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Sensory classification of table olives using an electronic tongue: Analysis of aqueous pastes and brines

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ABSTRACT

Table olives are highly appreciated and consumed worldwide. Different aspects are used for trade category classification being the sensory assessment of negative defects present in the olives and brines one of the most important. The trade category quality classification must follow the International Olive Council directives, requiring the organoleptic assessment of defects by a trained sensory panel. However, the training process is a hard, complex and sometimes subjective task, being the low number of samples that can be evaluated per day a major drawback considering the real needs of the olive industry. In this context, the development of electronic tongues as taste sensors for defects' sensory evaluation is of utmost relevance. So, an electronic tongue was used for table olives classification according to the presence and intensity of negative defects. Linear discrimination models were established based on sub-sets of sensor signals selected by a simulated annealing algorithm. The predictive potential of the novel approach was first demonstrated for standard solutions of chemical compounds that mimic butyric, putrid and zapateria defects (≥93% for cross-validation procedures). Then its applicability was verified; using reference table olives/brine solutions samples identified with a single intense negative attribute, namely butyric, musty, putrid, zapateria or winey–vinegary defects (≥93% cross-validation procedures). Finally, the E-tongue coupled with the same chemometric approach was applied to classify table olive samples according to the trade commercial categories (extra, 1st choice, 2nd choice and unsuitable for consumption) and an additional quality category (extra free of defects), established based on sensory analysis data. Despite the heterogeneity of the samples studied and number of different sensory defects perceived, the predictive linear discriminant model established showed sensitivities greater than 86%. So, the overall performance achieved showed that the electrochemical device could be used as a taste sensor for table olives organoleptic trade successful classification, allowing a preliminary quality assessment, which could facilitate, in the future, the complex task of sensory panelists.

1. Introduction

Table olives are a food product highly appreciated by consumers [1] and recognized as a source of bioactive compounds [2], and their commercialization represent substantial financial revenue. It is of major relevance to guarantee the quality and safety of the final product, which requires monitoring physicochemical, microbiological and sensory parameters of olives and brine solutions along the production, packing and storage chain [3]. Physicochemical, microbiological and sensory evaluations must be carried out following the methodologies,

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grading systems and procedures established by international regulations [4,5]. The analysis allows classifying table olives according to different grading scales, namely inedible (unsuitable for consumption) or edible (suitable for consumption). Table olives prices and consumers' preferences will greatly depend on their trade category. Table olives may be classified according to olive sizes (*e.g.*, bullets, fine, superior, extra large, jumbo, colossal, *etc.*), physical quality criteria (extra or fancy, first choice or select olives and second choice or standard olives) or organoleptic grading based on the median intensity of the defect predominant perceived (DPP) by a trained sensory panel during the analysis of both olives and brine solutions (extra, first choice, second choice and olives that cannot be sold as table olives) [3,6], as recommended by the International Olive Council (IOC) [5]. This latter commercial classification, although recommended and implemented already by several table olive producers, is not yet legally required. Panelists must evaluate olfactory defects (*e.g.*, abnormal fermentation, which includes butyric, putrid and "zapateria" sensations) as well as olfactory-gustatory negative attributes (*e.g.*, musty; rancid; cooking effect; soapy; metallic; earthy and winey–vinegary sensations). Sensory evaluation of table olives performed by trained panels is still quite applied [7–21], although it is not always feasible, mainly due to the scarcity of trained sensory panels, the cost and the time required for analysis, as well as due to the low number of samples that can be daily evaluated [22].

So, there is a clear practical need to develop alternative or complementary analytical methods that could allow the organoleptic assessment of table olives (olives and brine solutions). Some chromatographic based methods have been reported for assessing sensory attributes of table olives [23,24]. However, these methodologies are time-consuming, require sophisticated equipment and skilled technicians [22]. Other instrumental techniques (*e.g.*, headspace-mass spectrometry, mid-infrared spectroscopy and UV–visible spectrophotometry) fused with multivariate analysis showed to be a useful tool to classify olive oil samples based on their category and the presence of certain sensory defects [25]. Nevertheless, it is of utmost interest to investigate the potential of low-cost, fast and sensitive analytical procedures to evaluate the overall quality of table olives. Recently, electronic tongues (E-tongue) and/or electronic noses (E-noses) have been proposed for sensory and physico-chemical characterization of olive oils [26,27]. Panagou et al. [22] demonstrated the capability of an E-nose as a screening tool for quality control of fermented table olives based on their volatile patterns. The device enabled to discriminate green olives according to three major classes (acceptable, unacceptable and marginal) based on the evaluation of a sensory panel. The present work aims to evaluate, for the first time, the possibility of applying a potentiometric E-tongue combined linear discriminant analysis (LDA) and meta-heuristic simulated annealing (SA) variable selection algorithm, to: (i) identify and discriminate the most common negative sensory attributes of table olives; and (ii) to classify table olives according to their trade commercial quality classification [6]. For that, first the E-tongue capability to evaluate common negative organoleptic attributes due abnormal fermentation (*i.e.*, butyric, putrid and zapateria) was evaluated using standard solutions within the concentration ranges recommend by IOC during the training of a sensory panel [6]. Then, the capability of the E-tongue to distinguish, separately, selected samples of table olives or brine solutions, for which a single predominant negative attribute (*e.g.*, butyric, putrid and zapateria, winey–vinegary or musty defects) was perceived by a trained sensory panel [6]. Finally, the possibility of applying the E-tongue for assessing table olives trade quality category (previously established by the sensory panel considering the median intensity of the defect predominant perceived (DPP) in the tables olives and/or the respective brine solutions) was evaluated by using simultaneously the signal profiles recorded for table olives (aqueous diluted olive paste) and brine solutions, mimicking the usual classification procedure followed during the sensory analysis.

2. Materials and methods

2.1. Table olives samples

Forty four table olives commercial samples from different brands (18 brands) were purchased in local supermarkets in Bragança (Portugal) and Zamora (Spain), being 36 obtained from natural fermentation (aromatized with spices or not), 6 are Spanish-style (with or without added flavors), 1 is California-style (no aromatized) and 1 aromatized from mixed styles (natural fermentation, Spanish-style and California-style). Furthermore, the olives used in the production processes were from 7 Portuguese or Spanish cultivars namely cvs Cobrançosa, Galega, Gordal, Empeltre, Negrinha de Freixo, Hojiblanca and Manzanilla. The samples were stored in the original packaging, in dark at ambient temperature (~20 °C) until analysis or after opened in the refrigerator at 4 °C (being all of them analyzed before the end of the expiration date). It should be remarked that the number of different independent samples studied is of the same order of magnitude as those usually used in the literature regarding table olives analysis [17–20,22,28–30].

2.2. Table olives organoleptic analysis: sensory panel and sample preparation

The organoleptic evaluation of the table olives and respective brine solutions was performed by a trained sensory panel, formed by eight selected panelists that worked or studied at the School of Agriculture of the Polytechnic Institute of Bragança (Portugal), including individuals of both sexes and different ages (from 22 to 56 years). The training process included theoretical and practical sessions held twice a week and that followed the main recommendations of the IOC standard regulation [6]. The sensory panel was trained during 18 months, before performing the analysis reported in this work.

Sensory analysis of table olives involves, among other, the detection of negative attributes (*e.g.*, butyric, putrid and "zapateria" due to abnormal fermentation; and other defects like winey-vinegary, musty, cooking effect, rancid, *etc.*) and the assessment of the respective intensities. The intensities are scaled from 1 (lowest intensity, attributed when a defect is not perceived) to 11 (highest intensity) [6]. The type and intensity of the negative sensory attributes present in the table olives (olives and brine solutions) are the sole attributes used for commercially classifying the sensory quality of table olives [6]. The trade category classification is based on the median intensity perceived by the panel for the DPP. The table olive samples can be classified as extra ($DPP \leq 3$), first choice ($3 < DPP \leq 4.5$), second choice ($4.5 < DPP \leq 7.0$) or table olives that cannot be sold as table olives ($DPP > 7.0$). In this work, an additional category was taken into account for classification purposes (extra table olives free of any defect; extra_wd), including the table olives for which no organoleptic defect could be perceived by any member of the sensory panel (DPP=1). The inclusion of this new category relayed on the findings reported by Lanza and Amoruso [17], according to which the occurrence of a sensory defect changes the entire organoleptic profile of the table olives being samples classified as "Extra or Fancy", with DPP greater than 1.0, quite similar to samples with more intense negative attributes. The statistical data treatment was carried out using the official software (CALC-ENG V08 01–06–14 IOC TABLE OLIVE) provided by IOC [6]. For the sensory evaluation, the table olive samples were prepared following the guidelines of the official regulation IOC/OT/MO No 1/Rev.2 November 2011 [6].

2.3. E-tongue device

The E-tongue multi-sensor device included two print-screen potentiometric arrays (9.5 cm of width and 2.5 cm of height) containing each one 20 sensors (3.6 mm of diameter and 0.3 mm of thickness)