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Temperature-induced changes in dough elasticity as a useful tool in defining the firmness of cooked pasta

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Semolina from durum wheat is universally recognized as the best raw material for producing pasta with good cooking quality [1-2]. Ultrastructural observations have revealed that during cooking the faster the formation of a continuous protein network, the slower the starch swelling, thus ensuring consistency and the absence of stickiness in pasta [3]. On the contrary, if the protein network lacks elasticity or its formation is delayed, starch granules will easily swell, and part of the starchy material will pass into the cooking water, resulting in a product characterized by stickiness and poor consistency [3].

Semolina classification is currently based on tests carried out at room temperature and that consider, above all, protein quantity and quality, the latter evaluated by means of some indices such as gluten index and alveographic indices [4]. Alamri et al. [5] proposed the Glutograph-E instrument for evaluating the gluten quality to replace the farinograph, mixograph, extensograph and alveograph tests. More recently, Bong and Mathey [6] developed a method to measure the stretch and relaxation values of cooked pasta but up-to-now there is no evidence of the correlation between the Glutograph stretch and relaxation indices and the texture of cooked pasta. Recently, the Mixolab has been proposed for the study of the rheological behaviour of the dough during heating and cooling treatments [7]. However, the hydration level is higher than that used in the actual pasta-making and the continuous shear stress is responsible for the dough breakage. Thus, none of the majority of the current tests can evaluate the competition between starch gelatinization and protein coagulation that occurs during pasta cooking, thus neglecting the role of starch-protein interactions and of irreversible protein-protein interactions and induced by heating in defining pasta cooking quality. The main objective of the present research was to develop a rheological test able to give information related to protein coagulation and starch gelatinisation phenomena occurring during cooking. For this purpose, the Glutograph-E (Brabender GmbH&Co., Duisburg, Germany) was adapted to measure changes in elasticity induced by heating on sheeted dough, where proteins are arranged in a continuous and homogeneous network, that surrounds starch granules. The information obtained by this procedure were related to cooking performances evaluated by sensory analysis.

Four durum wheat semolina samples characterized by high variability for indices related to the quantity and the quality of proteins, determinants of pasta quality [1], were chosen (Table 1). Samples were characterized by means of standard methods, i.e., in terms of protein content [8], gluten content [9], gluten index [10], and W and P/L alveographic indices [11]. Dried spaghetti were produced according to D´Egidio et al.[1]. In particular, semolina and water (35% dough moisture) were mixed and extruded into a spaghetti shape (1.65 mm diameter) in an experimental press (30 kg/h; Namad Press, Namad, Italy). All samples were dried in an experimental drying cell (Afrem dryer, Afrem, France) using a low temperature drying cycle (50 °C max for 14 h) and stored at room temperature until analyzed.

Sensory properties of cooked spaghetti were evaluated after 13 min cooking (pasta:water ratio = 1:10) by a trained panel of 8 experts according to D'Egidio et al. [4]. Pasta firmness was expressed as the resistance of cooked pasta to chewing and it was scored on a 10 to 100 scale, where 100 corresponded to very good. The mean of the values given by the panelists was reported.

The sheeted dough samples used to set up the new procedure were produced by mixing semolina (50 g) and water (35% dough moisture) for 15 minutes at 63 rpm in a Farinograph-E (Brabender GmbH and Co KG, Duisburg, Germany). System temperature and water was kept at 40°C. An aluminum plunger for the 50 g farinograph bowl was used, in order to study the behaviour of the dough in a fixed volume, according to Matsuo and Irvine [12]. The dough prepared in the Farinograph was roll-sheeted in a home-made pasta machine (Marcato s.p.a., Campodarsego, Padova, Italy), using a constant sheeting speed (63 rpm). The dough was sheeted four times at each thickness (2.6, 2.3, 1.8, and 1.4 mm, thickness), folding the sheet at each step to obtain a continuous and homogeneous dough. The last step was carried out at 1.8

mm thickness and a sheet with a final thickness of 2.1 ± 0.2 mm was obtained. After forming, 2 pieces of 5 cm diameter were cut, overlapped (4.2 ± 0.1 mm thickness), and stored for 40 minutes to equilibrate them at a constant activity water value (aw = 1) in a climatic cell kept at 30°C by a jacket with a circulating water.

A creep-recovery test was carried out on dough-sheet, by using a Glutograph-E (Brabender GmbH and Co KG, Duisburg, Germany). The measuring system of the instrument consists of two parallel, round, finely orrugated plates mounted at a defined distance. In order to measure change in elasticity during heating, the Glutograph-E was modified as follows: (1) it was connected to a waterbath using steel tubes with silicone foam insulation; (2) the bottom aluminium plate was replaced with a plastic one, in order to limit heat dissipation; (3) the gap between the two bases was set up at 3 mm; (4) a temperature probe was placed inside the base, in direct contact with the sample.

After the resting time, dough sheet was placed between the two plates. The fixed distance and diameter of the two plates provided a defined sample volume and reproducible sample geometry. Excess dough was removed by using the cutter provided with the Glutograph-E. The exposed surfaces at the edge of the plates were coated with silicon to prevent drying during the test-time. Before analysis, the sample was rested for 5 min. During the test, while the upper plate remains still, the lower plate was turned with a constant force (0.08 N/m) for 10 seconds (stretching step). This constant force determined the extension of the dough. After stretching, the force was released for 30 seconds (relaxing step) and the sample recovered according to its elasticity. Stretching (10 s) and relaxation (30 s) were applied over and over during the test time, while the temperature progressively increased from 30 to 90°C at a heating rate of 1.2 °C/min.

A sample curve produced by Glutograph-E during a test is shown in Figure 1. For each peak recorded, stretching value was calculated as the difference between the maximum (B in Figure 1) and the minimum (A in Figure 1) value during the stretching step; while recovery was calculated as the difference between the maximum (B in Figure 1) and the minimum (C in Figure 1) value during the recovery step. Stretching and recovery values were plotted against temperature (Figure 2). The tracing reported in Figure 2 can be divided into three parts and in each of them semolina samples exhibited a particular behaviour in terms of elasticity. In the first part of the curve, stretching and recovery values increased with the increase in temperature, until a maximum in the temperature range of 53-57 °C. The maximum temperature value is likely related to the maximum temperature at which the protein network is still extensible and the starch granules are below the gelatinization temperature (data not shown). The increase in stretching and recovery values suggests a softening of the structure: starch gelatinization occurred and, until this value, the protein network was still able to interact and respond to the stresses of stretching. After the peak, stretching and recovery decreased as the temperature continued to increase, since prolonged heating produced stronger (stiffer) structures. In the last part of the curve, heating to 80 °C greatly decreased the stretching values indicating that the material was almost undeformable.

The conventional indices used to predict the pasta-making quality of semolina samples are summarized in Table 1. In the same table, the firmness of related cooked pasta - evaluated as the resistance of cooked pasta to chewing and considered the most comprehensive measure for cooking quality evaluation [4] – is also presented. Pasta from semolina A, B, and C showed high firmness; on the other hand, semolina D gave an acceptable product, even if characterized by poor firmness [13].

Both stretching and recovery curves, collected for each dough sample, were integrated every 5°C from 30 to 90°C. The loss of elasticity was calculated as (S-R)/S*100, where S is the area under the stretching curve, and R is the area under the recovery curve (Figure 3). In general, dough exhibiting high values of loss of elasticity gave a pasta with low firmness (see dough D) and likely related to a “weak” material structure; whereas dough with low values of loss of elasticity (see dough A, B, and C) were representative of high firmness and likely of a strong (stiff) structure. Even if the conventional tests for evaluating semolina quality (gluten index and alveographic indices) showed differences among semolina A, B, and C, no differences were detected as regards the loss of elasticity, in agreement with the firmness values. Both gluten index and alveographic test are carried out at room temperature and provide information only on the strength of the gluten network, neglecting the role of starch. On the other hand, the results suggest that this approach has the potential to provide information on the final results of two simultaneous phenomena - protein coagulation and starch gelatinisation – whose kinetics are the key for obtaining a pasta of good or poor quality. Further studies are underway at high heating rate and with larger sample numbers, testing also the changes in elasticity induced by heating on extruded dough, in order to propose a rapid but sensitive new test for evaluating semolina properties and its suitability for the production of high quality pasta.

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186 **Table 1** Semolina characteristics and sensory firmness of the related cooked pasta

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	Protein (g/100 g d.b.)	Gluten (g/100 g d.b.)	Gluten Index	W ($*10^{-4}$ J)	P/L	Pasta Firmness
Semolina A	13.3	10.9	97	390	2.52	78
Semolina B	12.4	9.6	86	219	1.27	75
Semolina C	13.4	11.0	82	274	1.04	78
Semolina D	11.1	8.4	81	171	3.25	67

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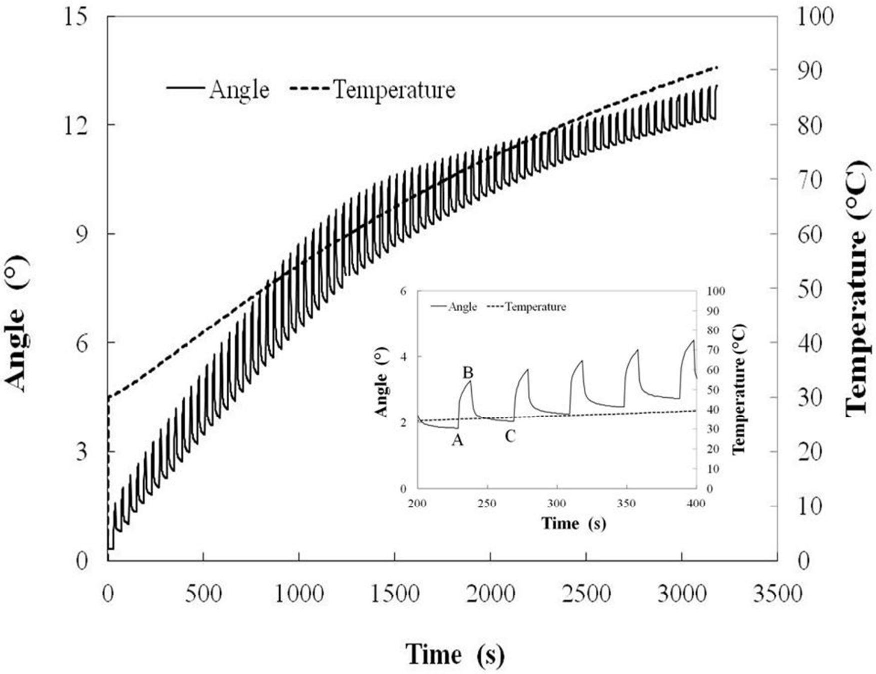

Fig 1 Sample curve produced by Glutograph-E.

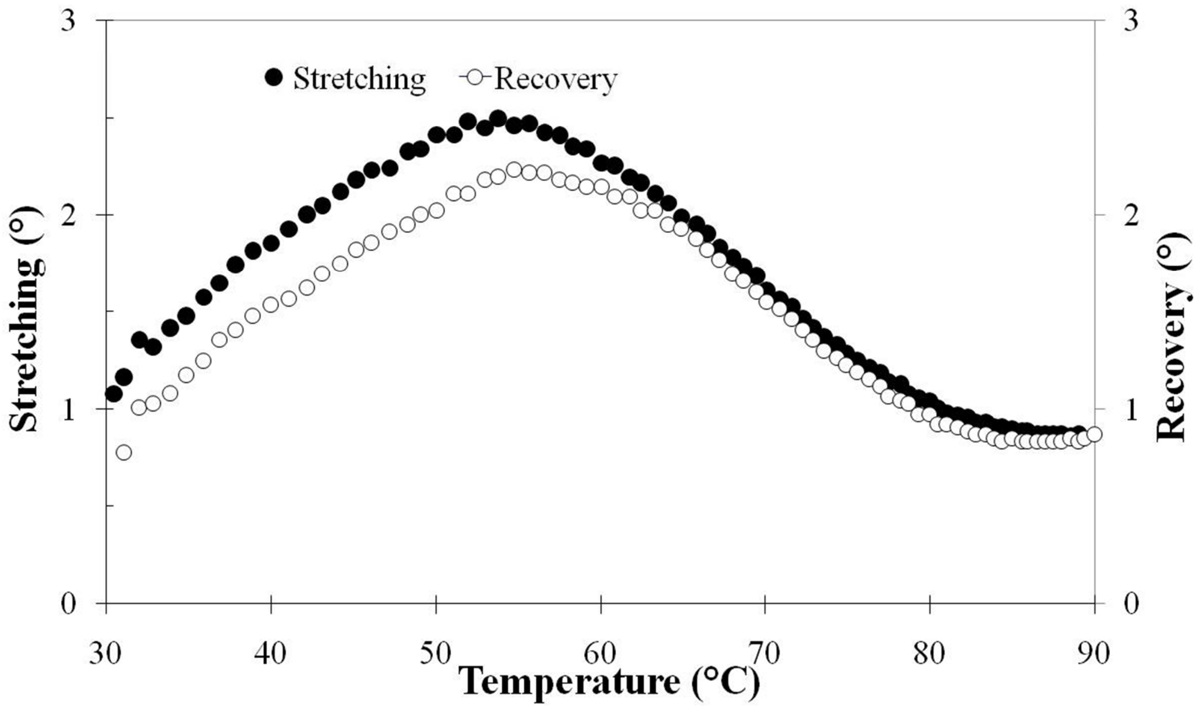

Fig. 2 Elaboration of the sample curve produced by Glutograph-E.

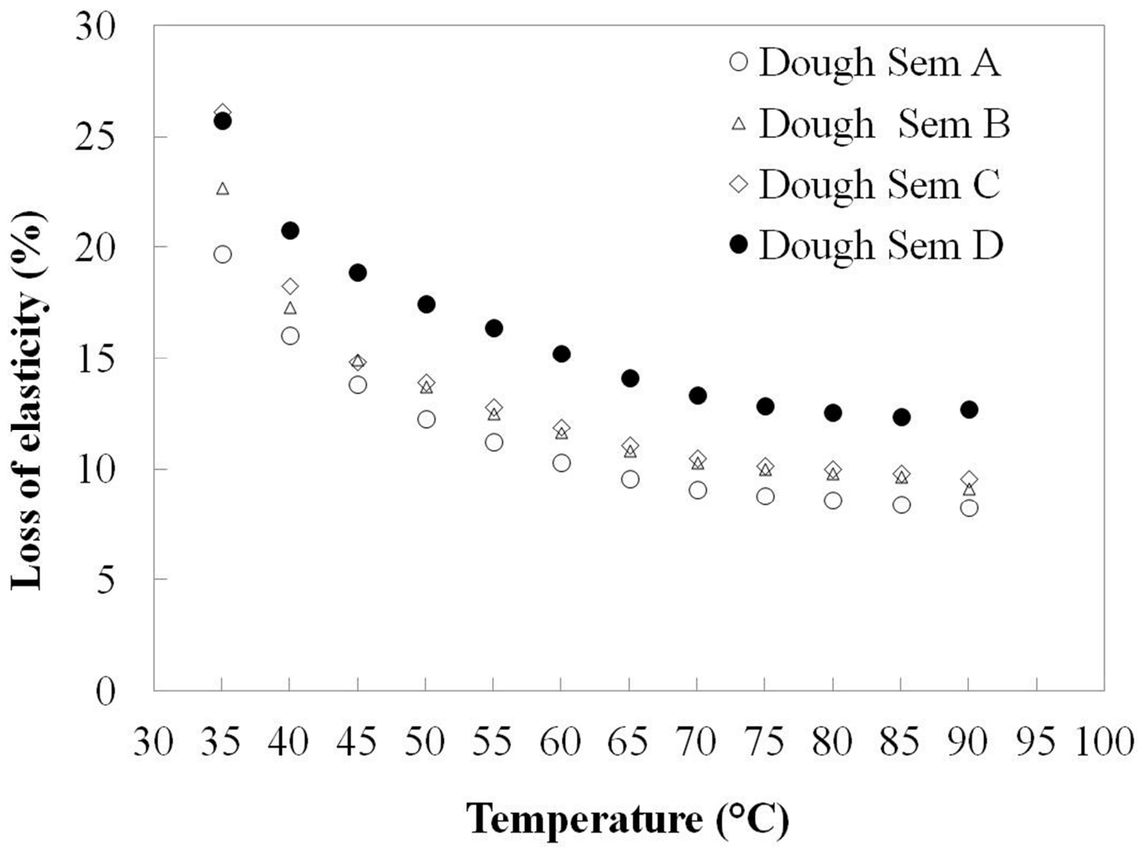

Fig. 3 Loss of elasticity during the stress relaxation test.