Effect of drying methods on the physical properties of durum wheat pasta

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ABSTRACT

The aim of the study was to evaluate the effect of drying methods on the physical properties of pasta. Pasta was processed from durum wheat semolina and dried at low temperature in a drying oven, at very high temperature in a convection-air oven, and under reduced pressure in a vacuum-drier. Pasta after extrusion without drying was referred as control. Cooking properties, color, and textural properties of the pasta were evaluated. The results show that drying method had a significant impact on the physical properties of pasta. Vacuum-drying resulted in bright yellow pasta characterized by high hardness, low adhesiveness, high water uptake, and low cooking losses. The study results demonstrate the beneficial effects of vacuum-drying on the physical properties of pasta.

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pasta; vacuum-drying; cooking quality; physical properties

1. Introduction

Drying conditions play a pivotal role in the pasta production process. They determine the final product quality, including appearance (i.e. color, surface texture, specks) and cooking behavior (Feillet, Autran, & Icard-Vernière, 2000; Mercier, Villeneuve, Mondor, & Des Marchais, 2011). Traditionally, manufactured pasta is dried at low temperature (i.e. 40–50°C) for a long period of time (i.e. up to 40 hours). However, due to the fact that conditions of low temperature, high relative humidity, and long drying time promote microbiological growth, which in turn causes hygienic and qualitative problems, high-temperature drying has been introduced to the industry (Sensidoni, Peres, & Pollini, 1999). The advantages of drying at high temperatures include reduced microorganism count and reduced drying cycle time (Güler, Köksel, & Ng, 2002). However, the use of high temperatures and long drying duration may promote oxidation, increase vitamin loss, and influence the color, taste, and aroma (Bazyma et al., 2006).

Convection drying is the most widely used method for food products. It is characterized by high specific energy consumption per mass unit that can reach 1.6–2.5 kWh/kg (Bazyma et al., 2006). During convection drying, the water primarily evaporates from the product surface, which may result in the formation of a surface barrier. As a result, natural moisture diffusion is hindered and internal stresses within the product may occur, leading to cracks and fractures in the pasta (Marchyo & Dexter, 2001).

During vacuum drying, water evaporation occurs under reduced pressure (Jaya & Das, 2003). Decreased pressure enhances mass transfer from the core of the pasta to the surface, as a result of the increased gradient of pressure between the inner and outer parts of the dried product (Alibas, 2007; Pérè & Rodier, 2002). Moreover, the vacuum reduces the boiling point of water, resulting in a lower required drying temperature (Durance & Wang, 2002).

During the drying process, a thermal deactivation of enzymes occurs. The most significant enzymes are amylases, lipoxidases, and lipoxigenases. Amylases are responsible for breaking down starch chains, which results in the freeing of the dextrans that are responsible for pasta’s adhesiveness and maltose, a reducing sugar, presence of which may promote Maillard reactions. In active form, lipoxidases and lipoxigenases catalyze the oxidation and destruction of the vitamins that are responsible for pasta’s yellow color (i.e. tocopherols, carotenoids). Due to the fact that enzymes can be deactivated by coagulation, pasta drying conditions are decisive in obtaining a high-quality product. However, all of these enzymes have different heat sensitivities. Moreover, all the reactions catalyzed...
by these enzymes require oxygen. During vacuum drying, moisture removal occurs in the absence of oxygen, which results in minimized oxidative degradations (Jena & Das, 2007).

A previous study has indicated that drying conducted in vacuum-drier showed higher quality compared to pasta dried at a very high temperature (Piwińska, Wyrwisz, Kurek, & Wierzbicka, 2015). Furthermore, the aim of the present study was to evaluate the impact of various drying methods on the physical properties of durum wheat pasta.

2. Materials and methods

2.1 Pasta preparation

Durum wheat pasta was prepared from commercial semolina obtained from Assmannmühlen GmbH (Guntramsdorf, Austria). It contained 720 g/kg of carbohydrates, 130 g/kg of proteins, 12 g/kg of lipids, and 26 g/kg of dietary fiber. Semolina was hydrated with tap water (water temperature 35°C) to obtain a total dough-water content of 340 g/kg on a wet weight basis and mixed for 10 min in a pasta machine (P3, La Monferrina, Italy). The dough was extruded at 50 rpm through a bronze penne forming die. After leaving the die, pasta drying was conducted using different techniques. Low-temperature drying (LT) was carried out at a constant temperature of 50°C for 480 min in a drying oven (Binder, BINDER GmbH, Germany). Very high temperature drying (VHT) was conducted in a convection air oven (Convect-Air Professional CPE 110, Küppersbusch, Germany) and it consisted of three stages. Pasta was pre-dried at 80°C for 10 min, then dried for 40 min at 94°C and 37% RH, and finally pasta was dried for 180 min at 80°C and 69% RH. Vacuum drying (VD) was carried out in a vacuum oven (VOS500, Mammert, Germany) that was equipped with a vacuum pump that had a range from 1 to 10 kPa. After each drying cycle, pasta was cooled to 35°C.

2.2 Pasta cooking quality

All of the cooking properties were evaluated after cooking at optimal cooking time, and evaluations were performed in triplicate. Optimal cooking time was determined according to AACC-approved method (approved method 66-50. AACC 2000). Optimal cooking time was indicated when the starchy white core of the pasta disappeared. To evaluate cooking properties, 10 g of pasta were cooked in 300 ml of distilled water. Water uptake was evaluated according to the method described by Petitot, Boyer, Minier, and Micard (2010). Swelling index was determined with the use of method described by Cleary and Brennan (2006). To determine cooking loss, which represents the amount of solid substance lost in the cooking water, cooking water was collected in a beaker, dried at 105°C for 16 h, and weighed (Chillo, Laverse, Falcone, & Del Nobile, 2008). Cooking loss was expressed as a percentage of the mass of the starting material.

2.3 Color

The color of the cooked pasta was determined with the use of a Chroma Meter (Model CR-400, Konica Minolta Inc., Tokyo, Japan). Values of lightness (L*, 100 = white, 0 = black), a* (− green + red), and b* (− blue + yellow) were determined according to CIE L*a*b* measuring system (measurement area: ○ 8 mm, 2° standard observers, illuminant D65). White calibration was performed in order to achieve accurate measurements (i.e. white reference standard: L* = 98.45, a* = −0.10, b* = −0.13). Measurement was carried out in 10 measuring points for each sample.

2.4 Textural properties

Textural properties of cooked pasta were determined using the Universal Testing Machine (Model 5965, Instron, MA, USA) equipped with a 35 mm cylindrical probe. Samples were subjected to double compression in order to obtain 70% of the initial pasta thickness at a constant rate of deformation (2 mm/s) with a 5 s waiting time between two cycles. Textural parameters of hardness, springiness, and adhesiveness were determined based on a texture profile analysis curve. Measurements were repeated five times.

2.5 Statistical analysis

The data was statistically evaluated with a one-way analysis of variance (ANOVA) test using Statistica version 10 for Windows (Statsoft Inc., Tulsa, OK, USA). A value of p ≤ 0.05 was used to indicate significant differences.

3. Results and discussion

3.1 Cooking quality

Pasta with high cooking quality should be characterized by high water uptake, low mass losses, low adhesiveness, and high hardness (Bruneel, Pareyt, Brijs, & Delcour, 2010). The cooking quality of pasta dried with different drying technologies is summarized in Table 1. Cooking time for dried pasta did not differ among the LT, VHT, and VD samples; however, it was significantly higher compared to control. The optimal cooking time for fresh pasta was shorter, which may be a result of higher moisture and faster rehydration than dried pasta, where water content was minimized to 120 g/kg. In durum wheat pasta, the ideal expected cooked weight is about three times heavier than the dry weight (Dick & Youngs, 1988; Doxastakis et al., 2007). The swelling index was the highest in LT and VD pasta. Samples dried at very high temperature had significantly lower swelling index compared to pasta dried at low temperature; however, they did not differ from the VD samples. The lowest swelling index was observed in fresh pasta, likely due to the shortest optimal cooking time. Water uptake was also higher in the LT and VD samples as compared to the VHT samples. All samples had significantly higher water uptake than the control pasta. Similar results were obtained by Zweifel (2001), who reported that pasta dried at a high temperature showed lower water uptake than pasta dried at a low temperature. During VHT drying, a stronger protein network might have been formed, which in turn could have led to decreased starch swelling, resulting in lower water uptake. The cooking yield of VD pasta (i.e. which had higher water uptake) might be related to the reduced-pressure drying process, because the rate of moisture transfer from core to surface is higher at lower pressures than it is at atmospheric pressure (Gunasekaran, 1999). The enhanced moisture
Cooking quality and color of pasta dried in different drying technologies

Table 1.

| Drying technology | Optimal cooking time (min) | Swelling index (g of water/g of dry pasta) | Water uptake (g/100 g of raw pasta) | Cooking loss (g/100 g of raw pasta) | L* | a* | b* |
|-------------------|-----------------------------|-------------------------------------------|-------------------------------------|-------------------------------------|----|----|----|
| Control           | 2.0                         | ±0.115                                    | ±3.04                               | ±7.56                               | 51.41| ±2.476| ±0.147| ±1.141 |
| LT                | 6.5                         | ±0.030                                    | ±2.94                               | ±6.27                               | 3.62 | ±0.157| ±0.171| ±0.822 |
| VHT               | 6.5                         | ±0.024                                    | ±2.14                               | ±6.36                               | 110.83| ±4.11| ±3.95| ±19.31 |
| Control           | 2.0                         | ±0.115                                    | ±3.04                               | ±7.56                               | 51.41| ±2.476| ±0.147| ±1.141 |
| LT                | 6.5                         | ±0.030                                    | ±2.94                               | ±6.27                               | 3.62 | ±0.157| ±0.171| ±0.822 |
| VHT               | 6.5                         | ±0.024                                    | ±2.14                               | ±6.36                               | 110.83| ±4.11| ±3.95| ±19.31 |

Means ± standard deviations (cooking quality, n = 3; color, n = 10). Means within a column with different superscripts are significantly different (p < 0.05).

Transfer from the pasta core during vacuum drying may lead to the prevention of surface barrier formation that cause internal stress within the product (Zweifel, 2001). Therefore, the use of vacuum-drying may reduce the internal stress and prevent structure deterioration, resulting in better cooking quality.

High-quality pasta should be characterized by low cooking loss. In durum wheat pasta, cooking loss values should not exceed 7–8 g/100 g (Martinez, Ribotta, León, & Arón, 2007). Vacuum-drying resulted in a lower cooking loss as compared to the LT and VHT samples. The highest cooking loss was observed in LT pasta that was dried for a long time. An increase in drying temperature caused a decrease in cooking loss. All samples showed higher cooking loss as compared to control, which might be correlated with the shorter exposure to water due to the control's shorter optimal cooking time. Decrease of cooking loss accompanied by an increase in drying temperature was also reported by Johnston (2001) and Güler et al. (2002). Lower cooking loss values in pasta dried at a higher temperature may be related to lower starch damage (Güler et al., 2002). Furthermore, as reported by Zweifel (2001), the reduction of mass loss at samples dried at a high temperature may be explained by a greater extent of protein denaturation and a stronger protein network than in pasta dried at a low temperature.

3.2 Pasta color

Table 1 shows the color measurement results for pasta dried with various drying technologies. The color of pasta is considered an important factor in determining consumer acceptance (Song, Zhu, Pei, Ai, & Chen, 2013). Generally, a bright yellow color is most desired by consumers (Petitot et al., 2010). Color is primarily affected by the intrinsic quality of semolina and the pasta processing conditions (Borrelli et al., 2000). Yellow and brown indicators of pasta color are related to the amount of pigment and enzymatic reactions, whereas red is correlated to non-enzymatic browning (Acquistucci, 2000).

The brightness of VHT samples showed significantly lower value as compared to other samples. Low temperature dried pasta was darker than the control. LD samples did not differ significantly from fresh and LT pasta. Reduced pressure caused the smallest decrease of lightness, as compared to the VHT and LT samples. A decrease of brightness value, combined with an increase in drying temperature, might be the result of the non-enzymatic browning that can occur at high temperatures (Anese, Nicoli, Massini, & Lerici, 1999). Reduced pressure allowed the pasta samples to obtain a relatively high brightness.

Drying technology had a significant impact on the redness of pasta samples. An increase in a* value was observed with increased drying temperature. Pasta dried with VHT technology showed the highest red value. Pasta dried in the vacuum oven had significantly higher a* value as compared to control. LT drying created pasta with the lowest red intensity. An increase in redness at increased drying temperatures may be related to Maillard reactions. During drying and especially at very high temperatures, non-enzymatic browning may occur, which in turn leads to brown discoloration of pasta due to melanoidins development (Anese et al., 1999). Increase in redness in pasta dried at a high temperature was also reported by Zweifel (2001).

Yellowness of samples dried at reduced pressure did not differ significantly from the control pasta or from pasta dried at VHT. The lowest b* value was observed in pasta dried at atmospheric pressure. The yellow color of durum wheat pasta is affected by both the presence of natural carotenoid pigment and the pigment’s oxidative degradation (i.e. caused by lipooxygenase (LOX) activity; Borrelli et al., 2000). High-temperature drying results in thermal inactivation of LOX, which in turn leads to a higher intensity of yellow color in durum wheat pasta (Johnston, 2001; Marchylo & Dexter, 2001). A long duration of low-temperature drying would have provided the greatest opportunity for the yellow pigment to undergo oxidative degradation, therefore samples dried at a low temperature showed lower yellowness compared to LD and VHT samples. Additionally, as vacuum-drying removes moisture in the absence of oxygen, the oxidative degradation of yellow pigment is minimized, and pasta created under these conditions is characterized by higher yellowness compared to pasta dried at atmospheric pressure.

3.3 Textural properties

The results of the hardness measurements are summarized in Figure 1. LT and VHT samples did not differ significantly from control, and LT samples showed the lowest hardness value. The highest hardness was obtained in LD samples.
Drying conditions impacted pasta hardness. High temperature and reduced pressure created firmer pasta as compared to low-temperature dried samples. Petitot et al. (2009) also reported increased hardness in pasta dried at high temperatures. Similar results were obtained by Cubadda, Carcea, Marconi, and Trivisonno (2007), who investigated the influence of drying temperature on the cooking quality of durum wheat pasta.

Figure 2 shows the results for pasta adhesiveness. LT pasta had the highest adhesiveness; however, this was not significantly different from the control sample. VHT and VD pasta showed significantly lower adhesiveness, when compared to LT and fresh pasta. Thus the application of high temperature and reduced pressure decreases pasta adhesiveness. Baiano, Conte, and Del Nobile (2006) also reported lower adhesiveness of spaghetti dried at higher temperature, and decreased adhesiveness was also observed to be associated with increased drying temperature in a study by Cubadda et al. (2007). Adhesiveness is related to the amount of amylose leaching from the gelatinized granules of starch (Sozer, Dalgıç, & Kaya, 2007). Therefore, values of adhesiveness could be associated with the cooking loss of pasta samples. Vacuum-dried samples showed the lowest values of adhesiveness and cooking loss, which may be due to the lowest starch damage during drying process. The springiness of pasta dried with various technologies is summarized in Figure 3. LT pasta showed the lowest value of springiness. VHT samples had lower springiness compared to the control, but did not differ significantly from the VD samples. VD samples did not differ significantly from the control and VHT samples. Samples dried at higher temperature showed higher ability to regain their original shape after compression, as compared to low-temperature-dried pasta. Similar results were obtained by Petitot et al. (2009), who noticed higher springiness in pasta samples dried at high temperature than in pasta dried at low temperature.

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4. Conclusion
This study found that drying conditions had a significant impact on the physical properties of pasta. Increased drying temperature caused an increase in the hardness and springiness of pasta. Moreover, higher drying temperature minimized cooking loss and adhesiveness, as compared to pasta dried at low temperature. The use of reduced pressure in the drying process had a beneficial effect on cooking quality and pasta color. Obtained pasta had higher water uptake compared to VHT pasta and lower cooking loss compared to other drying technologies. Vacuum-drying allowed the pasta to achieve a bright yellow color, and the pasta had high hardness and low adhesiveness.

Disclosure statement
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Figure 3. Springiness of pasta dried in various drying technologies. LT, low-temperature drying; VHT, very high temperature drying; VD, vacuum drying. Data are the mean ± SD of five replicates. * * * Mean values labeled with different letters are significantly different (P ≤ 0.05).

Figure 3a. Ligereza de la pasta secada con diferentes tecnologías de secado. LT – temperatura de secado baja, VHT – temperatura de secado muy alta, VD – secado al vacío. Los datos son el promedio ± SD de cinco réplicas. * * * Los valores promedio etiquetados con diferentes letras son significativamente distintos (P ≤ 0.05).
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