



Draft Manuscript for Review

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

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21 Keywords: durum wheat semolina; glutograph; elasticity; firmness of cooked pasta

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3 23 Semolina from durum wheat is universally recognized as the best raw material for producing  
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5 24 pasta with good cooking quality [1-2]. Ultrastructural observations have revealed that during  
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7 25 cooking the faster the formation of a continuous protein network, the slower the starch  
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9 26 swelling, thus ensuring consistency and the absence of stickiness in pasta [3]. On the contrary,  
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11 27 if the protein network lacks elasticity or its formation is delayed, starch granules will easily  
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13 28 swell, and part of the starchy material will pass into the cooking water, resulting in a product  
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15 29 characterized by stickiness and poor consistency [3].

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18 30 Semolina classification is currently based on tests carried out at room temperature and that  
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20 31 consider, above all, protein quantity and quality, the latter evaluated by means of some indices  
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22 32 such as gluten index and alveographic indices [4]. Alamri et al. [5] proposed the Glutograph-  
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24 33 E instrument for evaluating the gluten quality to replace the farinograph, mixograph,  
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26 34 extensograph and alveograph tests. More recently, Bong and Mathey [6] developed a method  
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28 35 to measure the stretch and relaxation values of cooked pasta but up-to-now there is no  
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30 36 evidence of the correlation between the Glutograph stretch and relaxation indices and the  
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32 37 texture of cooked pasta. Recently, the Mixolab has been proposed for the study of the  
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34 38 rheological behaviour of the dough during heating and cooling treatments [7]. However, the  
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36 39 hydration level is higher than that used in the actual pasta-making and the continuous shear  
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38 40 stress is responsible for the dough breakage. Thus, none of the majority of the current tests  
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40 41 can evaluate the competition between starch gelatinization and protein coagulation that occurs  
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42 42 during pasta cooking, thus neglecting the role of starch-protein interactions and of irreversible  
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44 43 protein-protein interactions and induced by heating in defining pasta cooking quality. The  
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46 44 main objective of the present research was to develop a rheological test able to give  
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48 45 information related to protein coagulation and starch gelatinisation phenomena occurring  
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50 46 during cooking. For this purpose, the Glutograph-E (Brabender GmbH&Co., Duisburg,  
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52 47 Germany) was adapted to measure changes in elasticity induced by heating on sheeted dough,  
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54 48 where proteins are arranged in a continuous and homogeneous network, that surrounds starch  
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3 49 granules. The information obtained by this procedure were related to cooking performances  
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5 50 evaluated by sensory analysis.  
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8 51 Four durum wheat semolina samples characterized by high variability for indices related to  
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10 52 the quantity and the quality of proteins, determinants of pasta quality [1], were chosen (Table  
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12 53 1). Samples were characterized by means of standard methods, i.e., in terms of protein content  
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14 54 [8], gluten content [9], gluten index [10], and W and P/L alveographic indices [11]. Dried  
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16 55 spaghetti were produced according to D'Egidio et al.[1]. In particular, semolina and water  
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18 56 (35% dough moisture) were mixed and extruded into a spaghetti shape (1.65 mm diameter) in  
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20 57 an experimental press (30 kg/h; Namad Press, Namad, Italy). All samples were dried in an  
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22 58 experimental drying cell (Afreem dryer, Afrem, France) using a low temperature drying cycle  
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24 59 (50 °C max for 14 h) and stored at room temperature until analyzed.  
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28 60 Sensory properties of cooked spaghetti were evaluated after 13 min cooking (pasta:water ratio  
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30 61 = 1:10) by a trained panel of 8 experts according to D'Egidio et al. [4]. Pasta firmness was  
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32 62 expressed as the resistance of cooked pasta to chewing and it was scored on a 10 to 100 scale,  
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34 63 where 100 corresponded to very good. The mean of the values given by the panelists was  
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36 64 reported.  
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39 65 The sheeted dough samples used to set up the new procedure were produced by mixing  
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41 66 semolina (50 g) and water (35% dough moisture) for 15 minutes at 63 rpm in a Farinograph-E  
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43 67 (Brabender GmbH and Co KG, Duisburg, Germany). System temperature and water was kept  
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45 68 at 40°C. An aluminum plunger for the 50 g farinograph bowl was used, in order to study the  
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47 69 behaviour of the dough in a fixed volume, according to Matsuo and Irvine [12]. The dough  
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49 70 prepared in the Farinograph was roll-sheeted in a home-made pasta machine (Marcato s.p.a.,  
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51 71 Campodarsego, Padova, Italy), using a constant sheeting speed (63 rpm). The dough was  
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53 72 sheeted four times at each thickness (2.6, 2.3, 1.8, and 1.4 mm, thickness), folding the sheet at  
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55 73 each step to obtain a continuous and homogeneous dough. The last step was carried out at 1.8  
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3 74 mm thickness and a sheet with a final thickness of  $2.1 \pm 0.2$  mm was obtained. After forming,  
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5 75 2 pieces of 5 cm diameter were cut, overlapped ( $4.2 \pm 0.1$  mm thickness), and stored for 40  
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7 76 minutes to equilibrate them at a constant activity water value ( $a_w = 1$ ) in a climatic cell kept  
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10 77 at  $30^\circ\text{C}$  by a jacket with a circulating water.

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12 78 A creep-recovery test was carried out on dough-sheet, by using a Glutograph-E (Brabender  
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14 79 GmbH and Co KG, Duisburg, Germany). The measuring system of the instrument consists of  
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16 80 two parallel, round, finely orrugated plates mounted at a defined distance. In order to measure  
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18 81 change in elasticity during heating, the Glutograph-E was modified as follows: (1) it was  
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20 82 connected to a waterbath using steel tubes with silicone foam insulation; (2) the bottom  
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22 83 aluminium plate was replaced with a plastic one, in order to limit heat dissipation; (3) the gap  
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24 84 between the two bases was set up at 3 mm; (4) a temperature probe was placed inside the  
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26 85 base, in direct contact with the sample.

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29 86 After the resting time, dough sheet was placed between the two plates. The fixed distance and  
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31 87 diameter of the two plates provided a defined sample volume and reproducible sample  
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33 88 geometry. Excess dough was removed by using the cutter provided with the Glutograph-E.  
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35 89 The exposed surfaces at the edge of the plates were coated with silicon to prevent drying  
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37 90 during the test-time. Before analysis, the sample was rested for 5 min. During the test, while  
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39 91 the upper plate remains still, the lower plate was turned with a constant force ( $0.08\text{ N/m}$ ) for  
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41 92 10 seconds (stretching step). This constant force determined the extension of the dough. After  
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43 93 stretching, the force was released for 30 seconds (relaxing step) and the sample recovered  
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45 94 according to its elasticity. Stretching (10 s) and relaxation (30 s) were applied over and over  
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47 95 during the test time, while the temperature progressively increased from  $30$  to  $90^\circ\text{C}$  at a  
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49 96 heating rate of  $1.2^\circ\text{C}/\text{min}$ .

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52 97 A sample curve produced by Glutograph-E during a test is shown in Figure 1. For each peak  
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54 98 recorded, stretching value was calculated as the difference between the maximum (B in  
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56 99 Figure 1) and the minimum (A in Figure 1) value during the stretching step; while recovery  
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3 100 was calculated as the difference between the maximum (B in Figure 1) and the minimum (C  
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5 101 in Figure 1) value during the recovery step. Stretching and recovery values were plotted  
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7 102 against temperature (Figure 2). The tracing reported in Figure 2 can be divided into three parts  
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9 103 and in each of them semolina samples exhibited a particular behaviour in terms of elasticity.  
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11 104 In the first part of the curve, stretching and recovery values increased with the increase in  
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13 105 temperature, until a maximum in the temperature range of 53-57 °C. The maximum  
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15 106 temperature value is likely related to the maximum temperature at which the protein network  
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17 107 is still extensible and the starch granules are below the gelatinization temperature (data not  
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19 108 shown). The increase in stretching and recovery values suggests a softening of the structure:  
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21 109 starch gelatinization occurred and, until this value, the protein network was still able to  
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23 110 interact and respond to the stresses of stretching. After the peak, stretching and recovery  
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25 111 decreased as the temperature continued to increase, since prolonged heating produced  
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27 112 stronger (stiffer) structures. In the last part of the curve, heating to 80 °C greatly decreased the  
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29 113 stretching values indicating that the material was almost undeformable.  
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34 114 The conventional indices used to predict the pasta-making quality of semolina samples are  
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36 115 summarized in Table 1. In the same table, the firmness of related cooked pasta - evaluated as  
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38 116 the resistance of cooked pasta to chewing and considered the most comprehensive measure  
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40 117 for cooking quality evaluation [4] – is also presented. Pasta from semolina A, B, and C  
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42 118 showed high firmness; on the other hand, semolina D gave an acceptable product, even if  
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44 119 characterized by poor firmness [13].  
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47 120 Both stretching and recovery curves, collected for each dough sample, were integrated every  
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49 121 5°C from 30 to 90°C. The loss of elasticity was calculated as  $(S-R)/S*100$ , where S is the area  
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51 122 under the stretching curve, and R is the area under the recovery curve (Figure 3). In general,  
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53 123 dough exhibiting high values of loss of elasticity gave a pasta with low firmness (see dough  
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55 124 D) and likely related to a “weak” material structure; whereas dough with low values of loss of  
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57 125 elasticity (see dough A, B, and C) were representative of high firmness and likely of a strong  
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3 126 (stiff) structure. Even if the conventional tests for evaluating semolina quality (gluten index  
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5 127 and alveographic indices) showed differences among semolina A, B, and C, no differences  
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7 128 were detected as regards the loss of elasticity, in agreement with the firmness values. Both  
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9 129 gluten index and alveographic test are carried out at room temperature and provide  
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11 130 information only on the strength of the gluten network, neglecting the role of starch. On the  
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13 131 other hand, the results suggest that this approach has the potential to provide information on  
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15 132 the final results of two simultaneous phenomena - protein coagulation and starch  
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17 133 gelatinisation – whose kinetics are the key for obtaining a pasta of good or poor quality.  
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19 134 Further studies are underway at high heating rate and with larger sample numbers, testing also  
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21 135 the changes in elasticity induced by heating on extruded dough, in order to propose a rapid but  
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23 136 sensitive new test for evaluating semolina properties and its suitability for the production of  
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25 137 high quality pasta.  
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186 **Table 1** Semolina characteristics and sensory firmness of the related cooked pasta  
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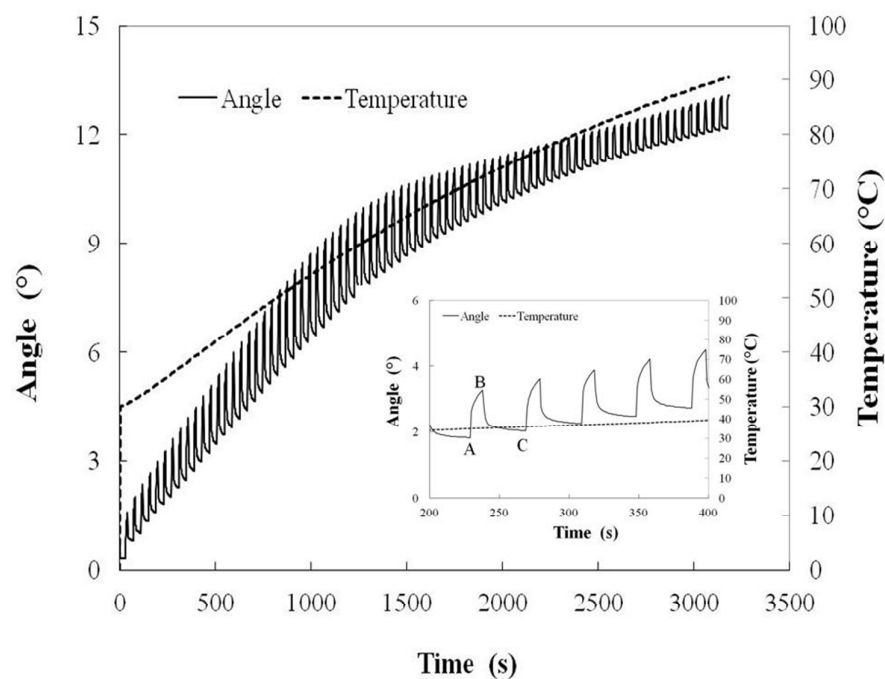
	Protein (g/100 g d.b.)	Gluten (g/100 g d.b.)	Gluten Index	W (*10 <sup>-4</sup> J)	P/L	Pasta Firmness
Semolina A	13.3	10.9	97	390	2.52	78
Semolina B	12.4	9.6	86	219	1.27	75
Semolina C	13.4	11.0	82	274	1.04	78
Semolina D	11.1	8.4	81	171	3.25	67

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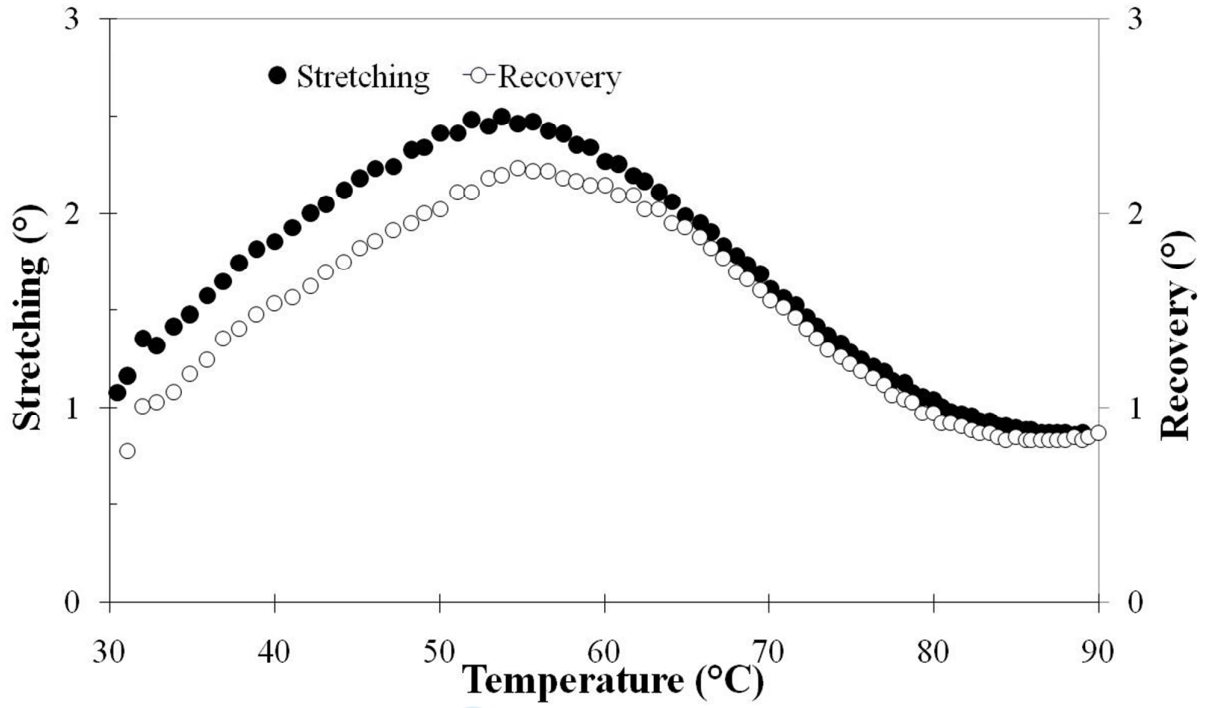
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195 **Fig 1** Sample curve produced by Glutograph-E.

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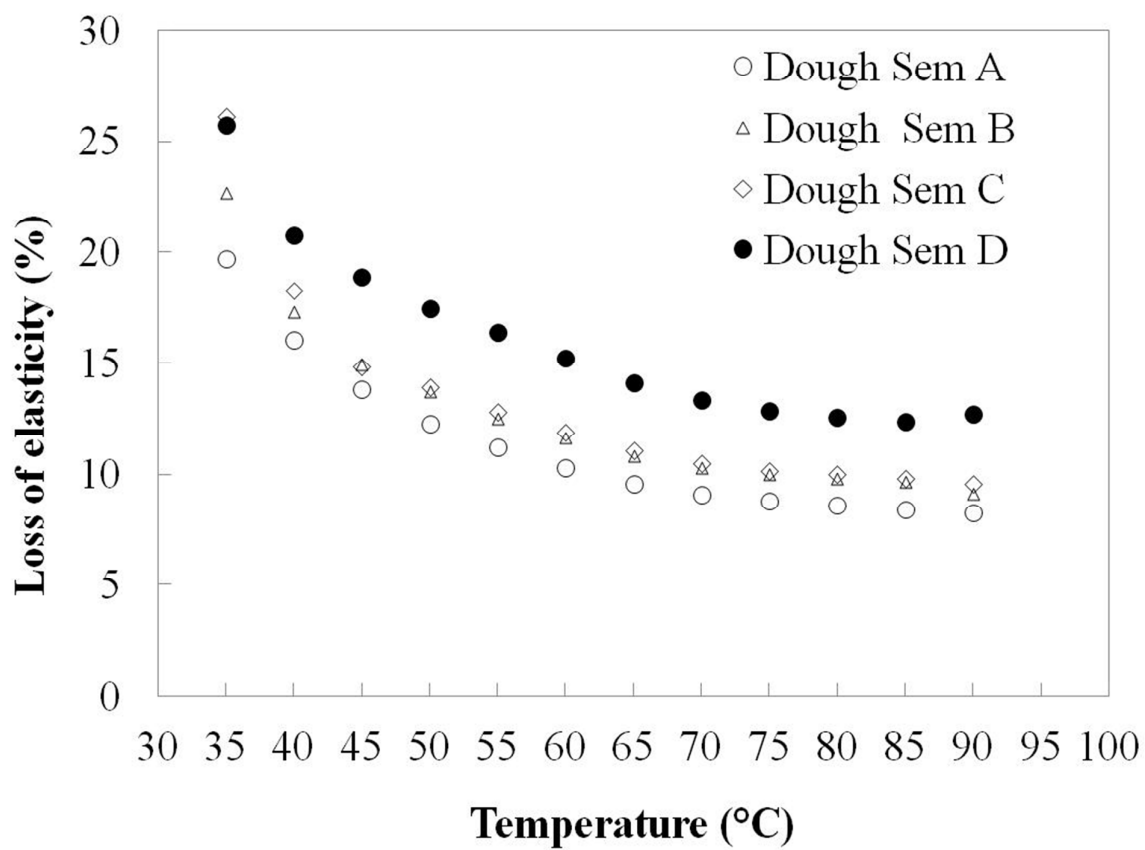


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198 **Fig. 2** Elaboration of the sample curve produced by Glutograph-E.

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