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# Influence of repeated extrusions on some properties of non-conventional spaghetti

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ABSTRACT

The influence of the re-extrusion (repeated extrusion) number on the rheological properties of non-conventional doughs, mechanical and sensorial characteristics of dry spaghetti was investigated. Moreover, the dough gelatinization degree was also evaluated. Amaranth, oat and quinoa flours were used to produce the spaghetti samples. Twelve non-conventional spaghetti samples were manufactured varying the re-extrusion number. The rheological properties of doughs 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. The re-extrusion number affected the extensional and shears viscosity of amaranth, oat and quinoa dough samples. The breaking strength of dry non-conventional spaghetti increased with the increase of the re-extrusion number for amaranth and oat. The dough gelatinization degree of the quinoa and oat significantly increased with the re-extrusion, whereas no influence of re-extrusion was found for the amaranth dough. Moreover, the re-extrusion number improved sensorial color and homogeneity for oat and quinoa dry spaghetti and had no effects on the sensorial characteristics of all cooked spaghetti.

## 1. Introduction

The growth of interest in functional and high nutritious foods gives the cereal industry an opportunity to develop products on the basis of non-conventional flours. Flours different from durum wheat semolina with high-protein content have been used as partial or total substitutes of semolina for pasta manufacture (Marconi and Carcea, 2001), which represent a compromise between nutritional improvement of the pasta and achievement of satisfactory sensory and functional properties. Amaranth and quinoa are pseudo-cereals and can be used to produce gluten-free cereal based products (Gambus et al., 2002; Taylor and Parker, 2002; Tosi et al., 1996). Amaranth has a protein content of 18% (Tosi et al., 2002), is recognized as lysine-rich, high-protein grains and it contains significant amounts of calcium, iron, potassium, phosphorous, vitamins and dietary fiber (Escudero et al., 1999). Quinoa has a high-protein content (14–16%) (Koziol, 1990a, 1992). In particular, the protein of quinoa seed is rich in histidine and lysine. Quinoa has a relatively high quantity of vitamins and minerals, iron and calcium (Risi and Galwey, 1984); moreover, lipids present in the quinoa seeds appear to have a high quality edible vegetable oil, similar in fatty-acid composition to soybean oil (Wood et al., 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 et al., 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 and Peterson, 1999; Hampshire, 1998; Panfili et al., 2003; Peterson, 2001; Zadernowski et al., 1999).

Use of non-conventional flours to produce pasta presents notable difficulties. Pasta obtained from non-conventional flours often does not have a similar quality to that of semolina. Pasta of high quality must have low breakage susceptibility (Del Nobile and Massera, 2002), high cooking resistance, satisfactory sensorial attributes (Menger, 1977), must not release an excessive amount of organic matter into the cooking water and must not show stickiness (Manser, 1981). To improve the quality of non-conventional pasta several studies were carried out. They included the use of starches, hydrocolloids, dairy products, gums and other non gluten proteins and their combinations as alternative to gluten (Chillo et al., 2007, 2009; Huang et al., 2001; Sukhcharn et al., 2004). To obtain good quality pasta from alternative materials it is often necessary to modify the traditional production process (Kent and 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 and Carcea, 2001).

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Five process variables of pasta production (water absorption, barrel temperature, screw speed, mixing time, and water temperature) were investigated and their effect on pasta quality was evaluated (Debbouz and Doetkott, 1996). Moreover, a study to determine the effects of semolina, hydration level during extrusion and flaxseed flour concentration on the physical and cooking characteristics of freshly extruded pasta was carried out (Manthey et al., 2008). Faraj et al. (2004) investigated the influence of extrusion cooking on resistant starch formation in waxy and regular barley flours. Zardetto and Dalla Rosa (2009) evaluated the chemical and physical characteristics of cooked fresh egg pasta samples obtained using extrusion. In addition, Sarghini et al. (2005) reported a fluid dynamics analysis of a single screw extruder for semolina dough. As the physical polymeric network is formed during extrusion (Zardetto et al., 2005) thanks to the high shear rate, the increase of re-extrusion number could in principle increase the strength of the polymeric physical network, which in turn could improve the quality of dry non-conventional pasta (color and breakage susceptibility). Moreover, the increase strength of the polymeric network could also have a positive effect on the properties of cooked pasta (sensorial characteristics). Therefore, the repeated extrusion could be an alternative method to manufacture good quality pasta from non-conventional flours difficult to be processed.

Rheology is of considerable importance in the manufacture of various foods as it influences the machinability, processing conditions and quality of products. Different methods, such as dynamic oscillatory measurements, creep testing, stress relaxation, viscoelastograph, etc., have been used to study the viscoelasticity of food materials (Chuang and Yeh, 2006). Capillary rheometers can be used to determine a range of material functions. They can quickly and easily measure the flow properties of a material over the full range of forces, pressures, geometry, and temperatures that are encountered in real processes. Capillary rheometer was used in this work to determine extensional and shear viscosity that is the measure of the resistance of a fluid that is being deformed, by either shear stress or extensional stress. Viscosity test gives an apparent rather than a true measure of viscosity at the test temperature. A series of corrections is appropriate to derive the true viscosity. The twin-bore instrument facilitates use of the Bagley correction. The basic premise of the correction is that pressure changes are occurring at the entrance to the die, along its length, and at its exit. The entrance and exit pressures can lead to significant errors in the calculated shear stress if not assessed (up to 20–30%). The real magnitude of the entrance and exit pressures can only be determined if a second measurement is made. Rosand developed the technique of using a very short or “orifice” dies to directly measure the entrance pressure. This is most efficiently done on twin-bore capillary rheometers.

Similarly to other food products, sensory properties and hedonic pleasure are important in functional products. Studies including actual tasting of functional foods indicate that excellent hedonic properties in functional foods are necessary and, for instance, a bitter taste in functional foods does not support the perceived healthiness of such foods (Tuorila and Cardello, 2002). The hedonic properties derived from tasting a food are certainly one of the most essential factors in repetitive food choices, and hedonic ratings (Peryam and Pilgrim, 1957) have been widely used in predicting the future success of novel food products.

This study investigated the effect of the re-extrusion (repeated extrusion) number on the rheological properties and the gelatinization degree of non-conventional dough (amaranth, oat and quinoa), as well as the mechanical and sensorial characteristics of dry spaghetti. Results of this study could provide the industry useful information about potential use of different grains in food formulations and the development of new functional products with improved sensorial properties and texture.

## 2. Materials and methods

### *2.1. Raw materials and spaghetti preparation*

Amaranth, oat and quinoa flours were bought from Bongiovanni mill (Mondovì, Cuneo, Italy). The spaghetti samples composition is reported in Table 1. To prepare non-conventional doughs a portion of flour was subjected to thermal treatment that is able to induce starch gelatinization as well as modification of the flour proteins (i.e., protein denaturation and/or crosslinking reactions). The percentages of used water and flour in order to obtain pre-gelatinized starch are also reported in Table 1. For preparing pre-gelatinized starch, the flour slurred in the water was heated to 80 °C. Afterwards, the pre-gelatinized starch, cooled at about 40 °C, was added to the flour to prepare the spaghetti doughs.

Spaghetti samples were produced in a pilot plant made of a kneader-extruder (60VR, Namad, Rome, Italy) and a dryer (SG600, Namad). The extruder was equipped with a die (length 30 cm with six passes from 5 cm), which ended with a bronze mold (diameter hole of 1.70 mm). A temperature probe was used to measure the dough temperature. For the quinoa and oat dough the temperature before each extrusion was about 27–28 °C; while the temperature of the extruder was 28, 29, 35 and 36 °C from first to fourth extrusion, respectively. Highest temperatures were found for the amaranth dough; in particular, the temperature before each

**Table 1**
Formulations and process conditions used in the preparation of the spaghetti samples.

| Spaghetti samples | Amaranth flour (%) | Oat flour (%) | Quinoa flour (%) | Pre-gelatinized flour (%) | Water (%) | Extrusion number | Drying temperature I step (°C) | Drying time I step (min) | Drying temperature II step (°C) | Drying time II step (min) | Drying temperature III step (°C) | Drying time III step (min) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 46.6 | – | – | 20 | 33.4 | 1 | 50 | 30 | 85 | 400 | 50 | 30 |
| A2 | 46.6 | – | – | 20 | 33.4 | 2 | 50 | 30 | 85 | 400 | 50 | 30 |
| A3 | 46.6 | – | – | 20 | 33.4 | 3 | 50 | 30 | 85 | 400 | 50 | 30 |
| A4 | 46.6 | – | – | 20 | 33.4 | 4 | 50 | 30 | 85 | 400 | 50 | 30 |
| O1 | – | 48.75 | – | 20 | 31.25 | 1 | 50 | 30 | 85 | 400 | 50 | 30 |
| O2 | – | 48.75 | – | 20 | 31.25 | 2 | 50 | 30 | 85 | 400 | 50 | 30 |
| O3 | – | 48.75 | – | 20 | 31.25 | 3 | 50 | 30 | 85 | 400 | 50 | 30 |
| O4 | – | 48.75 | – | 20 | 31.25 | 4 | 50 | 30 | 85 | 400 | 50 | 30 |
| Q1 | – | – | 53.3 | 20 | 26.7 | 1 | 50 | 30 | 75 | 400 | 50 | 30 |
| Q2 | – | – | 53.3 | 20 | 26.7 | 2 | 50 | 30 | 75 | 400 | 50 | 30 |
| Q3 | – | – | 53.3 | 20 | 26.7 | 3 | 50 | 30 | 75 | 400 | 50 | 30 |
| Q4 | – | – | 53.3 | 20 | 26.7 | 4 | 50 | 30 | 75 | 400 | 50 | 30 |