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# Properties of quinoa and oat spaghetti loaded with carboxymethylcellulose sodium salt and pregelatinized starch as structuring agents

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ABSTRACT

Spaghetti based on quinoa or oat were manufactured using two different structuring agents, carboxymethylcellulose sodium salt (CMC) and pregelatinized starch at three different percentages (0.1%, 0.2%, 0.3% and 10%, 20%, 30%, respectively). The dough rheological properties were determined using a capillary rheometer, the mechanical characteristics of dry spaghetti by a dynamic mechanical analyzer and the sensorial parameters by a trained panel. Elongational and shear viscosity declined or increased when CMC was added to quinoa and oat based dough, respectively. The stress at break for dry non-conventional spaghetti increased for oat spaghetti added with CMC and pregelatinized starch, whereas decreased for quinoa spaghetti. The sensorial parameters of dry and cooked spaghetti in quinoa and oat base were strongly affected by addition of CMC and pregelatinized starch as it was not possible to produce spaghetti in base either quinoa or oat without using the tested structuring agents.



## 1. Introduction

Grains different from durum wheat have been used (as partial or total substitutes) in production of particular kinds of "pasta" with healthy characteristics or directed to specific targets, such as people following a celiac diet (Kasarda, 2001). The amount of high protein flour (soybean, pea, lupine, bean, chickpea) that can be added to or substituted for semolina represents a compromise between functional properties, nutritional improvement and achievement of satisfactory sensory properties of the pasta (Marconi & Carcea, 2001). To obtain pasta of good quality from raw materials it is often necessary to modify the traditional production process (Kent & Evers, 1994). In particular, balanced formulations and adequate technological production processes have to be adopted to counteract any changes in the rheological properties caused by the incorporation of these new ingredients (Marconi & Carcea, 2001).

Quinoa is a pseudo-cereal with origins dating to the Incas. It can be used to produce gluten-free cereal based products (Gambus, Gambus, & Sabat, 2002; Taylor & Parker, 2002; Tosi, Ciappini, & Masciarelli, 1996). Quinoa has a high protein content (14–16%) (Koziol, 1990a, 1992) and in particular, the amino acid composition of seed protein is rich in histidine and lysine. Quinoa has a relatively high quantity of vitamins and minerals, iron and calcium (Risi & Galwey, 1984); moreover, quinoa seed oil has a similar composition in fatty acids to soybean oil (Wood, Lawson, Fairbanks, Robison, & Andersen, 1993) and are particularly rich in linoleate and linolenate (Koziol, 1990b). Oat has recently attracted research and commercial attention mainly due to its nutritional value (Gray et al., 2000; Peterson, Emmons, & Hibbs, 2001). Oat is well accepted in human nutrition and it is an excellent source of different β-glucan, arabinoxylans and cellulose. It contains relatively high levels of protein, lipids (unsaturated fatty acids), vitamins, antioxidants, phenolic compounds and minerals (Emmons & Peterson, 1999; Hampshire, 1998; Panfili, Fratianni, & Irano, 2003; Peterson, 2001; Zadernowski, Nowak-Polakowska, & Rashed, 1999).

High quality pasta has a good cooking resistance and firmness, does not release an excessive amount of organic matter into the cooking water and does not show stickiness (Dexter, Matsuo, & Morgan, 1983; Manser, 1981). Moreover, the pasta quality is related to a resistance to break to dry conditions (Dexter, Matsuo, & Morgan, 1981). Huang, Knight, and Goad (2001) produced non-gluten pasta with characteristics most similar to wheat-based pasta containing higher levels of modified starch, xanthan gum and locust bean gum. Modified starch and monoglyceride were used to produce extruded rise vermicelli. Sensorial analysis showed that vermicelli obtained were not significantly different from other three commercial product prepared with traditional method (Charutigon, Jitpupakdree, Namsree, & Rungsardthong, 2007).

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Sukhcharn, Charanjit, Amrinder, and Dharmesh (2004) studied the effect of sweet potato flour, soy flour, water, arabic gum and CMC on quality responses (sensory, solids loss and hardness) of pasta product by the system known as response surface methodology. The addition of an aliquot of pregelatinized flour or starch that promotes, during the drying cycle, the formation of a starch network capable of improving pasta cooking quality is another way to modify or improve the rheological properties of a formulation (Resmini & Pagani, 1983). The effect of CMC and pregelatinized starch on the quality of amaranthus spaghetti was evaluated (Chillo, Laverse, Falcone, & Del Nobile, 2007) and it emerged that spaghetti samples containing CMC presented better performances especially in cooking with respect to the spaghetti samples with pregelatinized starch.

The aim of this work was to assess the effects of two gluten substitutes, CMC and pregelatinized starch, both used at three different percentages, on the quality of the gluten-free spaghetti in base of quinoa and oat flour.

## 2. Materials and methods

### 2.1. Raw materials

The quinoa and oat flours were bought from Bongiovanni mill (Mondovì, Cuneo, Italy). CMC with 1500–4500 mPa s for 1% aqueous solution at 25 °C were bought from Fluka Chemie (GmbH, Deisenhofen, Germany).

### 2.2. Spaghetti preparation

The compositions of CMC solutions tested in this work are reported in Table 1. CMC was directly added to water, the solution was heated on a hotplate at 50 °C until it was completely dissolved. Afterwards, it was added to the flour to prepare the dough.

Water mixed with part of oat or quinoa flour (see Table 1 for composition) was heated at 80 °C to obtain pregelatinized starch. Afterwards, the pregelatinized starch was cooled at about 40 °C, and then it was added to the oat or quinoa dry flour to prepare the dough.

Spaghetti were produced from a pilot plant made of an extruder (60VR, Namad, Rome, Italy) and a dryer (SG600, Namad). The percentage weight fraction of raw materials used to prepare each of the spaghetti typologies tested in this work is reported in Table 1. The conditions applied were the following: kneading time 20 min, drying temperature 75 °C for quinoa and 85 °C for oat, drying time 6.6 h.

**Table 1**
Formulations used in the preparation of the twelve spaghetti typologies.

| Spaghetti typologies | Quinoa flour (%) | Oat flour (%) | PCS[a] (%) | CMC[b] (%) | Water[c] (%) |
|---|---|---|---|---|---|
| QC01 | 68.5 | – | – | 0.1 | 31.4 |
| QC02 | 68.4 | – | – | 0.2 | 31.4 |
| QC03 | 67.7 | – | – | 0.3 | 32.0 |
| QP10 | 64.5 | – | 10 | – | 35.5 |
| QP20 | 66.5 | – | 20 | – | 33.5 |
| QP30 | 66.5 | – | 30 | – | 33.5 |
| OC01 | – | 62.4 | – | 0.1 | 37.5 |
| OC02 | – | 64.3 | – | 0.2 | 35.5 |
| OC03 | – | 64.2 | – | 0.3 | 35.5 |
| OP10 | – | 64.5 | 10 | – | 35.5 |
| OP20 | – | 62.0 | 20 | – | 38.0 |
| OP30 | – | 62.0 | 30 | – | 38.0 |

[a] Pregelatinized starch (% w/w flour basis).
[b] Carboxymethylcellulose sodium salt (% w/w dough basis).
[c] % w/w dough basis.

### 2.3. Dough rheological properties

Elongational and shear viscosity of each dough sample were investigated by means of a Rosand capillary rheometer (Malvern Instruments, Malvern, Worcester, UK) with twin cylinders. Two different length dies with the same diameter (1 mm) were selected to measure the entry pressure losses. The length of left die was of 10 mm and the pressure was of 10 psi. Whereas, the length of right die was of 0.25 mm and the pressure was of 150 psi. The experiments were carried out at a temperature of 30 °C and at a shear rate between 10–2000 $s^{-1}$. In order to compare elongational and shear viscosity data of the investigated samples, three shear rates (10, 105.36, 1111.13 $s^{-1}$) were chosen as references. The Bagley correction was applied to all data from Rosand rheometer. Three measurements of the viscosity experiment were performed on each sample.

### 2.4. Stress at break

To determine the stress at rupture a spaghetti strand (35 mm-length) was used. Each spaghetti sample was fixed to a dual-cantilever clamp and submitted to stress–strain tests by a Dynamic Mechanical Analyzer (DMA-Q 800, TA Instruments, New Castle, DE, USA). Tests were carried out at 25 °C with a force ramp of 0.4 N/min. The stress at break is the recorded stress at the moment of rupture of the sample and is expressed in MPa. Ten measurements for each sample were performed.

### 2.5. Sensory analysis

Optimal cooking time (OCT) of the investigated spaghetti was evaluated submitting the samples to a panel of ten trained tasters. Each spaghetti sample was cooked at different times and tested by the panel. The panelists were then asked to indicate the OCT. The spaghetti samples were submitted to the panel for estimation of color, homogeneity of the uncooked pasta and stickiness, bulkiness, firmness, flavor and taste of the cooked pasta at optimum cooking time (Del Nobile et al., 2009). To this aim, a nine-point hedonic rating scale, where 1 corresponded to extremely unpleasant, 9 to extremely pleasant and 5 to satisfactory (acceptability threshold) was used (Chillo et al., 2007).

### 2.6. Statistical analysis

The results were compared by a one-way variance analysis (ANOVA). A Duncan's multiple range test, with the option of homogeneous groups ($p < .05$), was carried out to determine significant differences between spaghetti samples. STATISTICA 7.1 for Windows (StatSoft, Inc, Tulsa, OK, USA) was used for this purpose.

## 3. Results and discussion

In the following, the influence of CMC and pregelatinized starch on the rheological properties of quinoa and oat based dough as well as on the mechanical and sensory characteristics of dry and cooked spaghetti are presented separately. It is worth noting that spaghetti based solely on quinoa and oat flour were not used as a control because of the remarkable difficulties faced during the spaghetti extrusion step.

### 3.1. Dough rheological measurement

Table 2 lists both the elongational viscosity and shear viscosity at three shear rates (10, 105.36 and 1111.13 $s^{-1}$) for all examined samples. As can be inferred from this table, the trend is typical of

**Table 2**
Elongational and shear viscosity of the spaghetti samples at three shear rate (10, 105.36 and 1111.13 $s^{-1}$).

| Spaghetti typologies | Elongational viscosity at 10 $s^{-1}$ | Elongational viscosity at 105.36 $s^{-1}$ | Elongational viscosity at 1111.13 $s^{-1}$ | Shear viscosity at 10 $s^{-1}$ | Shear viscosity at 105.36 $s^{-1}$ | Shear viscosity at 1111.13 $s^{-1}$ |
|---|---|---|---|---|---|---|
| QC01 | $1877.86^{a} \pm 222.86$ | $187.87^{a} \pm 1.01$ | $17.61^{a} \pm 0.09$ | $2203.08^{a} \pm 37.66$ | $528.42^{a} \pm 17.45$ | $187.11^{a} \pm 6.56$ |
| QC02 | $1724.00^{a} \pm 181.37$ | $159.98^{b} \pm 6.66$ | $20.32^{b} \pm 1.13$ | $1784.85^{b} \pm 277.94$ | $793.12^{b} \pm 41.37$ | $244.40^{b} \pm 9.75$ |
| QC03 | $1123.96^{b} \pm 45.73$ | $150.26^{c} \pm 3.56$ | $15.71^{c} \pm 0.02$ | $986.59^{c} \pm 50.36$ | $409.36^{c} \pm 10.15$ | $197.50^{a} \pm 7.00$ |
| QP10 | $1645.87^{d} \pm 472.41$ | $137.68^{d} \pm 33.09$ | $18.00^{d} \pm 1.85$ | $2227.03^{d} \pm 556.05$ | $904.95^{d} \pm 178.19$ | $287.81^{d} \pm 17.28$ |
| QP20 | $3273.46^{e} \pm 88.45$ | $196.35^{e} \pm 2.10$ | $14.14^{e} \pm 0.45$ | $431.68^{e} \pm 27.13$ | $218.48^{e} \pm 10.45$ | $119.84^{e} \pm 3.59$ |
| QP30 | $472.96^{f} \pm 10.29$ | $47.00^{f} \pm 3.95$ | $6.90^{f} \pm 0.50$ | $1343.20^{f} \pm 8.73$ | $475.62^{f} \pm 7.26$ | $130.83^{e} \pm 4.56$ |
| OC01 | $182.51^{g} \pm 3.43$ | $35.14^{g} \pm 0.51$ | $6.17^{g} \pm 0.21$ | $2300.54^{g} \pm 51.12$ | $601.32^{g} \pm 17.69$ | $158.82^{g} \pm 0.14$ |
| OC02 | $304.98^{h} \pm 0.49$ | $61.46^{h} \pm 1.05$ | $16.74^{h} \pm 0.82$ | $5131.02^{h} \pm 16.99$ | $1264.12^{h} \pm 9.70$ | $214.00^{h} \pm 0.27$ |
| OC03 | $322.52^{i} \pm 3.69$ | $64.82^{i} \pm 0.5$ | $16.45^{h} \pm 0.72$ | $5095.84^{h} \pm 21.45$ | $1234.15^{i} \pm 7.48$ | $222.55^{i} \pm 2.46$ |
| OP10 | $135.58^{l} \pm 54.01$ | $29.52^{l} \pm 4.20$ | $7.45^{l} \pm 0.82$ | $3173.95^{l} \pm 815.34$ | $712.27^{l} \pm 0.54$ | $176.47^{l} \pm 9.58$ |
| OP20 | $205.49^{n} \pm 10.52$ | $40.06^{m} \pm 0.23$ | $9.61^{m} \pm 0.33$ | $2331.72^{l} \pm 27.27$ | $643.88^{m} \pm 7.44$ | $189.08^{m} \pm 1.36$ |
| OP30 | $160.69^{l,m} \pm 2.03$ | $35.66^{m} \pm 0.64$ | $10.69^{n} \pm 0.06$ | $2396.49^{l} \pm 53.95$ | $675.05^{n} \pm 0.38$ | $173.43^{l} \pm 1.56$ |

Mean of values ± standard deviation.
One-way variance analysis was performed to evaluate the statistical differences between the values of rheological parameters of four spaghetti group (QC, QP, OC and OP).
[a–n] Mean in the same column followed by different superscript letters differ significantly ($p < .05$).

pseudoplastic materials. The pseudoplastic behavior of a polymeric system can be explained as follows (Brydson, 1981). If the system of asymmetric particles, which are initially randomly dispersed, is subjected to shear, the particles tend to align themselves with the major axis, in the direction of shear, thus reducing the viscosity. The degree of alignment is a function of the deformation rate. At low shear rate, there is only a slight shift from randomness but at higher shear rate particles are almost completely oriented (George, Janardhan, Anand, Bhagawan, & Sabu, 1996).

As can be observed in Table 2, the elongational viscosity declines with the shear rate indicating a shear-thinning behavior of the studied samples. Moreover, at low shear rate there is a significant decrease in the elongational and shear viscosity with the CMC concentration for quinoa dough sample. On the other hand, at high shear rate, the quinoa samples added with CMC did not have a particular trend. On the contrary, the oat dough added with CMC showed a significant increase in the elongational and shear viscosity with CMC concentration. The different behavior observed for quinoa and oat samples can be attributed to the different intermolecular interactions that take place between CMC and the constituents of the tested flours. Results suggest that there is a stronger interaction between CMC and oat constituents, which bring about an increase in the dough elongational and shear viscosity with CMC concentration. On the contrary, due to the weak interaction between CMC and quinoa components, CMC seems to act more like a lubricant, which induces a reduction in the dough elongational and shear viscosity. The rheological behavior of the dough depends on several factors such as the nature of the protein matrix and its amount, the interaction between the protein matrix and the additives, starch, fat and fibre content, process conditions. Quinoa and oat are sources of starches which differ significantly in composition and morphology. This could be the cause of the different rheological behavior of the investigated doughs.

As can be noted in the table, for the quinoa dough both elongational and shear viscosity values were not affected by the pregelatinized starch concentrations in the examined range for the shear rate. Moreover, the table highlights that also for the oat dough the shear and elongational viscosity did not show a definite trend. The dough viscosity is directly influenced by the degree of starch gelatinization of the feed materials (Hsieh, Huff, Lue, & Stringer, 1991). Gelatinization is the major transition of starch during thermal processes and it is related to the characteristics of the starch granule, such as degree of crystallinity (Krueger, Knutson, Inglett, & Walker, 1987). This is influenced by chemical composition of starch; therefore, starches from different botanical sources, differing in composition, exhibited different transition temperatures and enthalpies of gelatinization (Kim, Wiesenborn, Orr, & Grant, 1995).

### 3.2. Spaghetti mechanical properties

Residual deformations (or alternatively 'residual stresses') are generally formed during the desiccation process of spaghetti due both to the presence of a water concentration gradient and the viscoelastic nature of the pasta matrix (Itaya, Kobayashi, & Hayakawa, 1995; Litchfield & Okos, 1988). Therefore, the extent of residual deformations may depend on the presence of structuring agents and on their concentrations. It has been often reported in literature that 'residual deformations' are the main cause for the breakage susceptibility or stress to break of dry spaghetti (Andrieu, Boivin, & Stamatopoulus, 1988). In Fig. 1a the stress at break for quinoa spaghetti sample added with CMC is reported. The QC02 sample

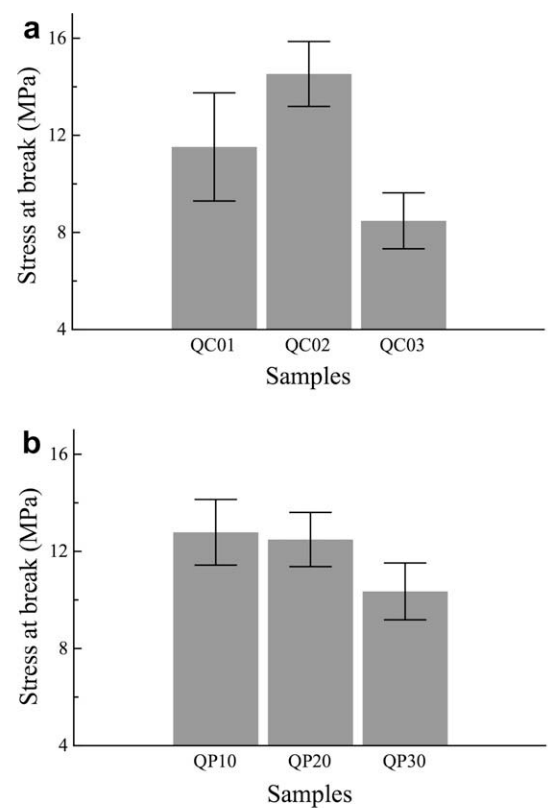


**Fig. 1.** (a) Stress at break for quinoa spaghetti samples added with 0.1%, 0.2% and 0.3% of CMC. (b) Stress at break for quinoa spaghetti samples added with 10%, 20% and 30% of pregelatinized starch.

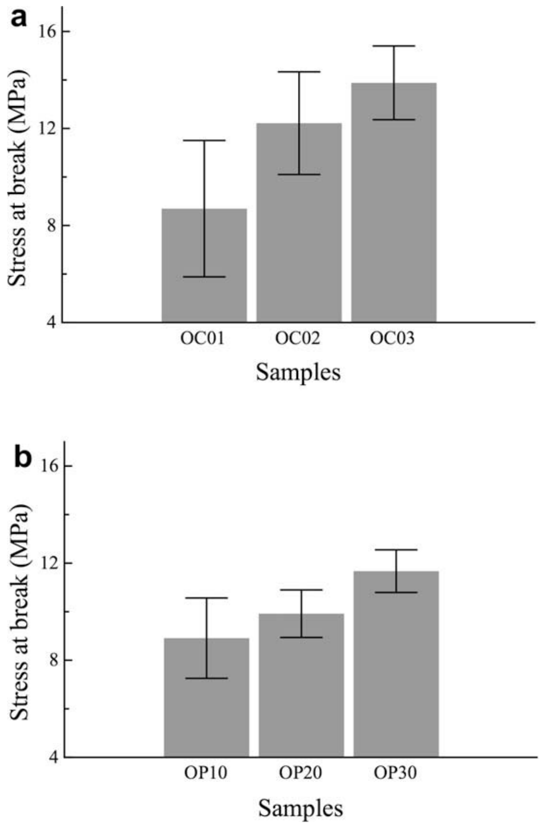


**Fig. 2.** (a) Stress at break for oat spaghetti samples added with 0.1%, 0.2% and 0.3% of CMC. (b) Stress at break for oat spaghetti samples added with 10%, 20% and 30% of pregelatinized starch.

had the highest stress to break, whereas the QC03 spaghetti sample reported the lowest value. Fig. 1b presents the stress at break for quinoa spaghetti sample added with pregelatinized starch. The samples with the 10% and 20% pregelatinized starch content showed the same behavior, while the one with the 30% pregelatinized starch content was less resistant to the break. Results suggest that the structuring agents tested in this study do not affect at a great extent the stress at break of quinoa based spaghetti. In accordance with what found for rheological measurement, most probably a weak interaction between structuring agents and quinoa components induces a reduction in the stress at break values. Unfortunately, it is not possible to establish the reasons of the behavior described before on the base of available data. In fact, the break properties of a given product depend on the properties of the matrix as well as on the presence of defects (Del Nobile & Massera, 2002; Itaya et al., 1995).

Fig. 2a shows the stress at break for the oat spaghetti samples with CMC, whereas Fig. 2b reports the stress at break for the oat spaghetti samples added with pregelatinized starch. In both case, an increase of stress at break with the rise of structuring agent concentration was observed. For example, the stress at break for oat spaghetti with CMC surged from 8.69 to 13.88 MPa, strongly improving its rupture resistance; whilst, for oat spaghetti samples added with pregelatinized starch, the stress increased from 8.90 to 11.66 MPa. The results obtained for quinoa spaghetti are according to those found for amaranthus spaghetti added with CMC and pregelatinized starch (Chillo et al., 2007). Probably, as noticed beforehand for rheological measurements, a stronger interaction between structuring agents and oat constituents bring about an increase of the resistance to the break of the samples. This could be due to the different composition and morphology of the oat starch with respect to that of quinoa.

### 3.3. Sensory analysis

The optimal cooking time values of tested spaghetti are listed in Table 3 along with the sensorial attribute as determined by the trained panelists. From the table emerges that the optimum cooking time for all non-conventional spaghetti was lower (about 5 min) than that of traditional semolina spaghetti (about 8 min) (Cafieri, Chillo, Mastromatteo, Suriano, & Del Nobile, 2008). This behavior can be ascribed either to the higher water diffusion coefficient or to the different dependence of the spaghetti mechanical properties on absorbed water concentration. In the former case, higher water diffusivity would speed up the water absorption process (Cafieri et al., 2008), which in turn would speed up spaghetti softening. Accelerated spaghetti softening could have been also caused by the ability of the tested spaghetti to loose their mechanical properties in the presence of water when compared to spaghetti in base durum semolina. As can be observed in table, the sensorial characteristics of dry spaghetti and OCT were not statistically different among the spaghetti samples in base of quinoa and oat with added CMC and pregelatinized starch. It is worth noting that the difference observed in the stress at break values were not detected by the panelists. Most probably this is due to the lower sensibility of the panelist if compared to the apparatus used to determine the dry spaghetti mechanical properties. The sensorial data on cooked spaghetti recorded by trained panelists allowed

**Table 3**
Optimum cooking time and sensory attributes of spaghetti samples.

| Spaghetti samples | OCT (min) | Dry spaghetti | | Cooked spaghetti | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Colour | Homogeneity | Bulkiness | Adhesiveness | Firmness | Flavour | Taste |
| QC01 | 5.5$^{a}$ ± 0.5 | 5.4$^{a}$ ± 1.3 | 6.4$^{a}$ ± 1.6 | 7.4$^{a}$ ± 0.8 | 7.1$^{a}$ ± 0.7 | 5.7$^{a}$ ± 1.0 | 5.4$^{a}$ ± 1.0 | 5.2$^{a}$ ± 1.4 |
| QC02 | 5.0$^{a}$ ± 1.0 | 6.1$^{a}$ ± 1.2 | 5.9$^{a}$ ± 1.6 | 6.5$^{a}$ ± 0.9 | 6.6$^{a}$ ± 1.1 | 5.4$^{a}$ ± 1.5 | 5.5$^{a}$ ± 1.2 | 5.2$^{a}$ ± 1.1 |
| QC03 | 5.5$^{\circ}$ ± 1.0 | 5.6$^{a}$ ± 0.9 | 5.4$^{a}$ ± 1.7 | 6.9$^{a}$ ± 0.7 | 7.3$^{a}$ ± 0.7 | 6.0$^{a}$ ± 1.3 | 5.2$^{a}$ ± 1.5 | 5.3$^{a}$ ± 1.2 |
| QP10 | 4.5$^{b}$ ± 0.5 | 6.0$^{b}$ ± 1.1 | 5.8$^{b}$ ± 1.2 | 7.3$^{b}$ ± 0.6 | 7.0$^{b}$ ± 1.2 | 6.0$^{b}$ ± 0.8 | 6.2$^{b}$ ± 1.2 | 5.5$^{b}$ ± 0.7 |
| QP20 | 5.5$^{b}$ ± 1.0 | 5.7$^{b}$ ± 1.1 | 6.0$^{b}$ ± 1.2 | 7.3$^{b}$ ± 0.6 | 7.1$^{b}$ ± 0.5 | 6.0$^{b}$ ± 1.4 | 6.2b ± 1.6 | 5.5$^{b}$ ± 1.0 |
| QP30 | 5.0$^{b}$ ± 0.5 | 6.4$^{b}$ ± 1.3 | 5.1$^{b}$ ± 0.8 | 7.4$^{b}$ ± 0.7 | 7.1$^{b}$ ± 0.7 | 6.0$^{b}$ ± 1.3 | 6.4$^{b}$ ± 1.4 | 5.0$^{b}$ ± 1.3 |
| OC01 | 5.0$^{c}$ ± 1.0 | 6.7$^{c}$ ± 1.3 | 6.0$^{c}$ ± 1.3 | 5.3$^{c}$ ± 1.2 | 3.7$^{c}$ ± 1.1 | 4.2$^{c}$ ± 1.0 | 6.4$^{c}$ ± 1.3 | 5.3$^{c}$ ± 1.4 |
| OC02 | 5.0$^{c}$ ± 0.5 | 5.8$^{c}$ ± 1.3 | 5.7$^{c}$ ± 0.8 | 5.2$^{c}$ ± 1.4 | 4.3$^{c}$ ± 0.8 | 4.5$^{c}$ ± 1.4 | 6.5$^{c}$ ± 1.6 | 5.7$^{c}$ ± 1.4 |
| OC03 | 4.5$^{c}$ ± 0.5 | 5.3$^{c}$ ± 1.5 | 5.5$^{c}$ ± 1.0 | 5.0$^{c}$ ± 1.1 | 3.9$^{c}$ ± 1.1 | 3.4$^{c}$ ± 1.3 | 5.5$^{c}$ ± 1.2 | 5.8$^{c}$ ± 0.9 |
| OP10 | 4.5$^{d}$ ± 0.5 | 5.7$^{d}$ ± 1.5 | 5.1$^{d}$ ± 1.3 | 3.7$^{d}$ ± 1.1 | 5.3$^{d}$ ± 1.1 | 4.2$^{d}$ ± 1.0 | 5.9$^{d}$ ± 1.4 | 5.9$^{d}$ ± 0.9 |
| OP20 | 4.5$^{d}$ ± 0.5 | 6.5$^{d}$ ± 1.0 | 6.1$^{d}$ ± 0.9 | 4.3$^{d}$ ± 0.8 | 4.3$^{d}$ ± 0.8 | 4.5$^{d}$ ± 1.4 | 5.9$^{d}$ ± 1.5 | 5.5$^{d}$ ± 1.1 |
| OP30 | 5.0$^{d}$ ± 1.0 | 6.0$^{d}$ ± 1.2 | 5.6$^{d}$ ± 1.3 | 3.9$^{d}$ ± 1.1 | 3.9$^{d}$ ± 1.1 | 3.4$^{d}$ ± 1.3 | 5.9$^{d}$ ± 1.3 | 5.1$^{a}$ ± 0.9 |

Mean of values ± standard deviation.
One-way variance analysis was performed to evaluate the statistical differences between the values of sensorial parameters of four spaghetti group (QC, QP, OC and OP).
$^{a–d}$ Mean in the same column followed by different superscript letters differ significantly ($p < .05$).

us to evaluate a possible sensorial impact of the addition of CMC and pregelatinized starch on the spaghetti quality. Data listed in Table 3 highlight that all spaghetti in base quinoa were scored above the acceptability threshold (i.e., five), whereas oat based spaghetti were scored unacceptable (i.e., score lower than 5) from the firmness and adhesiveness point of view for CMC loaded oat spaghetti, and from bulkiness, firmness and adhesiveness point of view for oat spaghetti added with pregelatinized starch. Moreover, no difference in the cooked spaghetti quality was detected by increasing the structuring agents concentration. Data showed in the table suggest that the structuring agents do work better with spaghetti in base quinoa if compared to oat based spaghetti. In fact, concerning the former, the attribute limiting the cooked spaghetti quality is the taste, regardless either the type of structuring agent used or its concentration, which is strictly related to the taste of quinoa by itself (Stuardo & San Martín, 2008). Regarding the quality of cooked spaghetti in base oat, bulkiness, firmness and adhesiveness seem to limit its quality, which are all related to the presence of the structuring agent and its interaction with the oat constituents. The adhesiveness is related to the amount of water absorbed by the matrix during the cooking process. The water absorbed from the starch causes the solubilization of amylose in water of cooking and the presence of amylopectin on the pasta surface. The latter is related to the adhesiveness of pasta. Therefore, more water is absorbed more amylopectin there is on the pasta surface. The high absorption of water is due to the presence of a low amount of resistant starch, which is less available to the imbibition (Skrabanja, Liljeberg, Kreft, & Björck, 2001). Moreover, as reported in literature, the increase of the amylose content decreases the adhesiveness (Gianibelli, Sissons, & Batey, 2005). Also in this case, the high adhesiveness of oat based spaghetti is due to the composition of the starch granules that differs from that of the quinoa.

## 4. Conclusions

The use of CMC and pregelatinized starch made possible the production of spaghetti in base quinoa and oat. This is most probably related to the structuring ability of the above-mentioned compounds. In fact, CMC and pregelatinized starch influenced both the rheological and mechanical properties of non-conventional doughs and spaghetti samples. In particular, CMC and pregelatinized starch had an effect on the elongational and shear viscosity. The elongational and shear viscosity declined, for the quinoa dough, with CMC concentration, while they increased with CMC concentration for the oat dough. The stress at break increased with the rise of structuring agent concentration for the oat spaghetti samples added with both CMC and pregelatinized starch. Regarding to the quinoa based spaghetti, results suggest that the structuring agents do not affect to a great extent the stress at break. In addition, the sensory attributes of dry and cooked spaghetti samples tested in this work were not significantly different with the concentrations of the investigated structuring agents.

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