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Comparative study of sensory and instrumental characteristics of texture and color of boiled under-exploited Andean tubers

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ABSTRACT

Andean tubers are traditional staple food with different sizes, forms, colors and textures which, nowadays, are under-exploited. The work's aims were 1) to determine the instrumental and sensory characteristics of texture and color of boiled Andean tubers; and 2) to establish the relationship between the perceived sensations and the instrumental analysis. Six tuber crops were evaluated by a trained panel and instrumental methods. *Oca amarilla*, *Oca morada*, and *Papalisa* were characterized by their colors. *Imilla*, *Runa* and *Cuarentona* were noted for their texture properties. Roughness, friability, adhesiveness and springiness could be predicted by instrumental firmness (r between 0.50 and 0.73). The dry matter, ranging from 10.4 to 30.4%, was associated with all the sensory texture descriptors according, but only showed Pearson's correlation with manual adhesiveness ($r = 0.62$, $P < 0.05$) and firmness ($r = 0.53$, $P < 0.05$). This research determined some of the Andean tubers characteristics to start an appropriate utilization in food technology.

1. Introduction

Andean tubers have been consumed for more than 3000 years by millions of Andean people such as *Incas*, *Quechuas* and *Aymaras*, as a staple food. These indigenous varieties have adapted to altitudes of between 1800 and 3800 m, a cool climate, shorter days, extreme daily temperatures and low rainfall (300 mm annually) (Jimenez, Rossi, & Samman, 2007), which are the most important characteristics allowing humans to survive because of the existence of these tubers in the Andean highlands (*Puna*) (Murra, 2002, ch. IV).

Andean tubers are characterized by a high productivity quality in the region, they can be grown without extensive inputs (pesticides, fertilizers or agrochemicals), and are an important source of energy, vitamins, minerals (Jimenez, Rossi, & Samman, 2009) and have a wide antioxidant profile that makes them ideal for health and nutrition (Andre et al., 2007).

The sensory characteristics (texture, aroma and color) of potatoes have been the focus of attention for several groups of research. The texture of steam-cooked potatoes from ten cultivars (Accent, Agria, Bildtstar, Bintje, Doré, Eba, Eersteling, Eigenheimer, Irene and Nicola) was sensory evaluated after two, four and nine months storage; based on the results obtained by regression analysis and Principal Component Analysis (PCA), the samples studied could be divided into four groups with respect to the descriptors mealy, crumbly, waxy and firm (Van Marle, Van Der Vuurst De Vries, Wilkinson, & Yuksel, 1997). Uniaxial compression, Texture Profile Analysis (TPA) and chemical measurements were related to sensory texture evaluation of potato quality during storage; mealy, grainy and easy to chew potatoes could be differentiated from moist, springy and firm potatoes (Thybo & Martens, 1999). An investigation into *Spunta* and *Agria* varieties affirmed that, after 90 days' storage, the total acidity increased, whereas instrumental firmness and dry matter decreased (Arvanitoyannis, Vaitsi, & Mavromatis, 2008). Other authors (Pevicharova & Nacheva, 2009) studied the sensory attributes – aroma, color and texture of boiled potatoes grown at two altitudes, the texture of cooked potatoes in relation to the dry matter content (Van Dijk, Fischer, & Holm, 2002) or with respect to the cooking process (García-Segovia, Andrés-Bello, & Martínez-Monzó, 2008).

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Regarding the culinary properties, it was demonstrated that the attributes yellowness, hardness, adhesiveness and moistness were important to qualify boiled, oven-fried and mashed potatoes (Seefeldt, Tønning, & Thybo, 2010) and if a variety was judged to be appropriate for boiled, it was also judged appropriate for the other two cooking methods (Seefeldt, Tønning, Wiking, et al., 2010). Also, new Danish potatoes were tested by a consumer's panel in order to study the effect of information on the perception of molecular gastronomic dishes [A molecular gastronomy dish is characterized by being experimental and usually highly scientific, often resulting in new combinations of foods, and application of sophisticated culinary processes] (Mielby & Bom Frøst, 2010). These recent works suggest that nowadays there is interest in consuming potatoes as a gourmet food and, in order to choose the best tubers, sensory screening is needed.

All these works were carried out on *Solanum tuberosum*, but Andean tubers have never been investigated to the same extent. Fortunately, they have become the object of researchers who are looking for new ways to use these valuable food sources within a framework of Andean food revaluation. In the *Quebrada de Humahuaca* and *Puna* (Argentina), the varieties have an incredible diversity in color, taste, nutritional value and culinary properties, characteristics that have now made them a gourmet product.

Oca (*Oxalis tuberosa*) from Argentina and Bolivia has been introduced and accepted in New Zealand where cultivars with bright yellow flesh color, no bitter taste and very slightly mealy textures were the most preferred for steamed and baked cooking methods (Sangketkit, Savage, Martin, Searle, & Mason, 1999). In New Zealand, the preferred sensory characteristics of cooked *ulluco* (*Ullucus tuberosus* Loz) was moderately hard, waxy or not mealy, not sweet and not bitter; the most preferred skin and flesh colors were described as red and yellow–red respectively (Busch et al., 2000), which not changed during cooking (Dubois, Savage, & Martin, 2007).

Moreover, seven varieties of *S. tuberosum* spp. *andigenum* – *Collareja*, *Revolución*, *Runa*, *Churqueña*, *Señorita*, *Imilla colorada* and *Imilla negra* – were studied (Jimenez et al., 2009) and phenotypic, agronomic and nutritional properties were investigated. Also, the agrophysiological characteristics of *Oca* (*Oxalis tuberose*), *Isaño* (*Tropaeolum tuberosum*) and *Papalisa* (*Ullucus tuberosum*) were assessed (Condori et al., 2008). Sensory and instrumental analyses of texture and color profile have not been reported.

The Andean region is recognized today as one of the most important centers of crop origin and diversity in the world. The study of the sensory and instrumental properties of the variability of roots and tuber crops, nowadays under-exploited, makes this region a reliable potential source of raw material for the industry (source of starch for example) with the consequence of the revaluation of Andean foods and the conservation of its biodiversity. This could also give opportunities to the inhabitants of the *Puna* to change their general economy.

Finally and just to clarify, instrumental methods tend to be cheaper, easier to perform, standardize and reproduce than sensory ones; hence a relationship between them should be established.

In this context, the aims of this work were 1) to determine the instrumental and sensory characteristics of texture and color of boiled Andean tubers; and 2) to establish the relationship between the perceived sensations and the instrumental analysis.

2. Materials and methods

2.1. Potato samples

The texture and color of six Andean cultivars, three *S. tuberosum* spp. *andigenum* (*Runa* potato from Humahuaca, 2940 m; *Imilla colorada* from San Antonio de los Cobres, 3800 m; C*uarentona* from Las Capillas, 3800 m), two *Oxalis tuberosum* (O*ca amarilla* and *Oca morada* from Iruya, 2800 m) and one *U. tuberosum* (*Papalisa* from Iruya), harvested in 2009, plus one of the most common potato varieties in Argentina (*S. tuberosum var. Spunta*), were evaluated by sensory and instrumental methods. The samples were selected from a list of ingredients of Andean culinary preparations (Goldner & Armada, 2010). All samples were washed in water to remove soil residue and then cooked by immersion in boiling tap water until the geometric center reached 98 ± 2 °C, tested by inserting a thermocouple (DIGI Sense, Scanning Thermometer, Barnant Company Division, IL, USA). This cooking process was selected as it is typical for these crops. After boiling, the tubers were manually peeled, cut into cylinders (10 mm diameter, 20 mm height) and put in PET (Polyethylene terephthalate) containers. The samples were native, from different regions of the Salta and Jujuy provinces in Argentina.

2.2. Panel training

Twelve voluntary assessors (9 females and 3 males, 25–32 years old) were selected from the PhD and Nutrition students of the Universidad Nacional de Salta, Argentina, and trained in the descriptive analysis of boiled tubers. Panelists were selected according to their interest in evaluating this type of food, willingness to participate in a trained panel for investigation work and their availability of time, and were initiated and trained in sensory analysis following the instructions of IRAM 20004 and 20006 (1996a,b).

During the training phase (10 sessions, 1.5 h per session) assessors performed the following task: 1) an introductory sensory analysis class and another focused on the most common terms used in texture description were given to them 2) how to test tubers samples and attributes generation without any restriction; 3) how to use the new vocabulary with the aid of standards of texture and color; 4) Use of structure scales with three, five and seven samples. Moreover, taking into account the results of (Lund, Jones, & Spanitz, 2009) and, in order to foster the intrinsic motivation, the panel leader cultivated autonomy as much as possible; and to improve the relatedness, individual feedback was performed session by session with positive verbal cues. Finally, volunteers received a certificate of participation. Table 1 shows the definition of attributes and composition of standards used during this phase. Color standards were kindly donated by Martel S.A., a dye company from Salta City, Argentina. Color attributes (yellow, red and green) were selected during a focus session (2 h) taking into account the color observed on the seven samples.

2.3. Sensory evaluation

The experiment was in two phases:

1) Expanded Triangle Test (ASTM, 1977, pp. 39–40), which was only performed on texture characteristics to compare tuber samples (21 pairs) and to collect the required information for sample characterization. During the tests, seven sessions of 1.5 h per session, each assessor performed six triangles. The 'believed' samples were selected by the assessors, who described the perceived texture attributes. Assessors were located in individual booths under red light conditions in order to mask any difference in tuber color.
2) Texture Profile Method (Brandt, Skinner, & Coleman, 1963) and Descriptive Analysis (Stone & Sidel, 1993) of color were carried out using a 9-point intensity scale. All samples were boiled before each session (2 sessions, 2 h per session) and presented in pots covered with lids identified by random three-digit codes