laid on sterile cotton and gauze on the wire grids and allowed to germinate in the controlled cabinet at 20 ± 2 °C at 80–90% relative humidity. The seeds were watered every 12 h with sterile distilled water to avoid microbial contamination and maintain the moisture content. Germinating stage was finished after 2 days. Germinated seeds or raw seeds were dried in an oven in 45 °C and milled (< 500 μm) on a laboratory grinder into whole grain flour with 100% extraction ratio.

Preparation of pasta samples

To prepare control pasta 100% wheat semolina was used. RQF and GQF were replaced with semolina at 0, 10, 20 and 30% (w/w) ratio for preparation of other pasta formulations. Control pasta sample was prepared using nearly 100:30 semolina:water ratio (1000 g semolina + 300 ml water) and amount of water used for pasta formulation with 10–30% RQF and 10–30% GQF was 330–355 ml and 340–365 ml, respectively. Pasta production was made according to the method specified in Brennan and Tudorica (2008). Pasta samples were prepared using a pilot scale pasta-producing machine (Dolly, La Monferrina, Moncalieri, Italy). Components were mixed in the kneading section of the pilot pasta unit (approximately 15 min) until the desired water hydration is achieved and penne die (short cut) was preferred for the shape of pasta samples. Pilot-scale dryer (EC25, La Monferrina, Moncalieri, Italy) was used for drying the samples. Drying was performed up to 10% moisture content at 8 h 50 min at 58 °C maximum. Samples were stored at room temperature in polyethylene package until laboratory analyses were performed.

Chemical analyses

Ash, crude protein and crude fat content were determined in raw materials (semolina, RQF and GQF) and pasta samples by AACC methods 08-01, 46-12 and 30-25, respectively (AACC 1990). The amount of phytic acid in raw materials and pasta samples was determined as colorimetrically according to the method specified by Haug and Lantzsch (1983). The phytic acid in the samples was extracted with HCl and precipitated by Iron III solution and the Iron amount in serum was determined by the spectrophotometric method. Ca, Fe, K, Mg, P and Zn elements were determined by ICP-AES (inductively coupled plasma atomic emission spectrometer) (Varian, Vista Model, Zug, Switzerland) (Skujins 1998). The total phenolic content (TPC) of the samples were determined using the Folin Ciocalteau reagent using the colorimetric method. The samples were rinsed in the agitated water bath for 2 h (24 ± 1 °C) in 40 ml solution (methanol/0.16 M HCL/water, 8:1:1, v/v) and centrifuged for 10 min in 3000 rpm. Then, the extracts were treated with 40 ml of 70% acetone for 2 h and added to the initial filtered part (Paśko et al. 2009). 0.1 ml supernatant, 0.5 ml Folin-Ciocaltaeu reagent (10%, v/v, water) and 1.5 ml Na_2CO_3 solution (20%, w/v, water) incubated at room temperature (24 ± 1 °C) for 2 h. After incubation, the absorbance values of the samples

were read on the spectrophotometer (Hitachi-U1800, Japan) at a wavelength of 725 nm and the total amount of phenolic was calculated in terms of gallic acid equivalents (Slinkard and Singelton 1977; Gamez-Meza et al. 1999). Antioxidant activity (AA) of raw materials and pasta samples was determined according to DPPH (2-2-diphenyl-2-picrylhydrazyl) method (Gyamfi et al. 1999; Beta et al. 2005). The DPPH method is based on the eliminating of DPPH by the antioxidant substances found in the sample. Extraction was carried out in accordance with the procedure specified in TPC. The obtained absorbance values were measured at 514 Nm in a spectrophotometer and the analysis results were evaluated according to the formula below:

$$\text{Inhibition } \% = \left[\left(\text{Abs}_{\text{control}} - \text{Abs}_{\text{sample}}\right)/\text{Abs}_{\text{control}}\right] \times 100.$$

Physical analyses

Color values of pasta samples and raw materials were determined by Minolta CR-400 (Konica Minolta, Japan) device. L* (brightness), a* (red-green) and b* (yellow-blue) values were determined. Firmness values of pasta samples were measured by TAXT Plus Texture Analyser (Stable Microsystems, Surrey, UK) and A/LKB-F was used as a probe (Yeyinli 2006).

The cooking properties of pasta samples were evaluated in terms of water uptake (WU), volume increase (VI) and cooking loss (CL). In determining the WU, 250 ml boiling distilled water was added to 20 g pasta sample and the pasta varieties were cooked for 10 min and then the weight difference (%) in the samples (dry and cooked) was determined. During the determination of the VI, samples were cooked for 10 min and filtered for 2 min, and then the VI was calculated by determining the volume of the water they carried in the measuring cylinder with distilled water. After cooking of pasta samples, cooking water of the samples were dried in the oven (FN-500, Ankara, Turkey) at 135 °C to evaluate CL value (Oh et al. 1985; Özkaya and Kahveci 1990).

Sensory analyses

The sensory properties of pasta samples were determined by 20 panelists. Pasta samples were evaluated in terms of taste, odor, appearance and overall acceptance. In the evaluations, the scale between 1 and 7 (1, extremely bad; 7, excellent) was used (Epler et al. 1998).

Statistics analyses

The data obtained from the research were subjected to the analysis of variance and the averages of the main variation sources which were statistically significant were compared by Duncan multiple comparison test. The results of the statistical analysis were summarized in the form of tables (Düzgüneş et al. 1987).

Result and discussion

The results of chemical and physical analyses of raw materials (wheat semolina, RQF and GQF) used in pasta preparation are given in Table 1. Ash contents of raw materials changed between 0.77 and 3.12%. Germination process resulted in a remarkable increase in ash content of quinoa flour. This increase in ash content may be due to the loss of dry matter (carbohydrate) during germination. In a similar study, Morgan and Hunter (1993) reported that ash content of barley (2.1%) increased up to 3.1% and 5.3%, six and eight days after the germination, respectively. In the present study, crude fat content decreased with germination from 4.32% (RQF) to 3.98% (GQF). Regarding the fat content, Cornejo et al. (2015) observed a progressive decrease from 6.74 to 5.58% in 24 h in germinating brown rice. Coulibaly and Chan (2011) declared that fat content decreased in foxtail millet during germination and such decrease maybe because of the lipolytic enzyme activities which used the fat at the beginning of germinating for energy production contributing the seed growth. Crude protein contents of raw materials ranged from 10.65% to 25.68%, and the germination led to significant increment ($p < 0.05$) from 18.69% (RQF) to 25.68% (GQF) in crude protein content of quinoa flour. Compared to wheat semolina, 2.4-fold higher protein content was found in GQF. Fazaeli et al. (2012) also reported a germination-dependent increase from 11.73 to 14.67% in the crude protein content of sprouted (6–8 days) barley. This change might most probably be related with the biosynthesis of new amino acids. Phytic acid content of RQF (970.97% mg/100 g) was higher than that of wheat semolina (268.65 mg/100 g). However, the germination resulted in a remarkable reduction (77%) in the phytic acid content (GQF 221.05 mg/100 g), even below wheat semolina. The decrease in phytic acid contents of legume seeds and cereal with germination has been frequently reported in the literature (Ibrahim et al. 2002). Such decreases are resulted from increasing phytase activity during germination/sprouting. Increasing phytase activity hydrolyzes the phytates and releases soluble minerals and protein. TPC of raw materials was ranged from 0.50 to 3.13 mg GAE/g and as expected, germination increased TPC content of quinoa

Table 1 Chemical and physical properties of raw materials

	Wheat semolina	RQF[A]	GQF[B]
Ash (%)	0.77 ± 0.02[c]	2.07 ± 0.07[b]	3.12 ± 0.02[a]
Crude fat (%)	0.66 ± 0.01[c]	4.32 ± 0.22[a]	3.98 ± 0.07[b]
Crude protein (%)	10.65 ± 0.40[c]	18.69 ± 0.43[b]	25.68 ± 0.19[a]
Phytic acid (mg/100 g)	268.65 ± 4.94[b]	970.97 ± 3.51[a]	221.05 ± 7.68[c]
TPC[C] (mg GAE/g)	0.50 ± 0.10[c]	1.48 ± 0.04[b]	3.13 ± 0.20[a]
AA[D] (%)	11.58 ± 0.31[c]	35.51 ± 0.91[b]	79.26 ± 1.56[a]
Ca (mg/100 g)	24.68 ± 0.45[c]	46.34 ± 1.11[b]	87.24 ± 0.35[a]
Fe (mg/100 g)	1.53 ± 0.04[c]	3.90 ± 0.05[b]	4.56 ± 0.05[a]
K (mg/100 g)	244.18 ± 2.09[c]	652.40 ± 5.78[b]	959.55 ± 6.84[a]
Mg (mg/100 g)	34.99 ± 2.13[c]	124.47 ± 1.24[b]	154.07 ± 1.96[a]
P (mg/100 g)	211.91 ± 1.75[c]	398.33 ± 4.26[b]	516.89 ± 6.41[a]
Zn (mg/100 g)	1.44 ± 0.01[c]	2.41 ± 0.06[b]	3.75 ± 0.08[a]
L*	88.15 ± 0.08[a]	85.60 ± 0.02[c]	86.76 ± 0.14[b]
a*	-0.73 ± 0.04[c]	0.90 ± 0.01[b]	1.61 ± 0.06[a]
b*	19.94 ± 0.26[a]	13.47 ± 0.07[b]	12.77 ± 0.08[c]

Means followed by the same letter within a row are not significantly different ($p < 0.05$). Values are the average of triplicate measurements on the duplicate samples. Chemical properties are based on dry matter

[A]Raw quinoa flour

[B]Germinated quinoa flour

[C]Total phenolic content

[D]Antioxidant activity

(2.1-fold). This increase in germination can be explained by the release of phenolic compounds attached to the cell wall or the formation of new synthesis by means of endogenous esterase enzymes during germination (Diaz-Batalla et al. 2006). Also, the raw materials were analyzed in terms of AA, it was determined that GQF (79.26%) had higher AA than both wheat semolina (11.58%) and RQF (35.51%). As expected, both types of quinoa flours have higher Ca, Fe, K, Mg, P and Zn content than wheat semolina. Germination resulted in an increase in all minerals analyzed in quinoa flours. It is thought that the loss of dry matter (especially carbohydrates and crude fat) during germination may cause the proportional increase of mineral content in quinoa seed. In a previous study performed on various mung bean cultivars, Ca, Fe and K amount increased by 34%, 50% and 65%, respectively as a response of 2-day germination (Vayupharp and Laksanalama 2013). In the present study, the highest increment was observed in Ca (88.3%) content and followed by Zn (55.6%) and K (47.1%) at the end of the germination process.

When color values of raw materials were considered (Table 1); L* and b* values were found higher in wheat semolina than both forms of quinoa flours. In addition, L* and a* values of quinoa flours increased by germination while b* value decreased. This may be attributed to a higher TPC of germinated seeds (Ha and Park 2011).

Duncan multiple comparison test results of chemical properties of pasta samples are presented in Table 2. Pasta containing GQF revealed higher ash, protein, TPC and AA than that of pasta prepared RQF. Germination of quinoa seed increased the amount of ash, protein, TPC and AA and decreased the ratio of crude fat and phytic acid of its flour (Table 1), so the change in raw material properties may be effect on the chemical properties of final product (pasta) (Table 2). The increment on quinoa flour ratio resulted in an increment of the ash, crude fat and protein content of the pasta samples. The highest ratio (30%) of quinoa flour in pasta formulation increased the ash, fat and protein content from 0.81%, 0.49% and 12.56% to 1.35%, 1.39% and 16.65%, respectively. In particular, quinoa flour at 30% ratio improved the protein content about 33%. Such a drastic change is very important in terms of protein enrichment of pasta. The interaction between quinoa flour type and quinoa flour addition ratio is presented in Fig. 1. While RQF utilization in pasta production increased the phytic acid content of the pasta up to 391.52 mg/100 g, GQF usage decreased the phytic acid to 173.82 mg/100 g. Utilization RQF in pasta formulation increased the phytic acid of the pasta samples due to high phytic acid content of RQF (970.97 mg/100 g) than wheat semolina (268.65 mg/100 g). As stated before, germination is a process that reduces the content of phytic acid. Phytic acid content of the GQF (221.05 mg/100 g) was even below wheat

Table 2 Duncan multiple comparison test results of chemical properties of pasta samples

Variance source	n	Ash (%)	Crude fat (%)	Crude protein (%)	Phytic acid (mg/100 g)	TPC[A] (mg GAE/g)	AA[B] (%)
QF[C] type							
RQF[D]	8	0.94 ± 0.16[b]	1.00 ± 0.40[a]	13.85 ± 0.98[b]	291.64 ± 74.31[a]	0.75 ± 0.18[b]	17.39 ± 4.23[b]
GQF[E]	8	1.15 ± 0.28[a]	0.89 ± 0.31[b]	15.13 ± 2.27[a]	189.60 ± 12.88[b]	0.95 ± 0.38[a]	22.12 ± 7.92[a]
QF ratio (%)							
0	4	0.81 ± 0.02[d]	0.49 ± 0.02[d]	12.56 ± 0.15[d]	205.08 ± 4.29[d]	0.54 ± 0.04[d]	12.39 ± 0.64[d]
10	4	0.93 ± 0.13[c]	0.82 ± 0.06[c]	13.96 ± 0.39[c]	225.44 ± 34.76[c]	0.68 ± 0.06[c]	17.03 ± 1.78[c]
20	4	1.10 ± 0.15[b]	1.09 ± 0.08[b]	14.79 ± 0.92[b]	249.31 ± 75.36[b]	0.96 ± 0.15[b]	21.99 ± 3.88[b]
30	4	1.35 ± 0.20[a]	1.39 ± 0.31[a]	16.65 ± 1.94[a]	281.67 ± 125.70[a]	1.22 ± 0.29[a]	27.61 ± 5.27[a]

Means followed by the same letter within a column are not significantly different ($p < 0.05$). Values are the average of triplicate measurements on the duplicate samples. Chemical properties are based on dry matter

[A]Total phenolic content

[B]Antioxidant activity

[C]Quinoa flour

[D]Raw quinoa flour

[E]Germinated quinoa flour

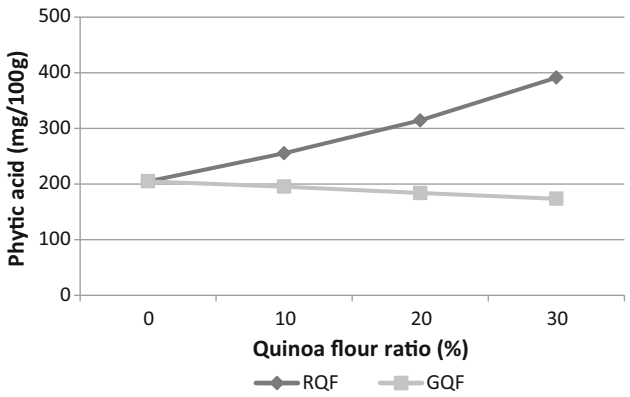

Fig. 1 Phytic acid content of pasta samples prepared with different ratios of RQF and GQF

semolina, and also raw material properties influenced the properties of the end product. Phytic acid is considered as an antinutrient which decreases the bioavailability of the minerals. Therefore, GQF usage may significantly improve the mineral bioavailability of pasta samples compared to RQF. Significant increases were also observed in TPC and AA of pasta samples containing 30% quinoa flour up to 1.22 mg GAE/g and 27.61%, respectively. As a result, the nutritional value increased by germination of quinoa also influenced on the final product, pasta. On the other hand increasing RQF/GQF ratio improved the nutritional status of the pasta. The results of many researchers are similar to the data we have obtained. Lorusso et al. (2017) used raw and fermented quinoa flour in pasta formulation. Utilization of raw quinoa flour (20%) in pasta formulation improved the ash content from 0.81% (semolina pasta) to 1.08%. Torres et al. (2007) reported that protein content of the pasta prepared with 10% germinated pea flour increased from 14.8 to 17.3%. Herken (2005) declared that addition of cowpea flour into the macaroni increased the phytic acid amount of the samples, and the macaroni with 20% germinated cowpea flour had 41% more AA than the control group.

Mineral contents of pasta samples are reported in Table 3. Utilization of GQF in pasta formulation improved the overall mineral matter compared to pasta prepared with RQF. Pasta samples prepared with 30% quinoa flour had the richest Ca, Fe, K, Mg, P and Zn content. In the present study, Ca, Fe, K, Mg, P and Zn content of quinoa flour increased 88.3, 16.9, 47.1, 23.8, 29.8 and 55.6% respectively by germination (Table 1). The mineral increment of pasta by GQF usage could probably be related with the chemical composition of raw material used. In a research conducted by Torres et al. (2007) Ca, K, Mg and Fe amounts of pasta samples containing 10% germinated pea flour were found as 70.7, 172.2, 55.9 and 2.91 mg/100 g, while same minerals was 51.7, 134.0, 52.9 and 2.63 mg/100 g in control pasta group, respectively. The recommended dietary allowances (RDAs) for adult males are 800 mg of Ca, 10 mg of Fe, 1.6–2.0 g of K, 350 mg of Mg, 800 mg of P and 15 mg of Zn. When 100 g (dry matter) pasta containing 30% GQF were consumed, 5.1% of RDA for Ca, 24.0% of RDA for Fe, 24.6% of RDA for K, 20.1 6% of RDA for Mg, 38.0% of RDA for P and 13.9% of RDA for Zn were taken by the human body.

Table 4 shows some physical properties of pasta samples. In the pasta formulation, the use of GQF increased the L* and a* values according to the use of RQF. Besides

Table 3 Duncan multiple comparison test results of mineral content of pasta samples (mg/100 g)

Variance source	n	Ca	Fe	K	Mg	P	Zn
QF[A] type							
RQF[B]	8	28.31 ± 3.04[b]	1.89 ± 0.27[b]	291.14 ± 48.62[b]	47.35 ± 10.17[b]	243.93 ± 27.90[b]	1.60 ± 0.13[b]
GQF[C]	8	32.93 ± 6.62[a]	1.99 ± 0.33[a]	336.28 ± 84.29[a]	52.21 ± 14.18[a]	257.54 ± 36.94[a]	1.77 ± 0.26[a]
QF ratio (%)							
0	4	24.34 ± 0.25[d]	1.58 ± 0.01[d]	229.64 ± 3.52[d]	34.90 ± 0.24[d]	212.17 ± 1.48[d]	1.44 ± 0.01[d]
10	4	28.86 ± 1.86[c]	1.81 ± 0.05[c]	287.49 ± 18.19[c]	44.48 ± 1.73[c]	234.89 ± 6.16[c]	1.60 ± 0.08[c]
20	4	32.82 ± 3.72[b]	2.08 ± 0.08[b]	340.59 ± 34.03[b]	54.19 ± 3.97[b]	263.04 ± 12.83[b]	1.77 ± 0.13[b]
30	4	36.46 ± 5.13[a]	2.32 ± 0.10[a]	397.14 ± 52.20[a]	65.56 ± 5.72[a]	292.84 ± 12.61[a]	1.93 ± 0.19[a]

Means followed by the same letter within a column are not significantly different ($p < 0.05$). Values are the average of triplicate measurements on the duplicate samples

[A]Quinoa flour

[B]Raw quinoa flour

[D]Germinated quinoa flour

Table 4 Duncan multiple comparison test results of physical properties of pasta samples

Variance source	n	L*	a*	b*	WU[A] (%)	VI[B] (%)	CL[C] (%)	Firmness (g)
QF[D] type								
RQF[E]	8	83.28 ± 1.32[b]	0.54 ± 0.13[b]	18.53 ± 1.03[a]	231.84 ± 21.39[a]	269.46 ± 22.10[a]	3.81 ± 0.92[b]	71.55 ± 21.41[a]
GQF[F]	8	83.72 ± 0.92[a]	0.64 ± 0.22[a]	18.18 ± 1.12[a]	217.36 ± 13.98[b]	261.70 ± 20.85[b]	4.20 ± 1.54[a]	66.10 ± 22.50[b]
QF ratio (%)								
0	4	84.72 ± 0.17[a]	0.39 ± 0.06[d]	19.69 ± 0.59[a]	201.29 ± 1.17[d]	239.06 ± 1.11[d]	2.55 ± 0.43[d]	97.23 ± 0.07[a]
10	4	83.94 ± 0.13[b]	0.51 ± 0.04[c]	18.77 ± 0.41[b]	219.82 ± 9.34[c]	255.69 ± 9.45[c]	3.66 ± 0.09[c]	78.45 ± 7.31[b]
20	4	83.38 ± 0.47[c]	0.67 ± 0.11[b]	17.80 ± 0.23[c]	232.03 ± 14.51[b]	276.31 ± 5.25[b]	4.16 ± 0.08[b]	54.31 ± 1.94[c]
30	4	81.97 ± 0.54[d]	0.80 ± 0.11[a]	17.15 ± 0.20[d]	245.26 ± 9.97[a]	291.24 ± 4.05[a]	5.65 ± 0.95[a]	47.31 ± 3.94[d]

Means followed by the same letter within a column are not significantly different ($p < 0.05$). Values are the average of triplicate measurements on the duplicate samples

[A]Water uptake

[B]Volume increase

[C]Cooking los

[D]Quinoa flour

[E]Raw quinoa flour

[F]Germinated quinoa flour

physical conditions and technological processes, colour of raw material can also affect the colour of the final product. As mentioned earlier, the amount of TPC increased by the germination of quinoa caused a more bright color image, which may influence the final product color. When the results were evaluated in terms of quinoa flour utilization ratio, it was seen that increasing quinoa flour in pasta formulation reduced the L* value. This may be due to the fact that L* value of wheat semolina, which is the main raw material of pasta, is higher than that of quinoa flours (Table 1). In addition to having higher protein and lysine content of quinoa flour than that of wheat semolina, the heat treatments during pasta drying may cause an increase in Maillard reaction and therefore decrease in L* value of pasta (Prinyawiwatkul et al. 1993). It is also observed that the addition of quinoa flour reduced the b* value and the lowest value was obtained from 30% quinoa flour usage in pasta sample. Smooth surface with a translucent bright yellow color are prefered for good pasta quality. Yellow color intensity caused by the carotenoid pigments of durum

semolina gives the desired color to the pasta surface. In present study, yellow color pigments in pasta formulation diluted with the addition of quinoa flour, and undesirable yellow color loss was occurred in pasta color especially in high quinoa flour usage ratios. Yellow colour loss are due to the usage of increased quinoa flour and also decreased amount of yellow pigments from semolina. Fiorda et al. (2013) confirm that the yellow color content of the pasta is due to the different color pigment contents of the raw materials used in the formulation.

Cooking properties, water uptake (WA), volume increase (VI) and cooking loss (CL) are important parameters affecting the technological quality of pasta. High CL values are indicative of poor pasta quality is due to the high starch solubility that cannot be trapped between the protein matrix. A good quality pasta should absorb at least 2 times its weight and 3–4 times its volume. WA values of pasta may decrease as protein amount increases in pasta formulation. This is due to the inhibition of the diffusion of water into the granules of the starch due to the strong protein network. The high protein content alone does not affect the cooking quality of the pasta. The quantity of protein is as important as its quality. (Pınarlı et al. 2002; Sözer and Kaya 2002). As can be seen in Table 4, GQF usage decreased WU, VI and firmness, while it increased the CL of pasta. Similarly, Grant et al. (1993) obtained lower WU values with germinated wheat flour usage in pasta formulation compared to the control group. Izydorczyk et al. (2005) declared that CL originated from weak protein-starch interaction or deterioration of the protein matrix. On the other hand, decrease in water absorption capacity by germination caused a reduction in VI. Poor protein quality due to germination leads to high CL (Liu et al. 2017). In a parallel study, 20% GQF used in noodle formulation and 76% lower firmness values determined compared to control samples (Seol and Sim 2017).

When the cooking properties results of pasta were evaluated in terms of quinoa flour utilization ratio, increasing amount of quinoa flour also increased the WU, VI and CL values of pasta. Pasta formulation containing 30% quinoa flour demonstrated the highest WU, VI and CL and the lowest firmness when compared to other pasta samples. WU and VI values of pasta samples are mainly dependent on the raw material properties. In a similar study, Ha and Park (2011) used different ratios of waxy and nonwaxy barley for noodle preparation, and they determined 134.62% VI in noodle containing 30% waxy barley, while the VI of control noodle was 121.43%. Also adding quinoa flour into the pasta formulation resulted in gluten dilution, so starch particles could pass into the cooking water more easily and cause blurry. Torres et al. (2007) produced pasta with germinated pea flour, and determined CL values as 3% in control group and 5.51% in pasta containing 10% pea flour.

Sensory analysis results are shown in Fig. 2. Increasing amount of RQF and GQF in the pasta formulation caused a slight decrease in the taste scores. The taste of the pasta samples prepared with GQF flour was slightly higher than the samples containing RQF. On the other hand, the odor scores of the GQF added pasta samples were found to be lower than the samples prepared by using RQF. When the taste and odor scores were evaluated together, it was seen that especially high utilization ratios of RQF/GQF (20–30%) decreased the taste-odor scores, but this decrease was not at a level that would adversely affect the appreciation of the panelists. Increased RQF/GQF ratios in pasta formulation decreased the appearance scores. Appearance score of pasta are affected by color and surface properties. The surface properties may vary depending on the amount of gluten in the pasta formulation and the drying conditions. Depending on the increase in utilization of quinoa flour, dilution of gluten amount present in the pasta dough is considered as the most important factor in degrading the surface properties and achieving lower scores.The above-mentioned decreases due to the use of quinoa flour in the appearances of the pasta were very little and remained within the limits of general appreciation. Although the use of increased RQF/GQF resulted in a slight decrease in the overall acceptability values, even the highest usage ratio (30%) remained within the limits of consumer appreciation and had an acceptable overall rating. In a study in which quinoa was used in pasta production by replacing certain proportions of wheat with and without fermentation, it has been stated that the use of 20% quinoa flour could improve the nutritional quality of pasta without adversely affecting technological and sensory properties (Lorusso et al. 2017).

Conclusion

Overall findings indicated that the use of RQF/GQF increased the nutritional quality of pasta. The use of high amounts can be evaluated to be within acceptable limits even though they adversely affected technological quality. When the results on chemical analysis are evaluated, the most remarkable results are the increase of protein ratio by 37% and the decrease of phytic acid by 77%. It means germination was an effective method to minimize the phytic acid content in pasta samples. As the quinoa is a good source of functional components, AA and TPC of pasta raised with RQF/GQF usage. Also, the use of quinoa flour in both forms augmented the Ca, K, Fe, Mn, Mg, P and Zn content of the pasta. Utilization of GQF in pasta formulation shoved higher mineral content compared to RQF. The loss of dry matter because of quinoa germination

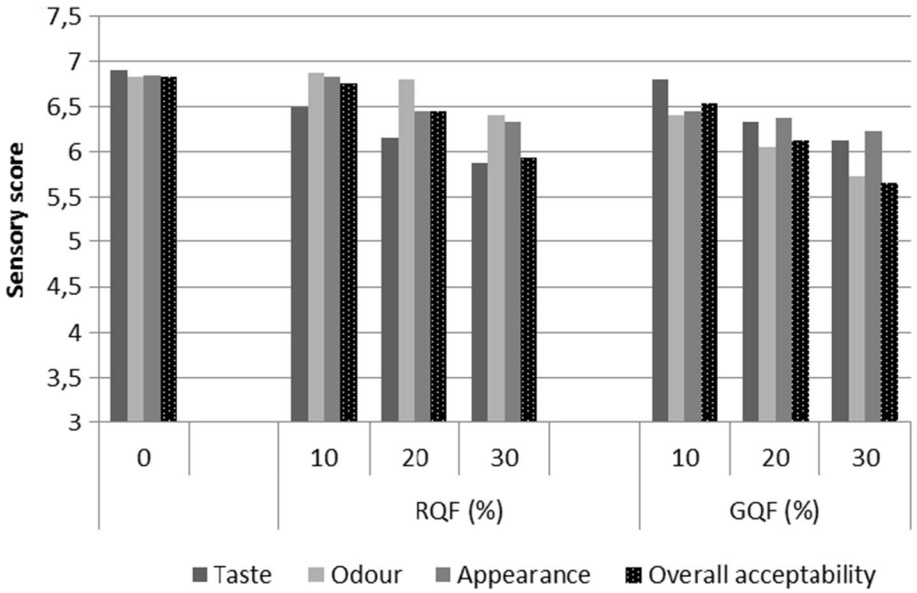

Fig. 2 Sensory scores of pasta samples prepared with different ratios of RQF and GQF

caused an increase in the amount of these minerals and such changes were reflected in the final product (pasta). When the pasta was evaluated in terms of their physical characteristics, the use of GQF in the pasta samples increased the L* and a* values in comparison to the use of RQF. The increasing amount of quinoa flour in pasta formulations decreased L* and b* values and increased a* value. Increases in darkness and redness in relation to the use of quinoa flours may be attributed to the possibility of increase in the Maillard reaction triggered by high protein content of quinoa. The use of quinoa flour in increasing ratios raised WU, VI, CL and reduced firmness of pasta samples. On the other hand, GQF usage in formulation led to decreases in WU, VI, and firmness, and increment in CL. In further studies, it is recommended to use GQF in the production of bread, cakes and biscuits to benefit from its superior nutritional properties such as high protein, mineral, TPC, AA and low phytic acid.

Acknowledgements This research was summarized from Ph.D. thesis (Necmettin Erbakan University the Graduate School of Natural and Applied Science Department in Food Engineering) by Berat Demir. This study was supported by the Scientific Research Project Unit of Necmettin Erbakan University, Konya, Turkey (Project Number, BAP-161419002).

Compliance with ethical standards

Conflict of interest Authors declare no conflict of interest.

References

AACC (1990) Approved methods of the American Association of cereal chemists, 8th edn. AACC, St. Paul

Beta T, Nam S, Dexter JE, Sapirstein HD (2005) Phenolic content and antioxidant activity of pearled wheat and roller-milled fractions. Cereal Chem 82:390–393

Brennan CS, Tudorica CM (2008) Evaluation of potential mechanisms by which dietary fibre additions reduce the predicted glycemic index of fresh pastas. Int J Food Sci Technol 43:2151–2162

Cornejo F, Caceres PJ, Martínez-Villaluenga C, Rosell CM, Frias J (2015) Effects of germination on the nutritive value and bioactive compounds of brown rice breads. Food Chem 173:298–304

Coulibaly A, Chen J (2011) Evolution of energetic compounds, antioxidant capacity, some vitamins and minerals, phytase and amylase activity during the germination of foxtail millet. Am J Food Technol 6:40–51

Diaz-Batalla L, Widholm JM, Fahey GC, Castaño-Tostado E, Paredes-López O (2006) Chemical components with health implications in wild and cultivated Mexican common bean seeds (*Phaseolus vulgaris* L.). J Agric Food Chem 54:2045–2052

Düzgüneş O, Kesici T, Kavuncu O, Gürbüz F (1987) Araştırma ve Deneme Metodları (İstatistiksel Metodları-II), Ankara Üniversitesi, Ziraat Fakültesi publication number: 1021, Ankara, p 381

Epler S, Chambers E, Kemp KE (1998) Hedonic scales are a better predictor than just-about-right scales of optimal sweetness in lemonade. J Sens Stud 13:191–197

Fazaeli H, Golmohammadi HA, Tabatabayee SN, Asghari-Tabrizi M (2012) Productivity and nutritive value of barley green fodder yield in hydroponic system. World Appl Sci J 16:531–539

Fiorda FA, Soares MS Jr, Da Silva FA, Grosmann MV, Souto LR (2013) Microestructure, texture and colour of gluten-free pasta made with amaranth flour, cassava starch and cassava bagasse. LWT-Food Sci Technol 54:132–138

Gamez-Meza N, Noriega-Rodriguez JA, Medina-Juarez LA, Ortega Garcia J, Cazarez-Casanova R, Angulo-Guerrero O (1999) Antioxidant activity in soybean oil of extracts from Thompson grape bagasse. J Am Oil Chem Soc 76:1445–1447

Grant LA, Dick JW, Shelton DR (1993) Effect of drying temperature, starch damage sprouting and additives on spaghetti quality characteristics. Cereal Chem 70:676–684

Gyamfi MA, Yonamine M, Aniya Y (1999) Free radical scavenging action of medical herbs from Ghana: *Thonningia sanguinea* on

experimentally-induced liver injuries. Gen Pharmacol 32:661–667
Ha DH, Park YK (2011) Quality characteristics of noodles added with domestic germinated barley. Korean J Food Preserv 18:131–142
Haug W, Lantzsch HJ (1983) Sensitive method for the rapid determination of phytate in cereals and cereal products. J Sci Food Agric 34:1423–1426
Herken (2005) Effect of processing on the selected properties of cowpea flour to be incorporated into spaghetti. Phd thesis. University of Gaziantep, Gaziantep, Turkey. Available from: https://tez.yok.gov.tr/UlusalTezMerkezi/tezSorguSonucYeni.jsp
Ibrahim SS, Habiba RA, Shatta AA, Embaby HE (2002) Effect of soaking, germination, cooking and fermentation on antinutritional factors in cowpeas. Nahrung 46:92–95
Izydorczyk MS, Lagasse SL, Hatcher DW, Dexter JE, Rossnagel BG (2005) The enrichment of Asian noodles with fiber-rich fractions derived from roller milling of hull-less barley. J Sci Food Agric 85:2094–2104
Koziol MJ (1992) Chemical composition and nutritional evaluation of quinoa (Chenopodium quinoa Willd.). J Food Compos Anal 5:35–68
Liu T, Hou GG, Cardin M, Marquart L, Dubat A (2017) Quality attributes of whole-wheat flour tortillas with sprouted wheat flour substitution. LWT-Food Sci Technol 77:1–7
Lorusso A, Verni M, Montemurro M, Coda R, Gobbetti M, Rizzello CG (2017) Use of fermented quinoa flour for pasta making and evaluation of the technological and nutritional features. LWT-Food Sci Technol 78:215–221
Morgan JV, Hunter RR (1993) Limiting factors in hydroponic barley grass production. In: Poster session presentation at the meeting of the Proceedings of the 8th International Congress on Soilless Culture, Hunter's Rest, South Africa.
Oatway L, Vasanthan T, Helm JH (2001) Phytic acid Food Rev Int 17(4):419–431
Oh NH, Seib PA, Chung DS (1985) Noodle III. Effects of processing variables on the quality of dry noodle. Cereal Chem 62:437–440
Özkaya H, Kahveci B (1990) The analysis methods of cereal and crops. The Journal of Food Technology Association, Ankara, Turkey (in Turkish)
Paśko P, Bartoń H, Zagrodzki P, Gorinstein S, Fołta M, Zachwieja Z (2009) Anthocyanins, total polyphenols and antioxidant activity in amaranth and quinoa seeds and sprouts during their growt. Food Chem 115:994–998
Pınarlı İ, İbanoğlu Ş, Öner MD (2002) Ham ve mikrodalgada kavrulmuş ruşeymle üretilen makarna üzerine araştırmalar. In: Paper presented at the cereal products technology congress and exhibition, Gaziantep, Turkey, pp 645–654 (in Turkish)
Prinyawiwatkul W, Beuchat LR, McWatters KH (1993) Functional property changes in partially defatted peanut flour caused by fungal fermentation and heat treatment. J Food Sci 58:1318–1323
Repo-Carrasco-Valencia R, Hellstrom JK, Pihlava JM, Mattila PH (2010) Flavonoids and other phenolic compounds in Andean indigenous grains: Quinoa (*Chenopodium quinoa*), kañiwa (*Chenopodium pallidicaule*) and kiwicha (*Amaranthus caudatus*). Food Chem 120:128–133
Skujins S (1998) Handbook for ICP-AES (Vartian-Vista). In: A short guide to vista series ICP-AES operation. Variant Int. AG, Zug, version 1.0, Switzerland
Seol H, Sim KH (2017) Quality characteristics of noodles with added germinated black quinoa powder. Korean J Food and Nutr 30:19–30
Slinkard K, Singelton VL (1977) Total phenolic analysis, automation and comparison with manual methods. Am J Enol Vitic 28:49–55
Sözer N, Kaya A (2002) Spagettinin Dokusal ve Pişme Özellikleri. In: Paper presented at the cereal products technology congress and exhibition, Gaziantep, Turkey, pp 339–351 (in Turkish)
Torres A, Frias J, Granito M, Vidal-Valverde C (2007) Germinated *Cajanus cajan* seeds as ingredients in pastaproducts: chemical, biological and sensory evaluation. Food Chem 101:202–211
Vayupharp B, Laksanalamai V (2013) Nutrients and anti-nutrients of high chlorophyll-mungbean sprouts as affected by different periods of germination and sprouting stages. Agric Biol Eng 6:121–129
Yeyinli N (2006) The Use of textural methods in determining the quality of pasta. Master thesis. University of Celal Bayar, Manisa, Turkey. Available from: https://tez.yok.gov.tr/UlusalTezMerkezi/tezSorguSonucYeni.jsp