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Effect of the intensity of cooking methods on the nutritional and physical properties of potato tubers

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ABSTRACT

The different intensities of common culinary techniques (boiling, baking and microwaving) produce several changes that reduce the nutritional and physical properties of potatoes. This study evaluated the effect of those cooking methods on the quality of commercial potato tubers (Agata, Kennebec, Caesar and Red Pontiac). The higher weight losses were obtained for baking, but the potato softening depended on the cultivar. Color losses were independent of the intensity of the treatment; however, microwaving promoted a prompt starch gelatinization with respect to the other methods. The resistant starch retention of baking and microwaving was higher than that of boiling, and the maximum retention of bioactive compounds was obtained with the lower core temperature during boiling, as well as higher temperature and shorter baking time and the lower power and longer microwaving time. Principal component analysis revealed significant relationships between the instrumental and functional properties of cooked potatoes.

1. Introduction

Potatoes (*Solanum tuberosum* L.) are an important source of carbohydrates and are consumed widely in the developing world and in the developed world (Bordoloi, Kaur, & Singh, 2012). The potato tubers are commonly cooked before consumption, and the traditional and most popular cooking methods include boiling, frying and baking. It is well known that cooking treatments induce significant changes in the physical and chemical compositions to influence the concentration and bioavailability of bioactive compounds in potato tubers (Price, Bacon, & Rhodes, 1997). However, both positive and negative effects have been reported depending on the differences in the process conditions and in the morphological and nutritional characteristics of potato samples (Liu, Tarn, Lynch, & Skjodt, 2007).

Heat-treatment is a complex process that involves many physical, chemical and biochemical changes in food. In particular, during potato cooking, starch gelatinization occurs, which affects the palatability, digestibility and causes softening of the raw starch matrix. Heat is transferred into the potato tubers primarily by convection from the heating media (water) (Barba, Calabretti, Amore, Piccinelli, & Rastrelli, 2008). Different cooking conditions have significantly different effects on the properties of potato tubers.

The physical properties of potatoes are great affected by the heat treatments. Texture and color are considered very important parameters in the cooking quality of potato samples, and they may influence consumer purchase of these potato products (Turkmen, Poyrazoglu, Sari, & Velioglu, 2006; Waldron, Smith, Parr, Ng, & Parker, 1997). Changes in the texture are usually dramatic, which is due to the membrane disruption and the associated loss of turgor (Waldron et al., 1997). The texture of cooked potato has also been associated with dry matter, sugars, etc. Many attempts have been made to determine the relationship between the texture of cooked potato and the physical or chemical properties of potato starch (Kaur, Singh, Sodhi, & Gujral, 2002). Others changes in the potato tuber microstructure and texture during cooking have been mainly associated with the gelatinization behavior of starch through the cell wall, and the middle lamellae structural components also play a role (Alvarez, Canet, & Tortosa, 2001). Additionally, cooked potatoes usually exhibit poor color quality compared with fresh tubers because of browning (Turkmen et al., 2006).

The cooking treatment leads to an increase in the rate of starch hydrolysis by gelatinizing the starch and making it more easily available for enzymatic attack during digestion (Bordoloi et al., 2012). Mulinacci et al. (2008) reported that microwaving tends to reduce the starch availability for digestive enzymes, as shown

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by hydrolysis curves that are consistently lower than those obtained for boiled potatoes. This finding is observed because the crystallinity of potato starch increases during microwave irradiation, and boiling tends to destroy the crystalline structure. The starch molecules undergo several physical modifications depending upon the type of starch, and the severity of the conditions applied affected the content of resistant starch (Yadav, 2011). The resistant starch (RS) content and the effects of different cooking methods on the RS content have been on studied by several researchers (Mulinacci et al., 2008; Yadav, 2011). However, the results regarding the effect on the RS conflicted.

Apart from being a rich source of starch, potatoes contain small molecules and secondary metabolites that play an important role in many treatments (Friedman, 1997). Potatoes are good sources of natural antioxidants, such as vitamins, carotenoids, flavonoids and phenolic compounds. These natural antioxidants show potential actions against the risk of several age-related diseases, such as cancer, cardiovascular disease, cataract and macular degeneration (Chuah et al., 2008). Although the phenolic content has been extensively studied for raw potatoes (Rumbaoa, Cornago, & Geronimo, 2009; Stushnoff et al., 2008), there have been many discrepancies regarding the effect of heat treatments on the phenolics and antioxidant activity of potato samples, which could be due to the different processing conditions. Some literature has suggested that a shorter cooking time and lower temperature increased or did not change the total phenolic content and the antioxidant capacity (Blessington et al., 2010; Lachman et al., 2013; Mulinacci et al., 2008; Navarre, Shakya, Holden, & Kumar, 2010; Perla, Holm, & Jayanty, 2012).

Although there is some previous research on the effect of potato processing, very little information is available on the main components and the bioactive compounds. Thus, it is critical to understand the effect of such processing techniques on the activity and composition and physiochemical properties of potatoes. Therefore, we evaluated the effect of temperature and time of culinary treatments (boiling, baking and microwaving) on the nutritional components and physical properties of commercial potato tubers. The relationships between the different cooking treatments and the potato properties necessary for obtaining higher quality cooked potato products were also assessed.

2. Materials and methods

2.1. Samples

Four potato cultivars (*S. tuberosum* L.) that are grown and consumed worldwide (Agata, Caesar, Kennebec and Red Pontiac) were selected according to their cooking type, which is defined by the European Cultivated Potato database, and they were obtained from Mercabarna (Mercados de Abastecimientos de Barcelona S.A., Barcelona, Spain). The average weight of the potato tubers ranged from 175.09 to 337.60 g. The physical characteristics of cultivars were described in a previous research work (Yang, Achaerandio, & Pujolà, 2015).

2.2. Sample preparation

Approximately 18 kg of each potato cultivar of a similar size and weight were selected, washed with tap water and dried on paper towels. The potatoes were cooked with the peels. In this study, three cooking methods, boiling, baking and microwaving, at two different intensities (time–temperature) were evaluated in the four cultivars selected. Each individual experiment was conducted in triplicate. The cooking conditions were determined in a preliminary experiment for each heat treatment (data not shown). In all cooking processes they have been used whole un-peeled potatoes. The conditions used in each cooking processing were:

a. Boiling: The potatoes were boiled in the covered pan using the magnetic induction heating at 100 °C and relation potato/water (1:3) during 50 min (Bo100/50) or 60 min (Bo100/60) (the time was from the start point).
b. Baking: The potatoes were baked in a domestic hot-air oven during 60 min at 250 °C (Ba250/60) or 65 min at 220 °C (Ba220/65).
c. Microwaving: The potatoes were cooked in a domestic microwave oven at 700 W during 25 min (M700/25) or at 560 W during 35 min (M560/35).

To acquire the experiment data and to validate the heat transfer model, copper–constantan thermocouples (TC Direct, Spain) were used to measure the temperature during the heat treatments. The cooking value, C_{100}, relates the quality loss during a high-temperature thermal process to an equivalent cooking process at 100 °C, and the value was estimated using the equation,

$$C = \int_0^t 10^{\left[\frac{T-T_{ref}}{Z_Q}\right]} dt \tag{1}$$

where Z_Q (Z-value) and T_{ref} (reference temperature) represent the most heat-labile component. Generally, the reference cooking value is characterized by $Z_Q = 33.1$ °C and $T_{ref} = 100$ °C (Ling, Tang, Kong, Mitcham, & Wang, 2015).

After processing, the cooked potatoes were cooled for 1 h and the flesh and skin were separated and analyzed. A portion of the samples were lyophilized using a freeze-drying instrument (Cryodos-45, Terrasa, Spain), packed in plastic bags and maintained at −20 °C until further use.

2.3. Physical analysis

2.3.1. Weight loss and dry matter

The weight loss was expressed by the ratio of weight difference between the fresh and processed samples to the original weight. The dry matter was analyzed following the gravimetric method (AOAC 931.04). Briefly, 3 g of ground potato samples were dried at 65 °C until they were a constant weight. The dry matter content was calculated as g kg^{-1}. The analyses were conducted in triplicate.

2.3.2. Determination of shear force and texture profile analysis (TPA)

The shear force of the potato tissues was measured using the texture analyzer (TA.XT plus, Stable Microsystems, Godalming, UK) and a Warner–Bratzler probe. The potato samples were hand-peeled and then cut into strips (1 × 1 × 6 cm) with a stainless steel slicer. The test conditions were a speed of 1 mm s^{-1} and a target distance of 22 mm. The shear force was taken as the area under the curve (N). Six potato strips were used for each sample. The cooking degree was calculated by the ratio of the final shear force to the original shear force as a measure for the degree of cooking in the potatoes (Bourne, 1989).

The texture profile analysis (TPA) was determined with a 75 mm diameter cylinder probe. The potato cylindrical samples were obtained using a plastic cork broker with a diameter of approximately 19.0 mm. Each cylinder was subsequently trimmed to a length of 10.0 mm using a mechanically guided razor blade. The following parameters were set: a test speed of 0.83 mm/s and a rest period of 5 s between the two cycles. The maximum extent of deformation was 40% of the original length (Alvarez et al., 2001). According to the definitions of Bourne (1978), the TPA values for hardness (N), cohesiveness (dimensionless), springiness (mm) and chewiness (N × mm) were calculated from the