Sprouting as a pre-processing for producing quinoa-enriched bread

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Abstract

The impact of 48 h sprouted quinoa (SQ) was assessed in bread-making. Wheat flour (WF) was replaced with SQ at different levels (i.e., 10:90, 20:80 and 30:70, SQ:WF ratio). Once the optimal replacement level of SQ was identified, the bread-making performance of this ingredient was compared with those of pearled quinoa (PQ), commonly used in bread-making.

Starch pasting properties and gluten aggregation behavior were not strongly affected at 20:80 level, even if statistically significant ($p \leq 0.05$). Regardless the replacement level, SQ caused an increase in dough water absorption and in softening degree, and a decrease in stability, suggesting weakening of the gluten network. During leavening, SQ improved dough development and gas production, due to increased sugar content. The best bread-making performance (highest bread specific volume and lowest crumb firmness) was obtained at 20:80 replacement level. Compared to PQ, SQ exhibited the best leavening capacity (high dough development, gas production and gas retention) and bread properties (high specific volume and low crumb firmness), likely due to its higher sugar content. Moreover, 20SQ bread was characterized by a decreased bitterness assessed by electronic tongue. In conclusion, sprouting might be considered a valid alternative to pearling to improve the characteristics of quinoa enriched bread.

Keywords: Chenopodium quinoa; germination; dough rheology; electronic sensing

Abbreviations: 10SQ, blend composed by sprouted quinoa and wheat flour at 10:90 ratio; 20PQ, blend composed by pearled quinoa and wheat flour at 20:80 ratio; 20SQ, blend composed by sprouted quinoa and wheat flour at 20:80 ratio; 30SQ, blend composed by sprouted quinoa and wheat flour at 30:70 ratio; BU, Brabender Unit; FU, Farinograph Unit; GPE, GlutoPeak Equivalent; GPU, GlutoPeak Unit; PQ, pearled quinoa; SP, sprouted quinoa; SV, specific volume; WF, wheat flour.

1. Introduction

Quinoa is a gluten-free grain from both agronomic and nutritional standpoint. Specifically, quinoa is particularly high in lysine, which is the limiting amino acid in cereals, it is a good source of minerals, phenolic compounds, dietary fiber and polyunsaturated fatty acids (Tang and Tsao, 2017). All these compositional traits account for the potential health benefits of quinoa seeds in contributing to the prevention of various diseases such as cancer, diabetes, cardiovascular diseases, and aging (Tang and Tsao, 2017). Thus, these characteristics are the driving force for enhancing the consumption of quinoa not only as seeds but also as an ingredient in various food applications, including both enriched wheat-based goods and gluten free products.

Despite the well-known nutritional features of quinoa, its consumption is limited by the bitter and astringent taste, due to saponin compounds (Suárez-Estrella et al., 2018). Nowadays, pearling is one of the main processes applied to quinoa to improve its acceptability in food formulation; it consists in the removal of the seed external layers, which are rich in saponins (Suárez-Estrella et al., 2018). On the other hand, a significant loss of bioactive compounds occurs during the pearling process (Suárez-Estrella et al., 2018). Nowadays, quinoa is proposed in bread-making only as flour from pearled grains. Specifically, in wheat-based bread, 250 g/kg of pearled quinoa seems to be the threshold level in terms of dough rheological properties and sensory acceptability (Rosell et al., 2009); conversely, bitter aftertaste was detected at higher quinoa enrichment levels (Lorenz and Coulter, 1991).

Recently, several authors reported the possibility to exploit sprouted grains to enhance the bread-making attitude of wholewheat (Cardone et al., 2020b), brown-rice (Watanabe et al., 2004), and pulses (Hallén et al., 2004; Marengo et al., 2017b). The improved bread characteristics (i.e. high specific volume and crumb softness) are mainly attributable to the activity of the hydrolytic enzymes (e.g. α-amylase) developed during sprouting (Goesaert et al., 2009). Moreover, sprouting process is associated with several grain nutritional and sensory improvements, in terms of increasing mineral and vitamin bio-availability and of decreasing antinutritional factors (e.g. phytic acid, trypsin inhibitors) (Lemmens et al., 2019). Thus, the sprouting of quinoa might be considered a useful approach to improve both its nutritional value and its bread-making attitude.

Up to now, the effects of sprouting on technological and sensory properties of quinoa dough and bread have not been extensively reported. In this context, Park & Morita (2005) studied the effects of the enrichment level of wheat flour with sprouted quinoa (up to 72 h), at 100g/kg replacement level only. Starting from the consideration above, the aim of this research was to assess the maximum enrichment level of sprouted quinoa suitable for achieving good bread-making performance. Once the optimal replacement level of sprouted quinoa was identified, the bread-making performance of this ingredient was compared with those of pearled quinoa, in order to assess the potential use of sprouted quinoa in bread-making.

2. Materials and methods

2.1 Materials

Quinoa seeds (*Chenopodium quinoa* Willd. var. *Titicaca*) were provided by Quinoa Marche s.r.l. (Ancona, Italy), who also carried out the pearling process on the seeds. The untreated seeds (5 kg) were sprouted at lab scale (Memmert GmbH Co. KG, Schwabach, Germany) at 22 °C for 48 h and dried (Self Cooking Center®, Rational International AG, Mestre, Italy) at 55 °C for 6 h, as previously reported by Suárez-Estrella (2019). Sprouting time was selected based on preliminary results: the maximum intensity of the macromolecular modifications can be seen at 48 h of sprouting, without compromising functionality, in terms of starch gelatinization and foaming capacity and stability (Suárez-Estrella, 2019).

Pearled (PQ) and sprouted (SQ) quinoa seeds were grinded by means of a Cyclotec 1093 (Foss Sample Mill, Höganäs, Sweden) lab-scale mill, in order to obtain flours with particle size < 250 μm. Commercial wheat flour (WF; protein: 123 mg/g db; W: $290*10^{-4}$ J) was provided by Molino Quaglia S.p.A. (Vighizzolo D'Este, Italy) and it was used alone or in mixture with either PQ or SQ flours. In particular, three sprouted quinoa:wheat blend ratios were investigated: 10:90 (10SQ), 20:80 (20SQ), and 30:70 (30SQ). In the second part of this study, the pearled quinoa:WF blend (20:80; 20PQ) was considered.

2.2 Methods

2.2.1. *Pasting properties*

Starch pasting properties were investigated by means of the Micro Visco-Amylograph (Brabender GmbH & Co. KG, Duisburg, Germany) as reported by Elkhalifa et al. (2017) with a modification (i.e. 3 min of pre-treatment at 30 °C).

2.2.2. *Gluten aggregation properties*

The aggregation kinetics of gluten protein were studied by using the GlutoPeak device (Brabender GmbH & Co. KG, Duisburg, Germany). Flour (9 g) was dispersed in distilled water (9 mL), scaling both of them on a 14% sample moisture basis. The test was performed by setting the paddle speed at 2750 rpm and the circulating water bath at 35 ºC.

2.2.3. *Mixing properties*

Mixing properties were performed by means of the Farinograph-E (Brabender GmbH & Co. KG, Duisburg, Germany) with a 50 g kneading bowl following the ICC 115/1 Approved Method (ICC, 1992).

2.2.4. *Leavening properties*

Dough samples were prepared using commercial baker's yeast (25 g/kg flour; Carrefour®) and salt (15 g/kg flour; Candor®). The bread-making conditions (i.e. amount of water and mixing time) were previously determined by means of the farinographic test. Dough samples were prepared with a lab-scale kneading (Artisan 5KSM150PS KitchenAid, St. Joseph, USA) equipped with a hook. At the end of mixing, an aliquot of 315 g of the dough was placed in the Rheofermentometer F4 device (Chopin, Tripette & Renaud, Villeneuve La Garenne, France) for 3 h at 30 °C, to measure dough development and gas production and retention during leavening.

2.2.5. *Bread-making*

The dough – prepared in the conditions reported in the Section 2.2.4 – was left to rest for 10 min at room temperature (20±1 °C), divided in three portions of 250 g each, molded into cylindrical shapes, placed into baking pans (length: 12.5 cm, width: 7.5 cm; height: 5 cm), and leavened at 30 °C (70% relative humidity) in a climate chamber (Self Cooking Centre®). The time necessary for leavening varied from 75 to 85 min, until the dough exceeded the top of the pans by 2.5 cm. Samples were baked at 220 ºC for 25 min (Self Cooking Center®), with steam injection for 5 s.

2.2.6. Bread characterization

Bread loaves were analysed 2 h after baking. Specific volume was obtained by the ratio between the loaf apparent volume, by sesame replacement method, and loaf weight. Crumb softness was measured according to the Approved Method AACC 74-09.01 (AACC 2001) by using a Texture Analyzer TA.XT plus C (Stable Micro Systems, Surrey, UK), equipped with a 100 kg*m/s^2 load cell. Specifically, an aluminum probe (36 mm Radiused Cylinder Probe) and a test speed of 100 mm/min were used. Samples were analysed after 2, 24 and 72 h from baking, keeping the loaves in a plastic bag at room temperature until test.

2.2.7. Electronic tongue assessment

Electronic-tongue (e-tongue) assessment was performed (n=3) on whole breads enriched in either sprouted or pearled quinoa at 20:80 replacement level, as well as on crusts and crumbs separately. The breads were freeze-dried (-80 °C for 72 h; Alpha 1-2 LD plus; Deltek s.r.l., Naples, Italy) and milled in a lab scale mill (IKA M20, Staufen, Germany). Analyses were performed with the Taste-Sensing System SA 402B (Intelligent Sensor Technology Co. Ltd, Atsugi, Japan) according to (Marengo et al., 2017a), with some modifications. Briefly, 10 g of samples were suspended in 150 mL of distilled water and centrifuged at 5,000 x g for 10 min at 20 °C. After centrifugation, the supernatants were tested.

2.2.8. Statistics

All the rheological analyses were carried out in triplicate. As regards bread-making, three baking tests were performed for each sample and three loaves were obtained from each baking test.

Thus, specific volume was replicated nine times while crumb firmness was measured on the three central slices of each bread obtained from each baking trial.

Analysis of variance (one-way ANOVA; $\alpha=0.05$) was assessed by Statgraphics Plus 5.1 (StatPoint Inc., Warrenton, USA) using the samples as factors. The significant differences ($p\leq0.05$) were determined by using Tukey HSD test. A t-test was applied for comparing sprouted with pearled samples. Data from e-tongue measurements were elaborated by Principal Component Analysis (PCA) using MINITAB 14 (v.12.0; Minitab Inc, State College, USA) software package.

3. Results

3.1. Effects of enrichment in sprouted quinoa

3.1.1 Pasting properties

As the level of SQ increased, no significant differences ($p>0.05$) were measured in terms of pasting temperature (62.2±1.2 °C for WF to 64.0±0.1, 64.7±1.5 and 63.6±1.2 BU for 10SQ, 20SQ and 30SQ, respectively), instead, viscosity during both heating and cooling steps decreased ($p\leq0.05$) (Figure 1a). Also, breakdown values decreased ($p\leq0.05$) from 128±8 BU for WF to 93±5, 71±6 and 56±4 BU for 10SQ, 20SQ and 30SQ, respectively, suggesting increase in heating stability in presence of quinoa. This behavior is due to the quinoa starch granules, that did not show a sharp peak but a plateau (Suárez-Estrella, 2019). Moreover, quinoa starch granules might be modified by sprouting, inducing a lower intensity of gelatinization (Suárez-Estrella, 2019). The decrease in viscosity during cooling resulted in a decrease ($p\leq0.05$) in setback values (from 505±11 BU for WF to 393±14, 326±5 and 288±7 BU for 10SQ, 20SQ and 30SQ, respectively), which seems to be related to starch retrogradation tendency.

3.1.2 Gluten aggregation properties

The gluten aggregation kinetics of WF was typical of a strong flour with good bread-making performance that is usually characterized by long aggregation time (104±3 s), high maximum torque (61±0.3 GPU) and energy (i.e., the area under the curve till 15 s after the maximum torque) values

(1480±4 GPE) (Figure 1b). Replacing WF with SQ promoted a significant decrease ($p \leq 0.05$) in maximum torque (60±0.6, 53±2.3 and 40±1.3 GPU for 10SQ, 20SQ and 30SQ, respectively) and energy values (1239±25, 1105±34 and 916±16 GPE for 10SQ, 20SQ and 30SQ, respectively). This trend suggested gluten weakening as the amount of quinoa increased. As regards the time required for gluten aggregation, the value did not follow a consistent trend. Specifically, the peak maximum time decreased ($p \leq 0.05$) in 10SQ (96±2 s), did not change ($p > 0.05$) in 20SQ blend (102±1 s) and increased ($p \leq 0.05$) in 30SQ (123±2 s).

3.1.3 Dough mixing properties

WF showed a long dough development time and high stability (Figure 1c), which is a common characteristic for strong flours. Replacing WF up to 200 g/kg significantly increased ($p \leq 0.05$) the amount of water (from 555±4 for WF to 572±1 and 580±1 g/kg for 10SQ and 20SQ, respectively) to achieve the optimal dough consistency (i.e., 500 FU). The further increase in SQ did not result in a significant increase ($p > 0.05$) in water absorption (582±2 g/kg for 30SQ). Up to 200 g/kg of the enrichment level, adding SQ to WF decreased ($p \leq 0.05$) the development time (from 6.8±0.3 for WF to 6.1±0.1 and 5.6±0.1 min for 10SQ and 20SQ, respectively) needed to reach optimal consistency, with no further decreasing at 300 g/kg of replacement level (5.5±0.3 min for 30SQ). The same trend was registered for stability time (23.8±1.2 min for WF to 5.6±0.2, 3.5±0.1 and 3.3±0.2 min for 10SQ, 20SQ and 30SQ, respectively), whose decrease was in agreement with the increase ($p \leq 0.05$) in the degree of softening, that varied from 17±2 FU for WF to 93±4, 132±5 and 152±3 min for 10SQ, 20SQ and 30SQ, respectively.

3.1.4 Dough leavening properties

At the beginning of the leavening phase (up to 1 h), the sprouted quinoa-enriched dough exhibited a rapid dough development, regardless of the quinoa enrichment (Figure 1d). Replacing WF up to 200 g/kg level led to an increase ($p \leq 0.05$) in dough development from 51±1 to 60±1 mm, respectively. Instead, higher replacement level (i.e., 30:70) increased ($p \leq 0.05$) this index up to 56±1 mm. Moreover, both WF and 10SQ dough samples required longer ($p>0.05$) leavening time (~ 2 h and 20 min) to reach the maximum dough height, compared to 20SQ and 30SQ samples (~ 1 h and 50 min). After 2 h of leavening, either dough with 20SQ or 30SQ were not able to hold gas inside the dough, resulting in a decrease ($p\leq0.05$) in dough height, as a consequence of the weakening of the gluten network. Dough weakening was less dramatic in 10SQ and therefore no loss in maximum height was detected up to 2.5 h of leavening. Finally, gas production increased ($p\leq0.05$) from 1250±54 mL for WF to 1426±26, 1469±10 and 1464±9 mL for 10SQ, 20SQ and 30SQ, respectively, whereas the dough retention capacity slightly decreased ($p\leq0.05$) in presence of SQ, with no significant differences ($p>0.05$) according to the enrichment level (93±1% for WF to 90±1, 90±1 and 88±1% for 10SQ, 20SQ and 30SQ, respectively).

3.1.5 Bread characteristics

Replacing WF with SQ did not cause negative effects on bread-making properties, except for 10SQ sample. Indeed, at this replacement level, the resulting bread was characterized by the lowest specific volume and the highest crumb firmness ($p\leq0.05$) (Figure 2). 20SQ showed the best baking performance in terms of specific volume, whose value were even higher ($p\leq0.05$) compared with WF and 30SQ loaves (Figure 2).

Unlike 10SQ bread, high replacement levels (20SQ and 30SQ) significantly decreased ($p\leq0.05$) crumb firmness, contributing to high crumb softness, not only in fresh bread (Figure 2) but also during storage (up to 72 h; data not shown).

3.2. Comparison between sprouted and pearled quinoa

Compared to using PQ, the blend enriched in SQ was characterized by a higher water absorption (~3%), shorter development time (-20%), lower stability (-49%), and higher degree of softening (76%) ($p\leq0.05$) (Table 1).

As regards dough performance during leavening, 20SQ dough showed a higher ($p\leq0.05$) maximum dough height (~22%) and retention capacity coefficient (~15%) than 20PQ dough (Table

1). In addition, the best leavening performance accounted for the highest specific volume of SQ-enriched bread (3.61±0.11 vs 2.60±0.10 mL/g for SQ and PQ, respectively). Moreover, the presence of SQ improved ($p \leq 0.05$) also crumb softness not only of fresh bread (2 h after baking) but also during storage (up to 72 h), compared to PQ-enriched bread (Figure 3).

The sensory traits of quinoa-enriched bread obtained from e-tongue measurement and elaborated through the Principal Component Analysis (PCA) are shown in Figure 4. The two main components accounted for 81.5% of the total variance. As shown in the score plot (Figure 4a), samples were clearly discriminated on PC1 (48.9% of the total variance) based on the treatment applied to seeds before milling (pearling or sprouting). In fact, the sprouted samples (S) were located on the right side (positive) of PC1. On the contrary, samples with pearled quinoa (P) were located on the left side (negative) of PC1. PC2 discriminated the samples (32.6% of the total of the variance) according to the assessed bread sections (whole bread, crumb, or crust). In particular, whole bread (W) as well as crumb (C) were located on the upper (positive), without great differences between them. Indeed, crumb represents more than 90% of the whole bread (data not shown). Whereas, bread crust (O) was located on the lower (negative) of PC2.

4. Discussion

The effects of replacing wheat flour with quinoa on dough and bread properties have been shown in previous studies (Chauhan, Zillman, and Eskin, 1992; Lorenz and Coulter, 1991). Briefly, when quinoa is blended with wheat, the dough water absorption and mixing tolerance index (or degree of softening) increased, whereas dough development time and loaf volume decreased (Chauhan et al., 1992; Lorenz and Coulter, 1991). At the same time, a worsening in crumb softness and overall acceptability have been reported (Lorenz and Coulter, 1991). To the best of our knowledge, most of the studies have been carried out on pearled quinoa, since pearling has been shown to improve product acceptability by decreasing the amount of saponins (Gómez-Caravaca et al., 2014). Beside pearling, sprouting has been shown to enhance the sensory profile of grains mainly due to the production of simple sugars (Heiniö et al., 2001). However, till now, the effects of sprouting on quinoa acceptability have not been yet addressed. On the other hand, from a technological standpoint, sprouted quinoa showed enhanced functional properties (i.e., increased foam stability, decreased retrogradation degree) encouraging its use as an ingredient in bread-making (Suárez-Estrella, 2019).

The impact of sprouted quinoa was assessed in bread-making in light of results previously reported in this study. Specifically, sprouted quinoa was added to wheat at different enrichment levels (i.e., 10:90, 20:80, and 30:70, sprouted quinoa:wheat ratio).

The first part of the study focused on starch and protein functionality of sprouted quinoa blends. Understanding the effect on starch is important because this component is responsible for bread staling. Instead, gluten properties are important because gluten plays a key role in leavened products by retaining the gas produced during fermentation. The pasting profile of quinoa blends suggested a gradual loss of the ability to gelatinize and retrograde up to 20:80 substitution level (Figure 1a). Changes in starch properties could be due to various factors: (1) the dilution effect, since the starch content in sprouted quinoa is lower than in wheat (Suárez-Estrella, 2019); (2) presence of fiber that restricts starch swelling during the initial stages of gelatinization (Collar et al., 2009); (3) starch hydrolysis by the amylases developed during sprouting, and formation of small glucose polymers that are less prompted to absorb water and gelatinize (Suárez-Estrella, 2019). The lower retrogradation tendency of 20SQ and 30SQ blends might account for the decrease in bread staling and the preservation of crumb softness even during storage (Figure 2b). A similar effect has been shown in wheat bread (Cardone et al., 2020a,b; Marti et al., 2018, 2017).

Regarding proteins, gluten protein aggregation in different conditions of hydration and shear stress, namely in slurry (i.e. GlutoPeak test) and in dough (i.e. Farinograph test) systems, was addressed. The former measures the gluten aggregation kinetic which is solely affected by gluten quality (Goldstein et al., 2010); the latter measures the dough formation which is affected by other components, including starch and fiber (Ahmed et al., 2013; Soh et al., 2006). Replacing WF, up to 20:80 replacing level, seems to have only a partial effect on gluten aggregation behavior, mainly affecting maximum torque rather than peak maximum time (Figure 1b). Since the maximum torque is correlated to gluten content (Marti et al., 2015a), its decrease upon quinoa enrichment might be related to gluten dilution. Similar trends have already observed in previous studies where flours high in fiber and low in gluten-forming proteins were added to wheat (Marti et al., 2015b). Increasing the amount up to 30:70 substitution level, the maximum torque decreased while the peak maximum time increased (Figure 1b), resulting in a decrease in the aggregation energy, and suggesting an extensive gluten weakening, unsuitable for bread-making. Indeed, usually flours for bread-making exhibit faster gluten formations and higher peaks compared to those for cookies or cakes (Lu and Seetharaman, 2014). Regardless the enrichment level, the GlutoPeak profile of quinoa-enriched flours showed a sharper peak compared to WF profile (Figure 1b), suggesting low resistance to intense shear stresses.

Findings on gluten weakening were confirmed on the dough system by using the farinograph test. Specifically, the worsening of dough mixing properties were evaluated by the decrease in stability and the increase in softening degree (Figure 1c). Gluten dilution, together with fiber enrichment, might account for such modification at high levels of quinoa enrichment (20:80 and 30:70). Moreover, the increasing replacement level caused an increase in water absorption, likely due to the higher fiber content present in the quinoa flour. It is well known the great ability of fibers to bound a high amount of water leading to a higher water absorption index, thanks to the presence of its large number of hydroxyl groups able to establish interactions with water through hydrogen bonds (Sudha et al., 2007). However, the water absorption of 30SQ dough was not different from the value of 20SQ. Our results partially confirmed previous study of Park et al. (2005) who reported that replacing 100 g/kg of wheat with 48 h sprouted quinoa did not result in any modification of the dough development time, while it caused an increase in the water absorption and a decrease in the stability indices. Differences in sprouting conditions (i.e., temperature, relative humidity) and grain variety might account for different results. The gluten dilution in SQ samples affects also the dough capacity to maintain its shape during proofing (Figure 2a). However, by carefully following the results provided by the farinographic test (i.e., water absorption, mixing time) (Figure 1c,d), the production of wheat bread enriched in sprouted quinoa was possible even at the highest replacement level (30:70). The best result in terms of specific volume was obtained by using 20SQ (Figure 2), in agreement with the results on dough properties during both mixing and leavening (Figure 1c,d). Dough development increased, as well as the leavening rate, likely due to the higher presence of simple sugars in sprouted quinoa (Suárez-Estrella, 2019), usable by the yeasts for CO_2 production. Indeed, the presence of sprouted quinoa also led to high gas production during leavening, in agreement with bread volume (Figure 2). The high bread volume might account for the crumb softness of sprouted quinoa-enriched bread (Figure 2b). The positive effect of sprouted quinoa on bread features was evident only at high enrichment levels (20SQ and 30SQ).

Taking into consideration both the dough and bread features, results showed that the 20SQ blend is the most suitable for bread-making. For this reason, the second part of the study focused on the comparison between sprouting and pearling as pre-processing for producing quinoa-enriched bread.

Despite the dilution of gluten proteins, the enrichment in sprouting quinoa was associated with the best leavening properties, in terms of dough development and gas production and retention, in comparison with pearled quinoa (Table 1). As stated above, the best dough leavening performance in sprouted quinoa was due to the higher sugar content (Suárez-Estrella, 2019). Specifically, using sprouted quinoa improved bread volume and crumb softness in both fresh (2h after baking) and stored (upon 72h) bread (Figure 3), thanks to the increased α-amylase activity during sprouting. The positive effects of α-amylase activity in bread-making have already been reported (Goesaert et al., 2009; De Leyn, 2006).

Sprouting should be preferred to pearling also in relation to the sensory properties, as assessed by electronic-tongue (Figure 4). The loading plot (Figure 4a) evidenced the tendency of bread made with sprouted quinoa to umami, richness, sourness and astringency and bitterness aftertastes; while, pearled quinoa samples were located on the left side of PC1, in correspondence of saltiness, bitterness and astringency. The location of sprouted samples at the opposite side of bitterness is an indicative of the suitability of sprouting process to decreasing the bitter perception of quinoa enriched bread.

5. Conclusions

Using sprouted quinoa at 20:80 replacement level in wheat formulation, it was possible to produce enriched bread with high specific volume, keeping low the crumb firmness even during storage (up to 72 h). Therefore, sprouting could be a suitable strategy for producing quinoa-enriched bread in order to increase the production and consumption of fiber-rich products, together with proteins characterized by high biological value.

In addition, comparing sprouting to pearling, which is the process actually used for enhancing the sensory acceptability of quinoa seeds and flours, results on both dough and bread clearly showed that sprouting was more effective in improving bread properties (i.e. specific volume and crumb softness) as well as decreasing bread bitterness. Thus, although pearling is - nowadays - the main pre-treatment of quinoa to decrease its bitter taste, sprouting might represents a valid alternative to this process to increase the use of quinoa in bread and other baked products. Moreover, sprouting is a quite simple process, requiring non technologically-advanced plants and easily transferable in low-income countries, as the world main producers are. Finally, the effect of sprouting on the actual saponins content – the main cause of quinoa bitterness – is worthy of interest. The effects related to the instrumental sensory properties of samples bode well.

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Figure captions

Figure 1. Pasting (a), gluten aggregation (b), mixing (c) and leavening (d) properties of wheat (WF; solid line), and with increasing replacement level of sprouted quinoa (10SQ: dotted line; 20SQ: dash line; 30SQ: dash-dotted line). 10SQ, blend composed by sprouted quinoa and wheat flour at 10:90 ratio; 20SQ, blend composed by sprouted quinoa and wheat flour at 20:80 ratio; 30SQ, blend composed by sprouted quinoa and wheat flour at 30:70 ratio.

Figure 2. Specific volume and crumb firmness (2 h after baking) of bread from wheat flour (WF) and with increasing replacement level of sprouted quinoa. 10SQ, blend composed by sprouted quinoa and wheat flour at 10:90 ratio; 20SQ, blend composed by sprouted quinoa and wheat flour at 20:80 ratio; 30SQ, blend composed by sprouted quinoa and wheat flour at 30:70 ratio.
Different letters in the same row indicate a statistically significant difference among samples (Tukey test HSD; $p \leq 0.05$).

Figure 3. Crumb firmness of wheat bread enriched in sprouted (triangle) or pearled (circle) quinoa. The asterisks indicate a statistically significant difference between the mean values (t-Test; ***$p \leq 0.001$).

Figure 4. Score plot (a) and loading plot (b) from e-tongue PCA of bread with pearled (circle) or sprouted (diamond) quinoa. P: Pearled; S: Sprouted; W: whole bread; C: crumb; O: crust. Aftertaste-A: aftertaste-astringency; Aftertaste-B: aftertaste-bitterness

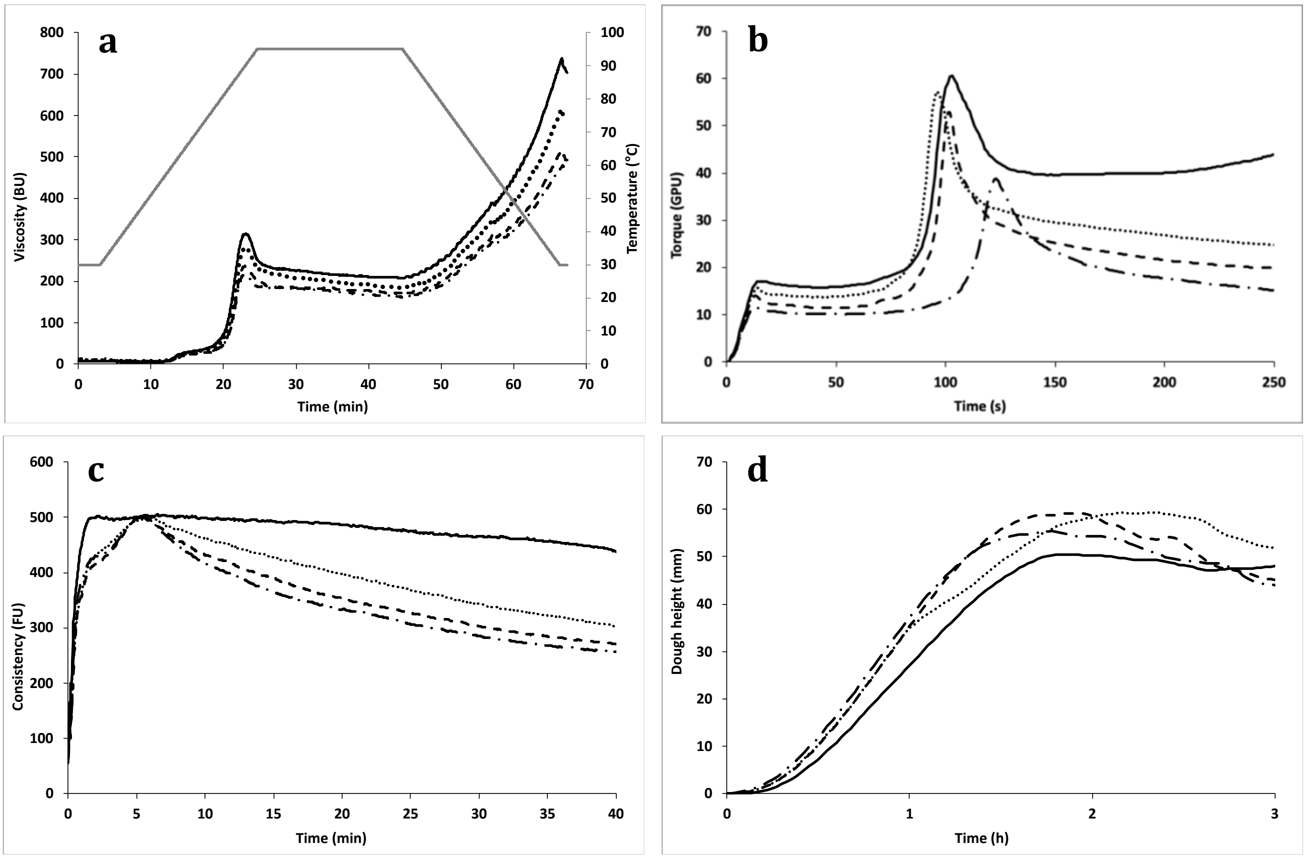
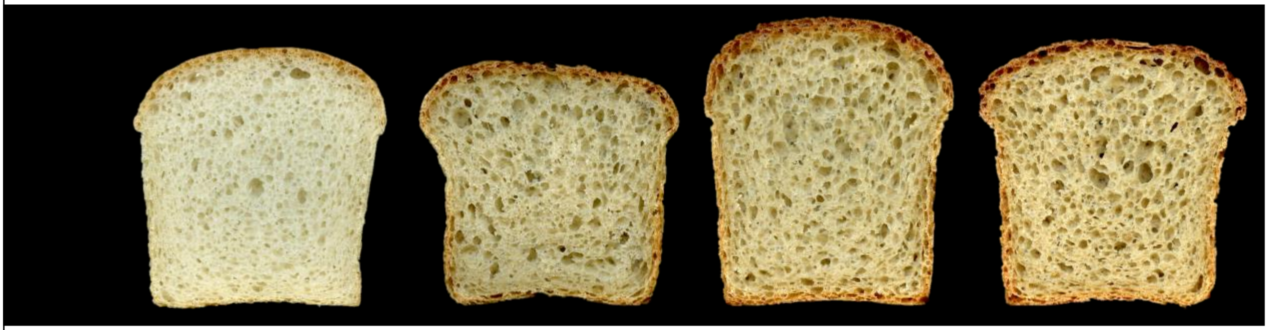

a
Viscosity (BU)
Temperature (°C)
Time (min)
0
100
200
300
400
500
600
700
800
0
10
20
30
40
50
60
70
80
90
100
b
Torque (GPU)
Time (s)
0
50
100
150
200
250
c
Consistency (FU)
Time (min)
0
5
10
15
20
25
30
35
40
d
Dough height (mm)
Time (h)
0
1
2
3

Figure 1.



	WF	10SQ	20SQ	30SQ
Specific volume (mL/g)	3.37 ± 0.11^{b}	3.18 ± 0.04^{a}	3.61 ± 0.11^{c}	3.38 ± 0.10^{b}
Crumb firmness (kg*m/s^{2})	9.4 ± 1.0^{c}	8.8 ± 0.9^{c}	5.6 ± 0.7^{a}	6.8 ± 0.9^{b}

Figure 2.

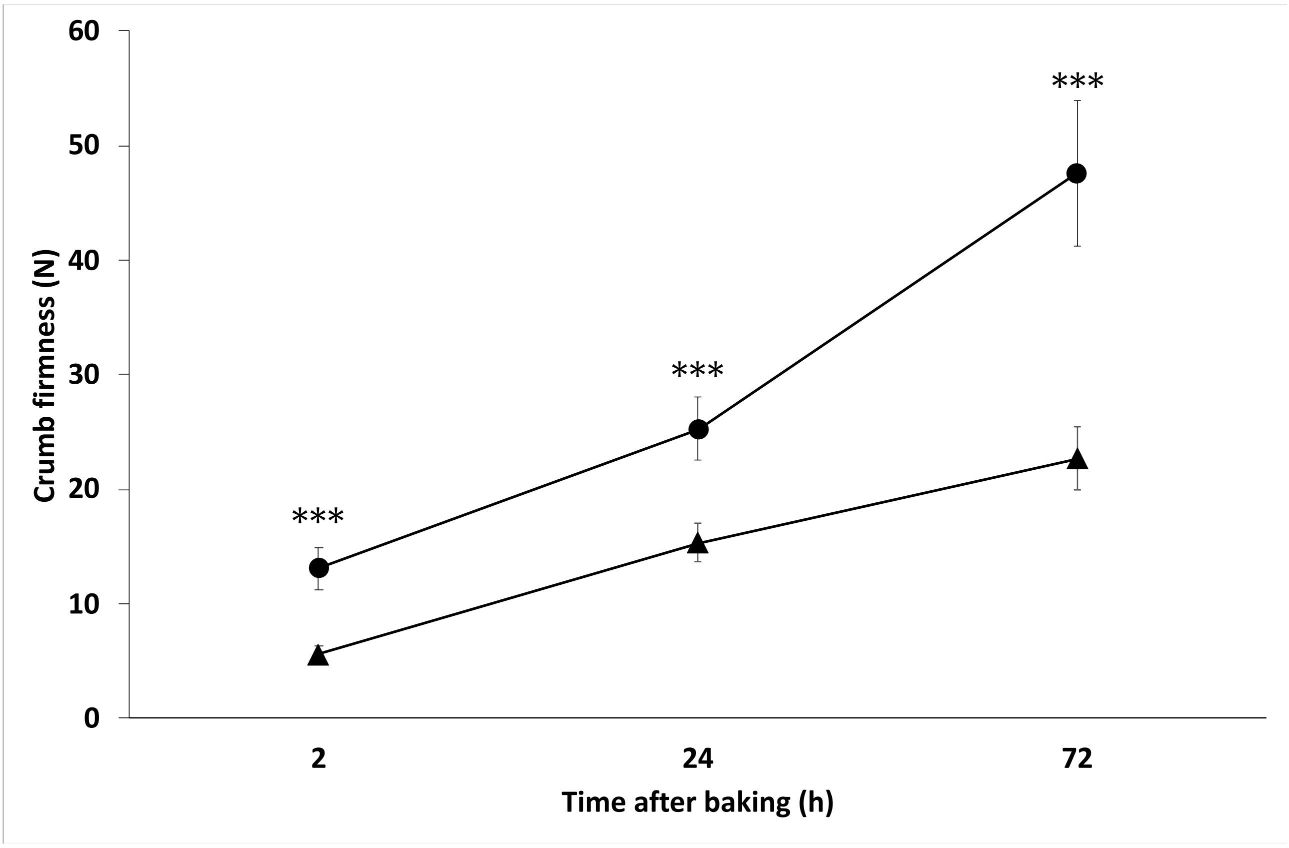


Figure 3.

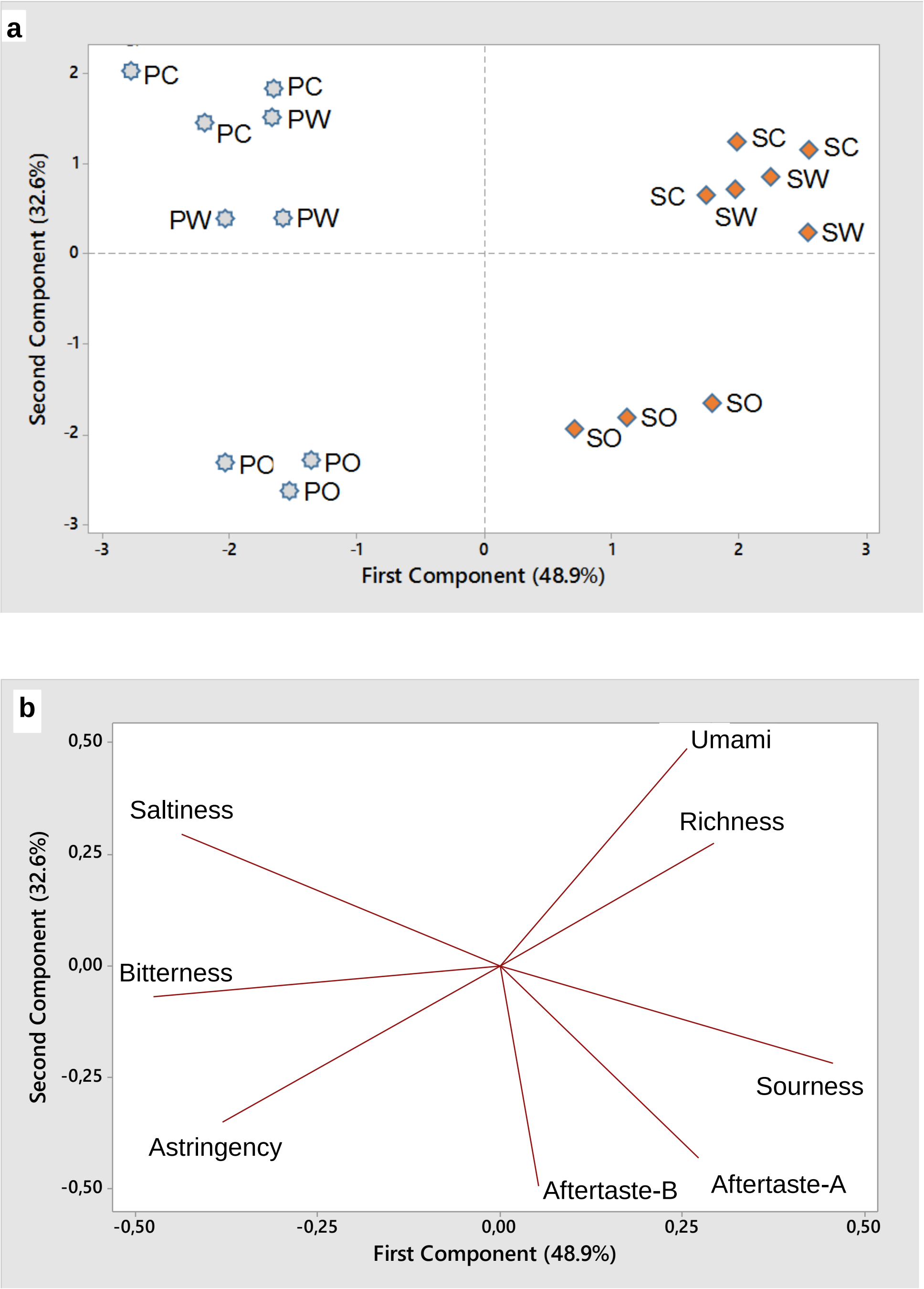

a
Second Component (32.6%)
First Component (48.9%)
PC
PC
PC
PW
PW
PW
PO
PO
PO
SC
SC
SC
SW
SW
SW
SO
SO
SO
2
1
0
-1
-2
-3
-3
-2
-1
0
1
2
3
b
Umami
Richness
Saltiness
Bitterness
Sourness
Astringency
Aftertaste-B
Aftertaste-A
0,50
0,25
0,00
-0,25
-0,50
-0,50
-0,25
0,00
0,25
0,50
Second Component (32.6%)
First Component (48.9%)

Figure 4.

Table 1. Mixing and leavening properties of enriched dough enriched in sprouted or pearled quinoa.

		20SQ	20PQ
Mixing properties	Water absorption (g/kg)	580±1	563±1***
	Development Time (min)	5.6±0.1	7.0±0.1***
	Stability (min)	3.5±0.1	6.8±0.7**
	Degree of Softening (FU)	132±5	75±5***
Leavening properties	Maximum dough height (mm)	60±1	49±2***
	Maximum height time (h)	1.9±0.1	2.0±0.2 n.s.
	Porosity time (h)	1.4±0.1	1.0±0.1***
	Total CO_2 (mL)	1469±10	1900±20***
	CO_2 retained (mL)	1315±9	1475±15***
	CO_2 released (mL)	153±1	424±13***
	CO_2 retention coefficient (%)	90±1	78±1***

20SQ, blend composed by sprouted quinoa and wheat flour at 20:80 ratio; 20PQ, blend composed by pearled quinoa and wheat flour at 20:80 ratio

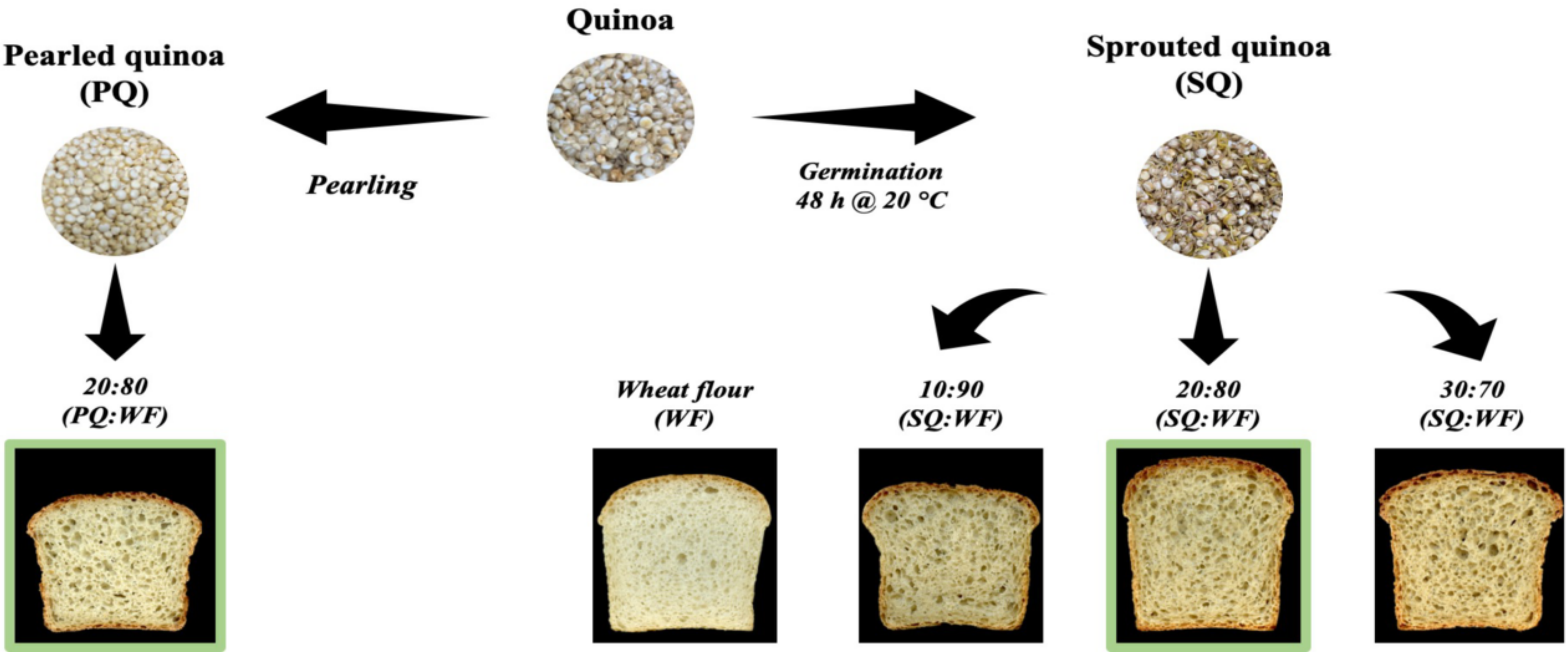
The asterisks indicate significant differences between the mean values of the sprouted and pearled quinoa samples (***$p \leq 0.001$; t-Test). n.s. indicates no statistical difference.

Sprouting as a pre-processing for producing quinoa-enriched bread

Diego Suárez-Estrella, Gaetano Cardone, Susanna Buratti, Maria Ambrogina Pagani, Alessandra Marti

Highlights:

- Enrichment of wheat bread with sprouted quinoa
- Using sprouted quinoa improved dough leavening properties and bread features
- Using 20% sprouted quinoa led to the highest bread volume
- Sprouting has to be preferred to pearling in quinoa bread-making


Quinoa
Pearled quinoa
(PQ)
Pearling
Germination
48 h @ 20 °C
Sprouted quinoa
(SQ)
20:80
(PQ:WF)
Wheat flour
(WF)
10:90
(SQ:WF)
20:80
(SQ:WF)
30:70
(SQ:WF)