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Effect of semolina particle size on the cooking kinetics and quality of spaghetti

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Abstract

A durum wheat was milled in order to obtain medium (M), medium coarse (MC) and coarse (C) semolinas with an average particle size of 275, 375 and 475 μm respectively. The three semolinas were characterized for their chemical and physical properties. The M semolina showed higher ash, protein and gluten content, a higher gluten extensibility but a lower gluten index and yellow colour than coarser semolinas. Spaghetti were produced with the three semolinas. Dried spaghetti were characterized for their diameter, hardness and colour and eventually tested for their cooking quality. Spaghetti from MC and C semolina showed higher optimum cooking time (OCT) than spaghetti from M semolina. Cooking time being equal, the weight and diameter increase was higher in spaghetti from coarser semolinas. Within OCT, the hardness of spaghetti from MC and C semolina was higher than that of spaghetti from M semolina. The high OCT and hardness (before OCT) of the semi-cooked pasta obtained from MC and C semolina could be useful in two-step cooking processes in which pasta is pre-cooked and cooled before the final cooking step.

Keywords: Semolina; particle size; spaghetti; cooking kinetics; quality

1. Introduction

Semolina particle size is a key factor in pasta making. Fine semolina gives a higher yield upon milling and is preferred by the pasta industry since it shows a high hydration rate an permits a homogeneous hydration, thus facilitating the mixing process [1]. Fine semolina is also particularly suitable for modern

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high speed extrusion processes, characterized by limited dough residence time, and confers to pasta a highly homogeneous colour with a higher yellow colour saturation than coarse semolina [2].

However, the re-grinding process, which is required for fine semolina making, could determine adverse effects on quality due to starch damage. Damaged starch is easily hydrolized by amylases during the pasta making process (mixing and pre-drying in particular) with the formation of reducing sugars which accelerate the Maillard reaction during drying and cause adverse effects on colour (browning) and nutritional value (loss of lysine) [3].

The damage of starch improves also granule swelling and solute leakage from the starch granule during cooking [4] and confers stickiness to pasta, expecially in products with low gluten quality [5]. Finally, the starch damage deplete the gelatinization enthalpy of wheat [6] and this could dramatically affect the cooking quality of pasta from fine semolinas. Since starch damage is more likely to occur when wheat varieties with hard kernels are grinded [4], in such cases the fractionation of the milling extract with the removal of flours could improve pasta cooking quality.

This work was aimed to study the effect of semolina particle size on chemical composition and cooking quality of spaghetti from a desert durum wheat (var. Kronos) characterized by hard kernels.

2. Materials and Methods

2.1. Materials

A desert durum wheat (*Triticum durum*, Desf.) var. Kronos cultivated in Arizona (USA) and harvested in May-June 2010 was used in this study. Durum wheat was milled in a industrial durum mill (Molino Casillo, Corato, Italy). Total semolinas and flours resulting from milling extraction (M) were characterised for their average particle size (a.p.s. 275 μm). Medium coarse (MC) semolina was obtained by removing all flours (< 200 μm) and the coarse fraction (CF1), with a.p.s. > 520 mm, from the milling extract. Coarse (C) semolina was obtained by removing the fraction < 300 μm from the milling extract and by mixing the residual fraction with CF1 in a 1:10 ratio.

2.2. Spaghetti processing

Spaghetti were produced with all of the three different semolinas by using the same operating conditions: semolina was mixed with cold water (18 °C) in a rotary shaft mixer so as to obtain a dough with 33 % moisture content. The dough was extruded with a Gibra (Braibanti, Milan, Italy) twin screw extruder with a barrel length of 1300 mm and a diameter of 950 mm, provided with a cooling system. The extruder was equipped with a bronze-bronze drawplate which had 612 dies of 2.2 mm diameter. The input feed rate was of 80 Kg h^{-1}, the screw speed was set to 12 rpm and cooling temperature was of 35 °C. In these experimental conditions the pressure behind the die reached 11 MPa. The output rate was of 0.5 m min^{-1} and pasta strands were cut in 26 cm long spaghetti using a cutting bar. Spaghetti were dried at 50 °C for 1 h in a Garbuio (Treviso, Italy) fan-assisted pre-dryer and finally dried in a static drier at 50 °C for 36 h.

2.3. Analytical determinations

The durum wheat was characterised for its test weight, hard vitreous amber colour kernels content and moisture, which were determined according to the official EU methods of analysis [7], whilst ash, protein and gluten content were analysed according to the official Italian methods of analysis [8]. The gluten quality was determined by the ‘Gluten Index’ using a Perten (Huddinge, Sweden) Glutomatic 2200 system and ‘Gluten Torsion Index’ using a Glutograph-E system (Brabender, Duisburg, Germany).

Semolina particle-size distribution was determined with a sifter (Bühler, Uzwil, Switzerland) by using 100 g of semolina and a 5 min sifting time.

Semolina was analysed for moisture, ash, protein and gluten content [8]. Gluten index of semolina was determined using the Perten Glutomatic 2015 centrifuge and the extensibility of gluten was measured by placing the washed-out gluten on two metallic blade, let it flow through a 1 cm gap under gravitational force for 1 h and eventually measuring the gluten elongation in mm.

Dried spaghetti were characterized for their diameter, hardness and colour according to literature [9]. Spaghetti cooking was carried out according to previous studies [9]. The optimum cooking time (OCT) was determined as the time required for the white core disappearance [9]. Weight increase, diameter increase, cooking loss and hardness were determined at different times during cooking [9] and overcooking (OCT + 25 %). Total organic matter released in rinsing water (TOM) and stickiness were determined as described elsewhere [9] on spaghetti cooked for OCT.

2.4. Statistical analysis

All the analyses were carried out on at least two pasta samples produced in two different extrusion processes. Data were reported as means. One way analysis of variance was applied to experimental data and comparison among means was carried out using a t-test. Weight increase, diameter increase and hardness loss kinetics were modelled using the Weibull cumulative distribution.

3. Results and Discussion

The quality characteristics of durum wheat kernels were reported in Table 1.

Table 1. Quality characteristics of Kronos durum wheat kernels

Test weight (Kg/hL)	Amber colour kernels (%)	Moisture (g/100g)	Ash ($g/100g_{dw}$)	Protein ($g/100g_{dw}$)	Gluten ($g/100g_{dw}$)	Gluten Index (%)	Gluten Torsion Index
83.10	86	6.93	1.92	15.5	11.3	77	6.57

Durum wheat was milled and sieved so as to reach an average particle size of 275, 375 and 475 μm corresponding to medium, medium coarse and coarse semolina respectively. The semolinas with higher particle size showed lower moisture, ash, protein and gluten content, on the other hand they showed a higher gluten index, yellow colour and a lower gluten extensibility than medium size semolina (Table 2).

Table 2. Chemical and physical properties of semolinas

Particle size (μm)	Moisture (g/100g)	Ash ($g/100g_{dw}$)	Protein ($g/100g_{dw}$)	Gluten ($g/100g_{dw}$)	Gluten Index (%)	Gluten extensibility (mm)	Colour b*
275	14.23a	0.88a	14.17a	11.54a	91b	28a	27.1c
375	13.74b	0.58c	13.48b	10.50b	94a	6b	34.6b
475	13.00c	0.65b	13.25b	9.50c	95a	3c	35.9a

Semolinas were processed in dried spaghetti using a low temperature drying process and the dried spaghetti characteristics were reported in Table 3. Spaghetti from coarse and medium coarse semolinas showed higher shrinkage during drying possibly due to their lower protein and gluten content; the shrinkage resulted in a denser structure and higher hardness. The high values of b* values of the coarse semolina permitted to obtain dried spaghetti with higher yellow colour than those obtained from MC and M semolinas, which did not differ among them in terms of colour.

Table 3. Chemical and physical properties of dried spaghetti from different semolinas

Particle size (μm)	Moisture (g/100g)	Diameter (mm)	Hardness (N)	Colour L*	Colour b*
275	11.14a	2.05a	107.09b	87.6a	27.2b
375	11.18a	1.97b	130.78a	88.2a	27.9b
475	11.03a	1.93b	123.59a	89.5a	28.6a

Spaghetti were cooked in boiling water and the OCT resulted of 17 min for spaghetti from M semolina and 18 min for spaghetti from MC and C semolina. Cooking kinetics were studied by weight increase along cooking and overcooking time (Fig. 1).

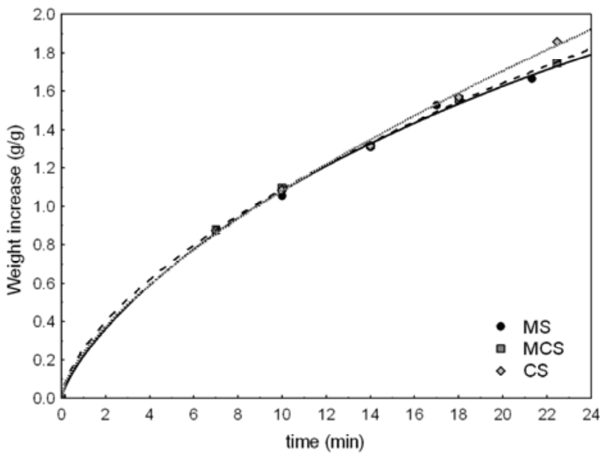

Fig. 1. Weight increase kinetics of spaghetti from different semolinas during cooking and overcooking time

Differences in weight increase among samples were evidenced only during overcooking; in this phase spaghetti from M semolina (MS) adsorbed less water than spaghetti from coarse and medium coarse semolinas (CS and MCS respectively).

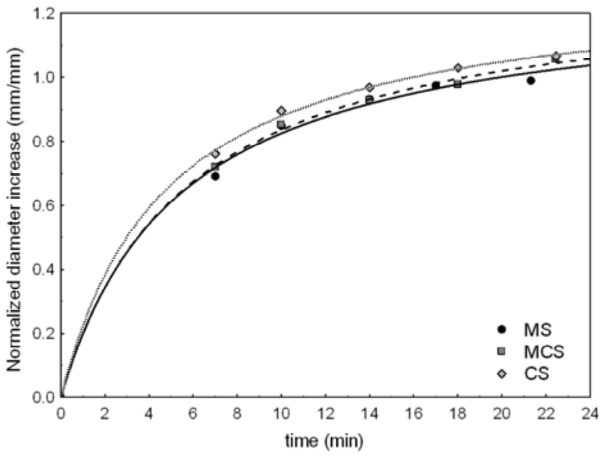

Fig. 2. Diameter increase kinetics of spaghetti from different semolinas during cooking and overcooking time

Cooking time being equal, the spaghetti from CS and MCS showed a higher diameter increase during cooking than those from MS (Fig. 2); this is likely due to the reduction of protein and gluten content of semolinas as resulting from the increment of the average particle size. Protein content and gluten network strenght are known to counteract starch granule swelling during cooking due to competition between protein and starch for water availability [9, 10]. The lower protein content of semolina with higher particle size could thus result in higher starch granule swelling and a consequent diameter increase.

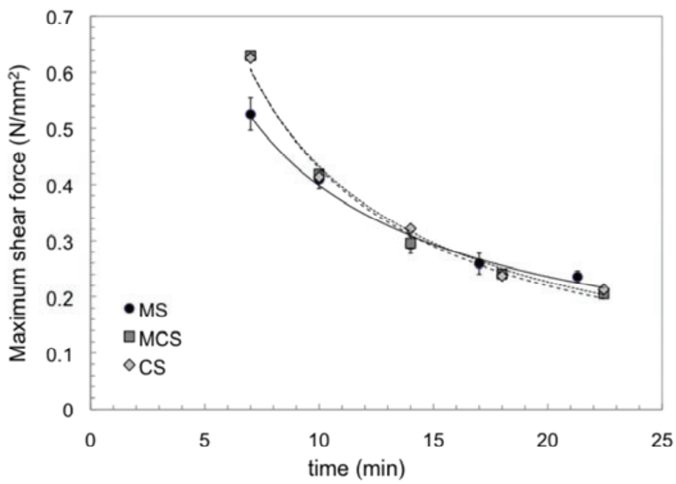

Fig. 3. Hardness of spaghetti from different semolinas during cooking and overcooking time

Within the optimum cooking time, the hardness (maximum shear stress) values of spaghetti from CS and MCS were higher than that of spaghetti from MS (Fig. 3). The higher particle size of MCS and CS permitted to maintain the spaghetti white core (consisting of ungelatinized starch) for a longer time but, after reaching the OCT, the lower protein and gluten content of the coarser semolinas resulted in spaghetti with a lower hardness than that of spaghetti from MS.

No differences in cooking loss (CL), total organic matter released after rinsing (TOM) and stickiness were found among spaghetti cooked for OCT (Table 4).

Table 4. Chemical and physical properties of dried spaghetti from different semolinas

Particle size (□m)	Moisture (g/100g)	Diameter (mm)	Hardness (N)	Colour L*	Colour b*
275	6.47a	0.52a	1.51a	76.3b	31.0a
375	6.62a	0.53a	1.71a	78.8a	30.8ab
475	7-09a	0.51a	1.84a	78.4a	30.3b

The colour of cooked spaghetti from CS was darker than that of spaghetti from MS, differently from what was observed in dried spaghetti (Table 3); this behaviour could be explained by the high water uptake and swelling of spaghetti from coarse semolina.

4. Conclusions

The high OCT, hardness and shear stress (before OCT) of the semi-cooked pasta obtained from coarse and medium coarse semolina could be useful in two-step cooking processes in which pasta is pre-cooked and cooled before the final cooking step. These are cooking processes widely used in restaurants and catering industry.

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