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Effect of the Relative Amount of Ingredients on the Thermal Properties of Semolina Doughs

Fabio Fanari[a], Gianluca Carboni[b], Massimiliano Grosso[a,]*, Francesco Desogus[a]

[a]University of Cagliari – Department of Mechanical, Chemical and Materials Engineering – Piazza d’Armi, 09123 Cagliari, Italy
[b]Agris Sardegna - Agricultural Research Agency of Sardinia, Cagliari, Italy – Cagliari, Italy
massimiliano.grosso@dimcm.unica.it

The thermal properties of doughs with a different relative amount of ingredients were investigated using Thermogravimetric Analysis (TGA). The doughs were prepared to mix water, semolina, yeast, and salt in different proportions. The gelatinized flour fraction plays an important role in the thermal properties’ definition, while the water amount influences the development of the dough network and consequently the starch gelatinization phenomena. The amount of yeast and salt influences the dough network force and consequently, the thermal properties. In such a way, it was possible to find some information on the relationship between the dough characteristics and the thermogravimetric analysis outputs. The study is devoted to acquiring deeper knowledge about the thermophysical characteristics of doughs in the breadmaking industrial processes, and about their changes during the different process steps, when the relative amount of ingredients changes. This could help to improve the controllability of the breadmaking plants and their energetic performances, and in particular the efficiency of “pani carasau” manufacturing, a typical toasted and high-quality Sardinian bread. Currently, in industrial productions, large amounts of it are lost because off-specification and it is not possible to prevent this, since the bread characteristics can be verified after baking, which is high energy consuming. Consequently, a deeper knowledge of the dough properties could help to decrease the amounts of off-specification products, resulting in a much more energy efficient and sustainable process.

1. Introduction

The industrial breadmaking performance strongly depends on the mixing conditions and on the relative amount of dough ingredients, that influences the molecular structure of the dough and the building of the so-called “glutinic network”, the main responsible for the dough mechanical properties (Miller and Hoseney, 2008). Proteins, starch, and water are the main components of dough, but usually, salt, yeast, and other additives are mixed to them to improve the texture and the flavour of the final product.

The Thermogravimetric Analysis (TGA) is an interesting tool that helps the study of the interactions among the dough components. The starch gelatinization and protein coagulation phenomena are the main processes that take place during dough heating (Tazrart et al., 2019). Both starch gelatinization and protein coagulation show an effect on the thermal behaviour, approximately in the same temperature range (55 – 80 °C) and moisture level (Fanari et al., 2019a). The amount and the mobility of water are the most important parameters with respect to starch gelatinization, gluten network building, thermal stability of proteins and glass transition temperature (Romano et al., 2015); the presence of other ingredients and their quantity can influence these parameters because of the competition with starch and proteins for the available water (Mamat and Hill, 2018).

In the literature, not many studies about this topic can be found, especially in recent years, except for those about the effect of salt, due to the interest for the human health problems caused by this ingredient. Angioloni and Dalla Rosa (2005) stated that salt makes the proteins harden and helps in conditioning the dough by improving its tolerance to mixing, producing more stable and stiffer dough, increasing the apparent viscosity and the glutinic network strength and exalting the portion of solid-like behaviour in the dough. Chakraborty et al. (2015) found out that proteins coagulation and amylase activity are slowed down by the salt content increasing in the dough, leading to a slowing of the gelatinization process, and also the glass transition temperature is

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reduced (Ribotta and Le Bail, 2007). Correa and Ferrero (2015) reported that the gelatinization shows a shift to higher temperatures when NaCl is added to the dough. However, in these more recent works, the role played by salt on the dough rheological properties is not clear, and the study of the dough thermal properties could be useful to understand how the salt affects the glutinic network building.

Regarding the yeast effect on the thermal properties of doughs, there is a lack of information in the literature. For the above reasons, the aim of this work is to investigate the influence of the relative amount of ingredients on the thermal properties of the dough. It is known that the dough components influence the properties of the final product and the optimal process conditions. By the TGA, it is possible to study the thermal properties of the dough by measuring its weight reduction caused by heating the sample to high temperatures. The weight reduction of dough is mainly related to water loss and sample degradation. These processes are due to the molecular structural interactions breaking, i.e., by the TGA technique it is possible to characterize some kinds of bonds that are established during the mixing and network building phases and to find information about the way how the relative amount of the different components influences the dough characteristics (Fanari et al., 2019a).

2. Materials and methods

The dough was prepared using commercial semolina with a protein content of about 13 %, distilled water, commercial baker yeast (*Saccharomyces cerevisiae*) and commercial iodized salt. The dough kneading was performed using a mixograph (National Manufacturing, Lincoln, NB) with 10 g of flour capacity. Three groups, each one of them consisting of three samples, were taken into account: I) samples, identified with letter “W”, made with 10 g of semolina and an amount of water, based on the semolina weight, of 50 % (W50), 55 % (W55) and 60 % (W60); II) samples, identified with letter “S”, obtained by mixing 10 g of semolina, 5 g of water and an amount of salt, based on the semolina weight, of 0.5 % (S0.5), 1.5 % (S1.5) and 3.0 % (S3.0); III) samples, identified with letter “Y”, constituted by 10 g of semolina, 5 g of water and an amount of yeast, based on the semolina weight, of 0.5 % (Y0.5), 1.5 % (Y1.5) and 3.0 % (Y3.0). Each sample was kneaded for 20 min before starting the thermal analysis. This time was identified as the mean optimum development time by considering the optimum time measured on the mixograph, as this parameter could be different from one sample to another one and affects the thermal properties (Fanari et al., 2019b). The optimum mixograph time is reached when the mixing process and the building of the network are completed, and the strength of the dough results to be the highest. For each sample, a small quantity (about 100 μg) of dough (prepared just before) was put into an alumina crucible and inserted into the TGA device (TA Instruments, SDT-Q600), then the sample was heated up to 600 °C with a temperature ramp of 5 °C/min. For each run, the weight loss of the sample was registered and then the percentage reduction and the derivative of the latter concerning the temperature were calculated. Two main peaks in the derivative curve (DTG) were individuated and characterized by the following parameters: peak temperature, height, and integral. For the first peak (peak 1) also the quantification of the left and right (concerning the peak temperature) integrals was performed, while for the second one (peak 2) an estimation of the temperature range (considered for the integral computation) was done. Peak temperatures and heights were determined using a regression curve (second or third-grade polynomial) in a strict range around the peak. Peak integrals were determined as the total weight loss percentage between the considered temperature range limits. This range was conventionally fixed in 25 – 200 °C for the first peak and determined for the second one from the intersections between the abscissa axis and the tangent passing for the inflection point of each (ascending and descending) part of the curve around the peak.

3. Results and discussion

The percentage reduction of the initial weight of the sample, and its derivative, with respect to the temperature, as outputs of the TGA analysis, are shown for the samples with different amounts of water (Figure 1), salt (Figure 2), and yeast (Figure 3). By observing the DTG curves in Figures 1, 2 and 3, first, it can be noted that they present two main peaks: the first one (peak 1) is in the temperature range 105 – 130 °C, the second one (peak 2) in the range 260 – 300 °C. The peak 1 parameters (temperature, height, integral values) for each sample are shown, respectively, in Figures 4, 5 and 6, while the peak 2 parameters for each sample are shown, respectively, in Figures 7, 8 and 9.

The peak 1, in the zone soon after 100 °C, is linked to the water evaporation, that is due to the presence of free water, but also to the starch gelatinization, that begins at about 45 °C, and finishes at about 85 – 90 °C, when also the gluten reticulation is almost complete, as also shown by Romano et al. (2015).

As it can be observed in Figure 5a, for the W samples, the height of the first peak is higher as the water content increases. For the S samples, the highest peak is for the S0.5 sample, and S1.5 and S3.0 the height of the peak tends to decrease and stabilize (Figure 5b), while for the Y samples this parameter increases, reaching a maximum for the sample Y1.5, and then again decreases (Figure 5c). Considering the temperature of the peak 1 (Figure 4), for the W samples, it decreases from about 123.8 °C to about 112.2 °C when increasing the water amount from 50 % to 60 % (Figure 4a). It decreases (from 123.8 °C to 111.1 °C) also by varying the salt amount from 0 % to 1.5 %, then slightly increases (119.3 °C) for the S3.0 sample (Figure 4b). Varying the yeast amount from 0 % to 1.5 %, the peak temperature decreases from 123.8 °C to 107.3 °C, then not significantly increases (108.5 °C) for the Y3.0 sample (Figure 4c).

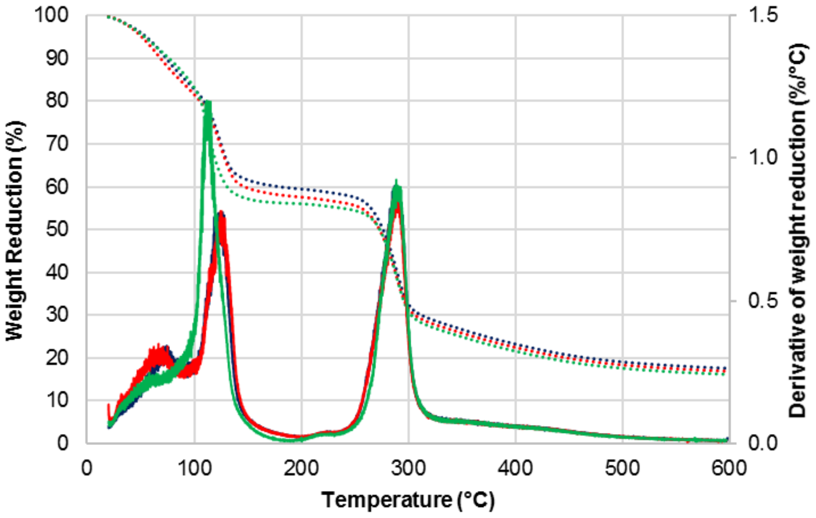

Figure 1: Weight reduction percentage (dashed lines) and derivative of weight reduction percentage concerning the temperature (continuous lines) as a function of temperature for the semolina-water dough samples with a water amount of 50 % (–), 55 % (–) and 60 % (–).

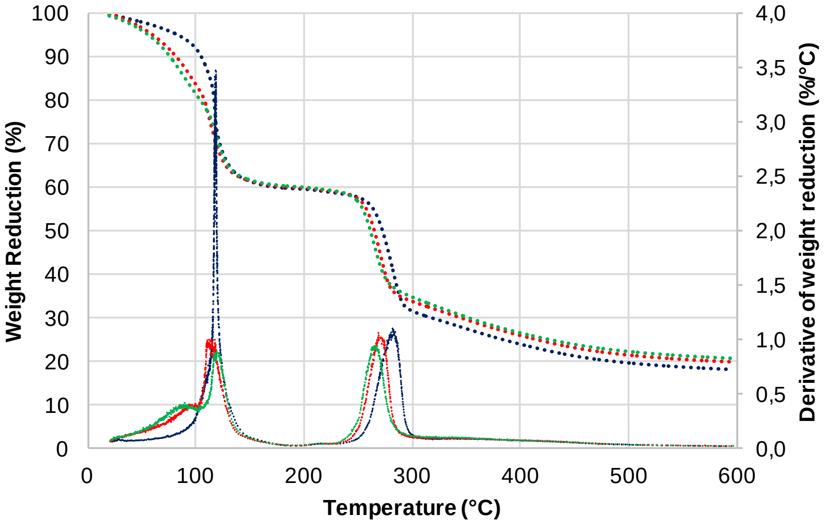

Figure 2: Weight reduction percentage (dashed lines) and derivative of weight reduction percentage concerning the temperature (continuous lines) as a function of temperature for the semolina-water dough samples with a salt amount of 0.5 % (–), 1.5 % (–) and 3 % (–).

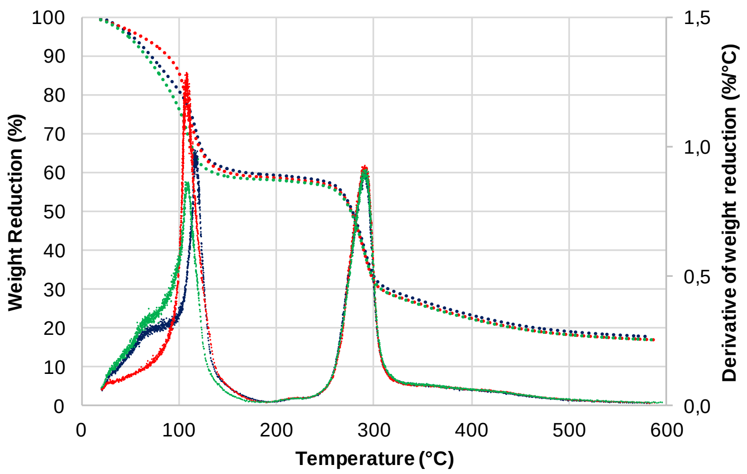

Figure 3: Weight reduction percentage (dashed lines) and derivative of weight reduction percentage concerning the temperature (continuous lines) as a function of temperature for the semolina-water dough samples with a yeast amount of 0.5 % (–), 1.5 % (–) and 3 % (–).

The peak 2 is linked to the sample thermal destruction and so to the protein and gluten denaturation that occurs at about 292 °C (Nawrocka et al., 2017). For this peak, the differences in the peak temperature for the different amount of ingredients are smaller than those for the peak 1, because the process of sample destruction mainly depends on the protein content, which is not dependent on the amount of the other ingredients besides semolina. Despite this, analyzing the peak heights in Figure 8, it can be noted that the trend is similar to that of the peak 1 one, except for the W samples, in which there is a slight minimum for the W55 sample. In addition, it is possible to note that the peak 2 temperature for the S samples significantly decreases as the salt amount increases. This phenomenon could be due to the salt influence on the protein process hydration, which leads to a weaker protein structure (Avramenko et al., 2018).

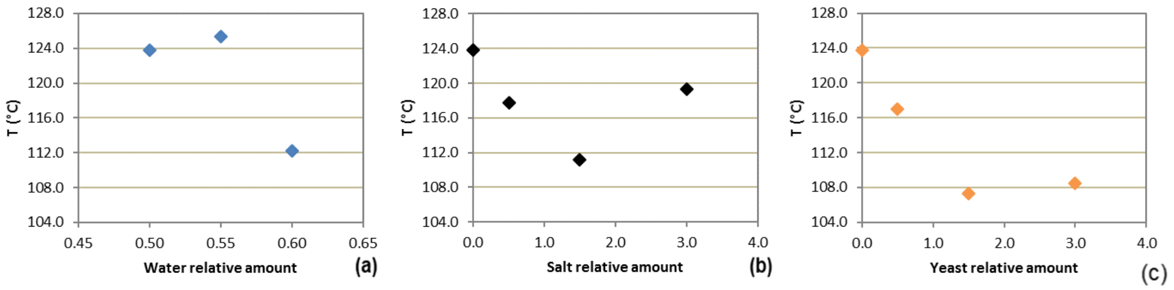

Figure 4: Peak 1 temperature as a function of the water (a), salt (b) and yeast (c) relative amount.

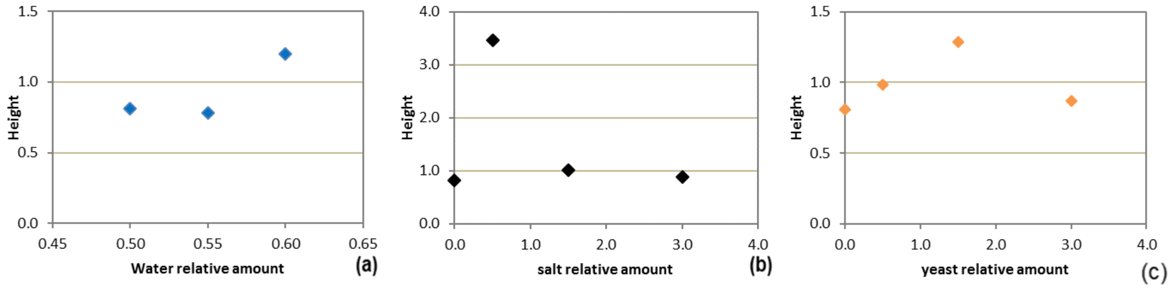

Figure 5: Peak 1 height as a function of the water (a), salt (b) and yeast (c) relative amount.

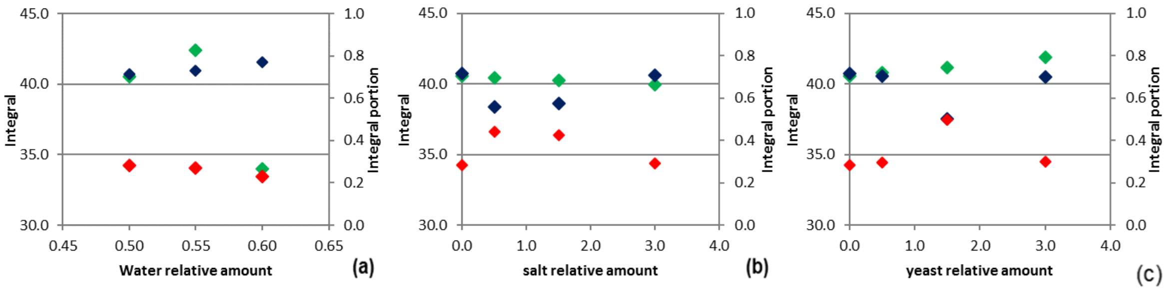

Figure 6: Left (blue) and right (red) portions (with respect to the peak temperature) and total values of integrals (green) of the peak 1 as a function of the water (a), salt (b) and yeast (c) relative amount.

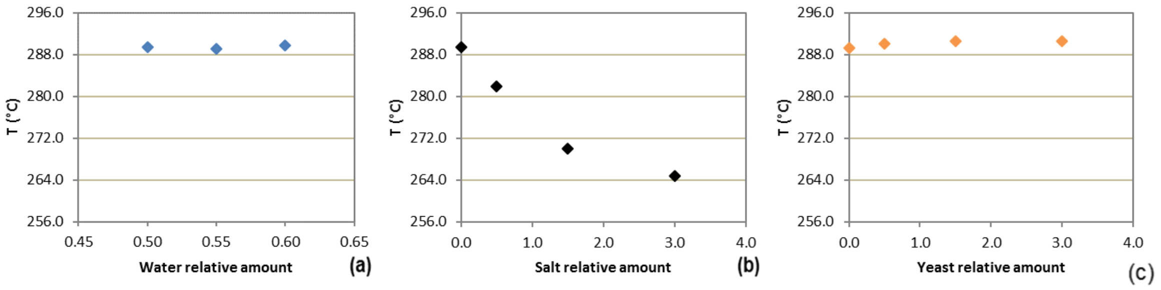

Figure 7: Peak 2 temperature as a function of the water (a), salt (b) and yeast (c) relative amount.

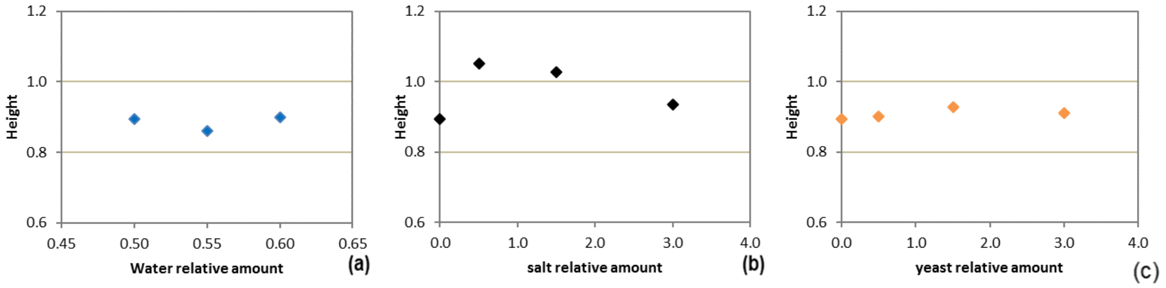

Figure 8: Peak 2 height as a function of the water (a), salt (b) and yeast (c) relative amount.

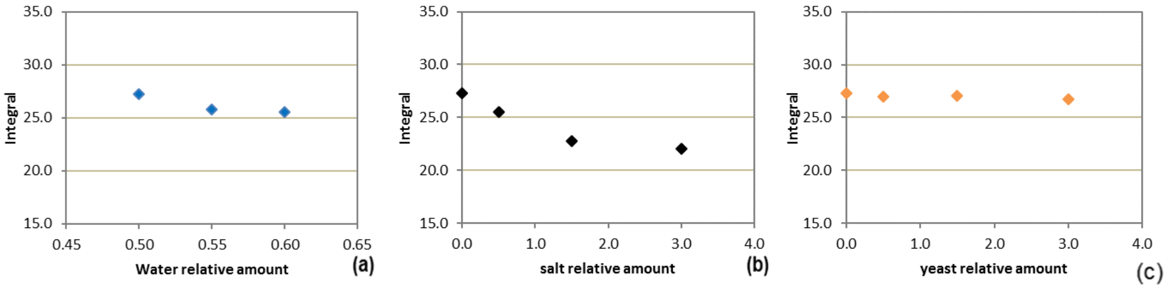

Figure 9: Peak 2 integral as a function of the water (a), salt (b) and yeast (c) relative amount.

The peak 1 integral values, reported in Figure 6, tend to decrease when the water and the salt amount increases, while they increase with an increase in the yeast amount. On the other side, the peak 2 integral values (Figure 9) slightly decrease in every case. Regarding the peak 1, the left portion (concerning the peak temperature) of the integral, which is related to the starch gelatinization and the gluten reticulation, is always greater than the right portion and increases as the water content increases. The S samples show a minimum for the S0.5 sample, as well as the Y samples, present a minimum for the Y1.5 one.

To find optimal process conditions from the above results, the following main aspects should be noted. The amount of water should be maintained between 50 and 55 %, as higher amounts negatively impact on the dough structure building: the peak 1 appears at lower temperatures and with greater heights, which means that too much free water is present. The amount of yeast, for the same reasons, should be minimized, but the optimum value should be more carefully investigated also together with the leavening time, which is also expected to produce effects on the final product properties. Also, the amount of salt should be minimized, mainly due to its negative effect on the strength of the protein structure, as can be seen from the behaviour of peak 2 temperature and integral, but it should be more deeply investigated concerning the impact on the organoleptic properties of the final product.

4. Conclusions

The TGA, conducted on semolina doughs with different amount of ingredients, revealed to be an interesting tool to show the differences in the dough characteristics, mainly due to the different composition and availability of water, which change during the molecular network building. The peak 1 of the DTG curve showed to be strongly affected by the water amount which is added to the dough, with a decreasing of the peak temperature of about 12° C when the water percentage goes up to 60 %. Also, the salt and yeast amount influence the peak 1 temperature, decreasing it off about 15° C, due to the effect on the amount of free water in the dough. The peak 2, linked to the molecular structure breaking in the sample, is influenced only by the salt, which significantly reduces the peak temperature of about 25°C when added in the amount of 3 %. The free water availability turned out to be one of the most important properties affecting the dough structure building (starch gelatinization and gluten network formation), and its amount should be carefully dosed. Also, the yeast and salt amount are the critics, but their role is not completely deductible from the obtained results and needs to be evaluated together with the leavening process (not addressed in this work) and the organoleptic properties of the baked bread. The study will be continued investigating more in deep the effect of the yeast and salt relative amount to find an optimum value, also considering the process steps which are subsequent to the dough kneading.

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