LWT - Food Science and Technology 78 (2017) 215–221

Contents lists available at ScienceDirect

LWT - Food Science and Technology

journal homepage: www.elsevier.com/locate/lwt

Use of fermented quinoa flour for pasta making and evaluation of the technological and nutritional features

Anna Lorusso [a], Michela Verni [a], Marco Montemurro [a], Rossana Coda [b], Marco Gobbetti [a], Carlo Giuseppe Rizzello [a, *]

[a] Department of Soil, Plant and Food Science, University of Bari Aldo Moro, 70126 Bari, Italy
[b] Department of Food and Environmental Sciences, University of Helsinki, Helsinki, Finland

ARTICLE INFO

Article history:
Received 13 October 2016
Received in revised form
23 December 2016
Accepted 24 December 2016
Available online 27 December 2016

Keywords:
Quinoa
Pasta
Lactic acid bacteria

ABSTRACT

Pasta was prepared by replacing 20% of semolina with native and fermented quinoa flour and the effects of substitution on the technological and nutritional characteristics were evaluated. The addition of quinoa reflected the chemical composition of pasta, which had higher fiber, protein, and free amino acids content than semolina pasta, particularly in the case of pasta containing quinoa flour fermented with selected lactic acid bacteria. Furthermore, free amino acids, total phenols, and the antioxidant activity of pasta prepared with fermented quinoa flour were up to twice as high than the other types of pasta. When fermented quinoa flour was used, the water absorption during cooking was the lowest, even though cooking loss was also observed. The use of quinoa flour affected the textural characteristics of pasta, increased the tenacity and, when fermented, also the elasticity. The effects of quinoa fermentation were evident on the nutritional quality of fortified pasta, showing the highest *in vitro* protein digestibility, protein nutritional indices (Essential Amino Acid Index, Biological Value, Protein Efficiency Ratio, and Nutritional Index), as well as lowest predicted glycemic index. These results indicate the positive effect of fermented quinoa flour on pasta fortification.

1. Introduction

Pasta has a primary role in human nutrition, thanks to its complex carbohydrate profile, the large global distribution, and the extended shelf life (Chillo, Laverse, Falcone, & Del Nobile, 2008). The World Health Organization (WHO) and Food and Drug Administration (FDA) consider pasta a good vehicle for the addition of different nutrients to diet, since it can be fortified with protein, dietary fibers, vitamins and minerals (Chillo et al., 2008).

There is an increasing interest of producers, consumers, and the scientific community towards the addition of high-protein vegetable ingredients deriving from legumes and pseudocereals to pasta formulations (Chillo et al., 2008; Rizzello et al., 2017; Valcárcel-Yamani & da Silva Lannes, 2012; Wang & Zhu, 2016). Even though fortification represents an efficient method to improve the nutritional quality of pasta, the replacement of semolina is still a challenge for the food industry (Rizzello et al., 2017), since the addition of alternative ingredients markedly affects technological and sensory properties.

Quinoa is a pseudo-cereal originating from South America where its use as a staple food can be dated to pre-Hispanic times (Diaz et al., 2015). It has a high-protein content (14–16 g/100 g) (Chillo et al., 2008; Rizzello, Lorusso, Montemurro, & Gobbetti, 2016a) and its amino acid composition, rich in histidine and lysine, is close to the ideal protein balance recommended by the FAO (Chillo et al., 2008; Rizzello et al., 2016a). Quinoa has a relatively high quantity of vitamins and minerals, iron and calcium (Chillo et al., 2008); moreover, lipids have a high quality, and are particularly rich in linoleate and linolenate (Chillo et al., 2008), having a linoleic:linolenic acid ratio which falls closer to the recommended values (5:1–10:1) for a healthy diet (Diaz et al., 2013). During the last years, the production of quinoa markedly increased, thus emphasizing its suitability for an extended cultivation in different climatic regions of North America, India, and Europe (Rizzello et al., 2016a; Stikic et al., 2012). Due to its nutritional quality, quinoa can have a role in functional food applications, which is an increasing trend in the developed world. Some studies have highlighted the potential of quinoa in gluten-free extruded

* Corresponding author.
E-mail address: carlogiuseppe.rizzello@uniba.it (C.G. Rizzello).

http://dx.doi.org/10.1016/j.lwt.2016.12.046
0023-6438/

food such as pasta (Schoenlechner, Drausinger, Ottenschlaeger, Jurackova & Berghofer, 2010) and corn-based snacks (Diaz et al., 2013).

Recently, quinoa flour sourdough fermented by autochthonous lactic acid bacteria (Rizzello et al., 2016a) was used for the enrichment of wheat bread. Free amino acids, soluble fibers, total phenols, phytase and antioxidant activities, and the *in vitro* protein digestibility, markedly increased during fermentation (Rizzello et al., 2016a). The results collected encouraged the use of quinoa and selected starters for the manufacture of novel and healthy products.

In this work, fermented quinoa flour was used for pasta fortification with the aim of enhancing its nutritional features. Fermentation with lactic acid bacteria has been previously applied to the manufacture of pasta with the aim to confer specific nutritional characteristics. Durum wheat semolina was fermented with a pool of selected lactic acid bacteria targeting gluten reduction (Curiel et al., 2014; Di Cagno et al., 2005) and *Lactobacillus plantarum* strains were used to produce vitamin B2-enriched pasta (Capozzi et al., 2011). In the present study, native and fermented quinoa flour were used as ingredients in semolina pasta manufacture aiming at evaluating the effects on the nutritional and technological properties of the fortified pasta.

2. Materials and methods

2.1. Raw materials and microorganisms

Organic quinoa (*Chenopodium quinoa*) dehulled seeds imported from Argentina (Fundacion Nuevagestion, San Ignacio de Loyola, Jujuy) were used in this study. Quinoa flour (QF) obtained by milling with a M20 miller (IKA Werke GmbH and Co. KG, Staufen, Germany), was characterized by the follow proximal composition: moisture, 11.4 g/100 g; protein, 13.0 g/100 g; lipids, 5.0 g/100 g; total carbohydrates, 60.5 g/100 g; total dietary fibers, 8.4 g/100 g; ash, 0.6 g/100 g.

Wheat (*Triticum durum*) semolina was purchased from Mininni mill (Altamura BA, Italy). Its proximate composition was: moisture, 10.2 g/100 g; protein, 12.1 g/100 g; fat, 1.8 g/100 g; ash, 0.6 g/100 g and total carbohydrates, 75.5 g/100 g.

Lactobacillus plantarum T6B10 and *Lactobacillus rossiae* T0A16 (previously isolated from quinoa flour) (Rizzello et al., 2016a) were used as starter for quinoa flour fermentation. The lactic acid bacteria strains were routinely propagated at 30 °C in MRS broth (Oxoid, Basingstoke, Hampshire, England).

2.2. Quinoa fermentation

Prior to fermentation, *L. rossiae* T0A16 and *L. plantarum* T6B10 were cultivated at 30 °C until the late exponential phase of growth was reached (approx. 12 h). Cells were harvested by centrifugation (10,000xg, 10 min, 4 °C) and washed twice in 50 mmol/L sterile potassium phosphate buffer (pH 7.0). The lactic acid bacteria cells were suspended in the water used for dough preparation and inoculated at an initial cell density of approx. log 7.0 cfu/g of dough. Quinoa dough was prepared by mixing quinoa flour and tap water with a dough yield (DY, dough weight x 100/flour weight) of 160, corresponding to 62.5 and 37.5 g/100 g of flour and water, respectively. The dough was fermented at 30 °C for 16 h and used as ingredient for pasta making as described below. The pH of quinoa dough was determined by a pHmeter (Model 507, Crison, Milan, Italy) with a food penetration probe. Total titratable acidity (TTA) was determined according to AACC method 02–31.01 (AACC, 2010). Presumptive lactic acid bacteria were enumerated using MRS agar medium (Oxoid, Basingstoke, Hampshire, United Kingdom) supplemented with cycloheximide (0.1 g/L). Plates were incubated at 30 °C for 48 h, under anaerobiosis (AnaeroGen and AnaeroJar, Oxoid).

2.3. Pasta making

Experimental pasta was manufactured using a pilot plant La Parmigiana SG30 (Fidenza, Italy). Formulas for doughs used for pasta making are reported in Table 1. All the doughs for pasta making were made with a DY of 130, corresponding to a mixture of 23 g/100 g water and 77 g/100 g flour. A reference pasta was made only using wheat semolina (WP).

Two types of pasta containing quinoa were made: quinoa pasta (QP) in which the 20% of semolina was replaced by native quinoa flour, and a fermented quinoa pasta (FQP), in which the fermented quinoa dough was added to obtain the same percentage of replacement of semolina with quinoa flour. Ingredients were mixed in three steps (1 min mixing and 6 min hydration). Then, the final dough was mixed for 30 s and extruded at 45–50 °C, through a n.76 bronze die (150 mm diameter). The extruded material was cut with a rotating knife for short pasta shapes to obtain grooved "maccaroni". For drying, pasta was arranged on frames (1.5 kg for frame) and treated according to the cycle described in Table 1S, at low temperature (55 °C).

2.4. Hydration test, cooking time, cooking loss and water absorption

The method of Marti, Fongaro, Rossi, Lucisano, and Pagani (2011) (ratio pasta: water of 1:20, 180 min of incubation) was used to determine the hydration at 25 °C, while the method of Schoenlecher et al. (2010) was used to determine the cooking time. The optimal cooking time (OCT) corresponded to the disappearance of the white core. Cooking loss (expressed as grams of matter loss/100 g of pasta) was evaluated by determining the amount of solids lost into the cooking water (Curiel et al., 2014). The increase of pasta weight during cooking (water absorption) was evaluated by weighing pasta before and after cooking. The results were expressed as $[(W_1 - W_0)/W^0]*100$, were W_1 is the weight of cooked pasta and W_0 is the weight of the uncooked samples.

2.5. Chemical characteristics of pasta

Total titratable acidity (TTA) was determined as mentioned in 2.2. Protein (total nitrogen × 5.7), lipids, ash, total dietary fibers (TDF) and moisture contents were determined according to the AACC approved methods 46-11A, 30–10.01, 08-01, 32–05.01, and 44-15A, respectively (AACC, 2010). The amount of total starch was determined using Ewers' polarimetric method (ISO 10520:1997).

Table 1
Formulas for pasta making. All the doughs had a final DY of 130, corresponding to 23 g/100 g water and 77 g/100 g flours mixture. WP, reference pasta made using only wheat semolina; QP, quinoa pasta in which the 20% of semolina was replaced by native quinoa flour; FQP, fermented quinoa pasta, in which the fermented quinoa dough was added to obtain the same percentage of replacement of semolina with quinoa flour.

	WP	QP	FQP
Semolina (g/100 g)	77	61.6	61.6
Quinoa flour (g/100 g)	–	15.4	
Fermented quinoa dough* (g/100 g)	–	–	24.64
Water (g/100 g)	23	23	13.76

Fermented quinoa dough (DY 160) was fermented at 30 °C for 16 h. *Lactobacillus rossiae* T0A16 and *L. plantarum* T6B10 were used as starters and inoculated at ca. log 7.0 cfu/g.