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Full Length Research Paper

Tools for breeding 'calçots' (*Allium cepa* L.), an expanding crop

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'Calçots', the floral stems of second-year onion resprouts of the 'Ceba Blanca Tardana de Lleida' landrace, have a growing market. Different constraints have prevented the inclusion of sensory attributes in 'calçot' breeding programs. Thus, we aimed to: (i) elaborate a sensory ideotype representing consumers' preferences for 'calçots', (ii) design an easy protocol for preparing samples and training a sensory panel to evaluate them, and (iii) describe the sensory attributes of 'calçots' derived from the main Spanish landraces of onion to point out possible strategies for breeding for sensory quality. A selected group of consumers determined that the sensory ideotype of 'calçots' should have high sweetness, low fiber perception, and no off flavors. Samples of 50 'calçots' from a single accession, roasted in the oven at 270°C for 18 min, stripped of their two external leaves, cut off at a height of 20 cm, and puréed, proved adequate for sensory panel evaluation even after being frozen and defrosted. A panel was trained until it was good at distinguishing between accessions (when neither the panelist effect nor the interaction panelist × accession was significant). This trained panel found many significant differences in sensory traits among the 'calçots' from Spanish landraces of onion. Although, none of these landraces was as close to the ideotype as the 'Ceba Blanca Tardana de Lleida' landrace traditionally used for 'calçots', crosses with some of these varieties would probably lead to heterotic base populations for breeding. The genotypic correlations found suggested that agromorphologic and sensory advances are compatible, so the information given should promote the inclusion of sensory quality as a new breeding objective.

Key words: Ideotype, 'Calçot', onion, sensory attributes, genetic variability, sample preparation, spanish landraces, panel training.

INTRODUCTION

'Calçots' are the floral stems of second-year onion resprouts of the 'Ceba Blanca Tardana de Lleida' landrace. These resprouts are harvested in winter when they reach the optimum size for consumption: about 2 cm in diameter with a compact white edible base about 20 cm long. Each onion yields between 1 and 20 'calçots' (Figures 1 and 2), but their thickness is negatively correlated with the number of 'calçots' per onion. The 'calçot' is a typical product of Catalonia (northeast Spain), where they are usually grilled or roasted and accompanied with 'romesco', a sauce made from hazelnuts, almonds, dried round sweet peppers ('nyores'), grilled tomatoes, olive oil, vinegar, and mild paprika. This tradition dates from the 1930s and has recently started to spread to other regions of Spain and other countries; the current market volume is about 20 million euros. Thus, 'calçots' are emerging as a new product in the Spanish and international markets, but no scientific information about the characteristics of 'calçots' and few specific tools for breeding them are available.

Farmers have elaborated an agronomic ideotype consisting of plants with 12 marketable 'calçots' that can be harvested simultaneously (that is, that reach the commercial stage described above simultaneously), and some breeding programs are underway to achieve this ideotype. However, no ideotype has been defined for the

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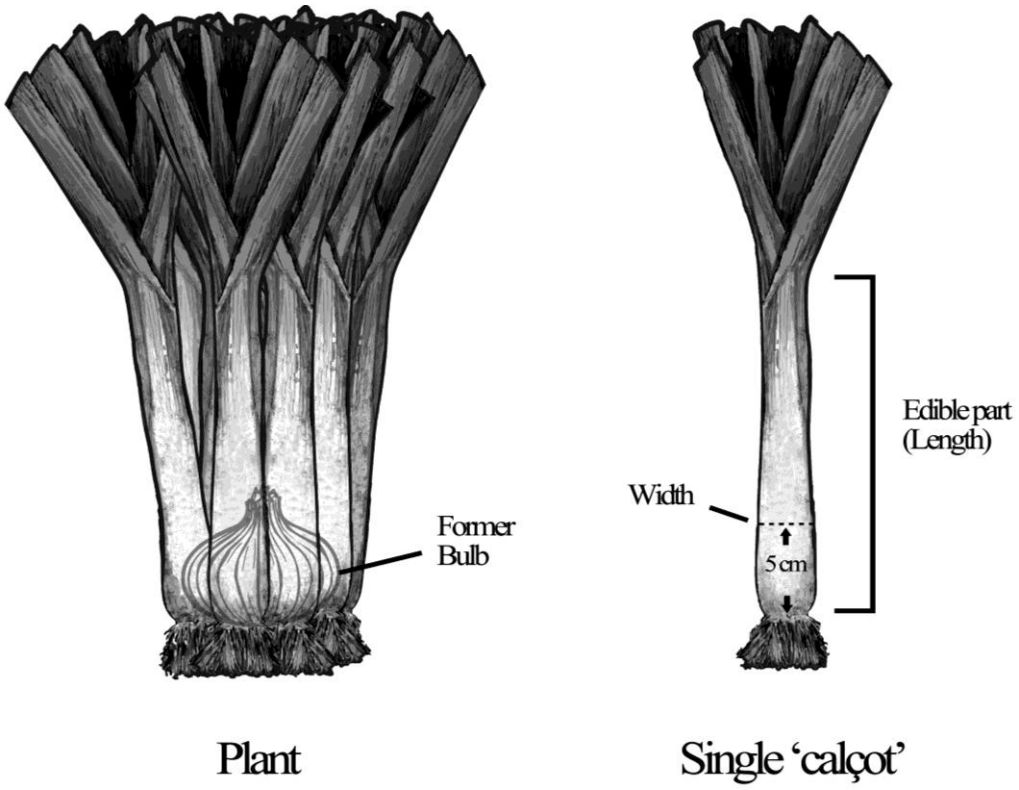

Figure 1. Schematic drawing of a 'calçots' plant derived from one onion, and a single 'calçot' with morphological characteristics labeled.

Figure 2. Photograph of the typical commercial presentation of 'calçots'.

optimum sensory traits for this product, although it has the European label of Protected Geographical Indication (PGI). Sensory analysis requires a strict normalized working methodology, careful experimental design, and appropriate statistical tools (Lawless and Heyman, 1998; Meilgaard et al., 1999). Although methods have been developed for the sensory analysis of some food products of great economic importance, such as wine (Amerine and Roessler, 1976; Gerbi et al., 1997), cheese (Bérodier et al., 1997; FIL, 1997; Lavanchy et al., 1993) and olive oil (Guerrero et al., 1996; IOOC, 1996), methods to evaluate the sensory quality of many other foods, such as cooked onions, remain to be developed. The lack of a sensory ideotype and methods to evaluate the sensory qualities of 'calçots' has discouraged breeders from including sensory traits in breeding programs and precluded regulating authorities efforts at quality control. On the other hand, it is unknown whether calçots' obtained from other varieties of onions would have sensory attributes similar to those valued in the calçots obtained from the 'Ceba Blanca Tardana de Lleida'. Moreover, it remains to be determined whether the agronomical ideotype established by farmers is compatible with the sensory ideotype. This information is very important for improving the agronomic, morphologic and sensory quality of 'calçots', to help expand the market, and to disseminate this particular way of consuming onions.

To favor the inclusion of sensory traits as an objective target in 'calçot' breeding, complementing the agromorphologic traits, we aimed to: (i) elaborate a sensory ideotype representing consumers' preferences for 'calçots', (ii) design a simple protocol for preparing samples and training a sensory panel to evaluate them, and (iii) describe the sensory attributes of 'calçots' derived from the main Spanish landraces of onion to evaluate their possible role in breeding 'calçots'.

MATERIALS AND METHODS

Elaborating an ideotype

Samples

We used five accessions (different populations) of the landrace 'Ceba Blanca Tardana de Lleida' coming from diverse locations throughout Catalonia with different soil types and climates (Lleida, Tarragona, La Masó, Cabrils, and Tordera) and cultivated in their place of origin. As the genetic differences between populations were unknown (the accessions corresponded to local populations but they had not been characterized), we reasoned that differences in genetic and environmental factors would provide enough phenotypic variability to enable us to elaborate a sensory ideotype.

'Calçots' are typically grilled over an open flame, but their popularity has led to easier culinary elaborations like oven roasting. As open flame preparation makes it impossible to ensure uniform cooking conditions, we decided to roast the 'calçots' in an oven. After several tests, we determined that the optimum roasting conditions were 18 min at 270°C. As commercial 'calçots' all have similar thickness and length, using a set cooking time yielded homogeneous culinary results despite the variety of entries. Following the typical practice employed by consumers, we removed the two most external leaves from the 'calçots' so that only the internal, edible part remained. We cut the lower 20 cm of the 'calçots' (Figure 1) lengthwise into four parts, and then we cut these parts transversally into 5 cm-long pieces to present to the tasters (thus 16 sensory samples were obtained from each 'calçot').

Advisory group

We formed a focus group (Lawless and Heyman, 1998) to define consumers' preferences for the sensory traits of 'calçots'. The group consisted of a) 18 people with ties to the production, commercialization, and culinary preparation of 'calçots', all of whom had extensive knowledge about consumers' sensory preferences through their professional activities, and b) seven people randomly chosen from our laboratory, all of whom had also eaten 'calçots' before.

Protocol for evaluation by the advisory group

We presented the advisory group with samples of the five accessions as described above. Group members were asked to consider whether the roasted 'calçots' differed substantially from those grilled on an open flame. Furthermore, group members were asked to decide whether they noticed differences in sensory qualities between the samples. If members noticed sensory differences, they were asked to define the attributes that differed and whether they preferred high or low values for these attributes. Finally, members were asked to describe a sensory ideotype for the 'calçot'. The five accessions were evaluated in duplicate; at the end of the second session, a joint discussion of the results was held to reach a consensus about the sensory ideotype of the 'calçot'.

Fine tuning the method of sample preparation

An analysis based on the variability of degrees Brix among 'calçots' from the same onion and among 'calçots' from different onions in the same population revealed that there was wide variability not only between 'calçots' from different onions (coefficients of variation > 15%), but also between 'calçots' from the same onion (coefficients of variation 5 to 10%). This high variability in a trait related, together with titratable acidity, to consumers' preferences of vegetables (Harker et al., 2002; Vangdal, 1985) led us to suspect that the sampling method used before was inefficient because it could not provide a good estimate of the mean phenotypic value of the accession (unless very many 'calçots' were evaluated for each accession). Furthermore, the samples cooled off very quickly, distorting the evaluation. To overcome these problems, we decided to use a puréed mixture of 50 peeled 'calçots' from the same accession proceeding from many different onions; this approach increased the representativeness of the sample considerably. We also performed tests to determine whether the sensory attributes of the purée remained unchanged after freezing to enable us to prolong the period of sensory analyses beyond the harvest season (from December to March).

To fine-tune the method we randomly chose 50 onions from an accession of 'calçots'. As each onion produces several 'calçots', we designed a sensory test that consisted of:

(a) Randomly selecting one commercial-size 'calçot' from 10 of the 50 plants, preparing them according to the protocol described above, and presenting samples to the panel for evaluation.
(b) Randomly choosing one commercial-size 'calçot' from each plant, preparing the 50 'calçots' according to the protocol described

above, peeling them, and puréeing them with a mixer (Taurus BAPI 850) to homogenize them. Half of the purée obtained was presented to the panel and the other half was frozen at -20°C.

This approach was used five times in two accessions; thus, at the end of the trial, the panel had evaluated 10 samples of freshly elaborated purée, 10 samples of the same purée defrosted one month after freezing, and 10 samples consisting of fragments of 10 'calçots' from some of the onions used to prepare the purées.

Training a specialized panel

The panel consisted of 14 tasters previously trained in the sensory analysis of beans (Romero Del Castillo et al., 2008). The panel was now trained to discriminate each of the three attributes defined by the preliminary advisory group (sweetness, fiber perception, and off flavors) in a total of six training sessions (two sessions per attribute). To validate the panel, three additional sessions were held in which the panelists evaluated in duplicate the five accessions used previously.

Attributes were measured on semi-structured visual scales labeled from 0 to 10 (Romero Del Castillo et al., 2008). In the training process, diverse products were used as references for the extremes of the scales and for some intermediate points.

Sweetness

To train the panel in this attribute, we used two onion purées (the sweet landrace 'Cebolla de Fuentes' and the less sweet landrace 'Cebolla Grano de Oro') and two 'calçot' purées with different degrees of sweetness (one unadulterated 'calçot' purée and the same 'calçot' purée after adding 20 g sucrose per 200 g sample).

Fiber perception

To train the panel in this attribute, we used four purées: leek and celery (the reference for the maximum perception of fiber), leek alone, 'calçot', and spinach (the reference for the minimum perception of fiber).

Off flavors

To represent the extreme typical flavor of 'calçots', we used the accession that the advisory group of consumers had scored highest for this attribute. The other extreme of the scale represented any intense flavor that was clearly different from that of 'calçots' (regardless of whether these flavors coexisted with the typical 'calçot' flavor). We used purées of leek, spinach, onion, and moldy onion as reference points for different degrees of off flavors.

To elaborate the purées of 'calçots' and of leeks, we followed the protocol described above. We used the same protocol to prepare the onion purées, but we adjusted the cooking time because the optimum varied with the size of the onion. Celery and spinach were boiled for 15 min and then puréed in the same way as the 'calçots'. Each sample presented to the panelists consisted of approximately 8 g of purée served at 60°C on a small plate identified by three randomly chosen numbers.

Study of variability

Plant material

In addition to the 'Ceba Blanca Tardana de Lleida' landrace, we used 14 Spanish onion landraces selected for their gastronomic prestige (Carravedo and Mallor, 2007) (Table 1); all materials were supplied by the germplasm bank of the *Instituto para la Conservación y Mejora de la Agrodiversidad Valenciana*. All entries were cultivated at La Masó (41°3'47"N, 01°13'12"E), located in the center of the Protected Geographical Indication 'Calçot de Valls' and having soil and climate representative of this area. Onions developed during the spring and harvested in July, were replanted in August in 15 cm-deep furrows at a density of 8000 plants per hectare. The resprouts arising in the autumn were covered with land two or three times (as is traditional in the cultivation of 'calçots') to increase the length of the white edible part. The plants were harvested individually from December to March, when they reached the commercial standard.

Sensory analysis

Purées of 'calçots' from the different landraces were prepared and served as described previously and the trained panelists evaluated each accession twice in eight sessions; in each session, panelists evaluated four samples for the attributes sweetness, fiber and off flavors.

All tests were carried out in a room designed for sensory tests that fulfilled the standards set out by the International Organization for Standardization (ISO 8589, 2007).

Morphological analysis

'Calçot' weight, length of the edible part, and width (diameter measured 5 cm from the beginning of the root) were recorded in the same 50 'calçots' used to prepare the puree for each variety. These traits were chosen because they are key aspects in the PGI labeling.

Statistical analysis

We performed ANOVA using R statistic software (Team, 2009). The linear model $x_{ijk}= \mu + a_i + p_j + a*p_{ij} + e_{ijk}$ enabled us to calculate the accession effect (a), the panelist effect (p), and the interaction between panelists and accession. Significance for the factors was considered at a $P \leq 0.05$ level. We used the same R statistic software to perform the least significant difference test for multiple comparisons (Mendiburu, 2009). Modifications of this model were used to compare the different preparations described.

RESULTS

Sensory ideotype of the 'calçot'

The focus group found no significant differences between oven-roasted 'calçots' and those grilled over an open fire in the traditional manner. They pointed out that the flavor of the samples roasted in the oven was unaffected by burnt and smoky flavors present in samples prepared in the traditional manner.

During the tasting sessions, diverse attributes were proposed for the sensory classification of 'calçots', but in the final meeting the group reached the consensus that 'calçots' should be characterized by pronounced sweetness, low fiber perception, and the absence of off flavors.

Table 1. Accessions of onions used in the study.

Accession	Source	Variety name
BGV001392	Inca (Balearic Islands)	Ceba Mallorquina
BGV001624	Manresa (Barcelona)	Ceba de Figueres
BGV003277	Bembirbe (León)	Cebolla de Villafranca del Bierzo
BGV004701	Massamagrell (Valencia)	Cebolla Babosa (a)
BGV004724	Crevillente (Alicante)	Cebolla Babosa (b)
BGV010676	Grazalema (Cadiz)	Cebolla del Terreno Blanca
BGV010701	Nerja (Málaga)	Cebolla de Nerja
BGV010702	Ibarra (Guipuzcoa)	Cebolla Amarilla de Ibarra
BGV010827	Logrosan (Cáceres)	Cebolla Blanca del Golosa
BGV010832	Coron (Pontevedra)	Cebolla Longa de Corón
BGV010834	Souto (La Coruña)	Cebolla de Betanzos
BGV011045	Amposta (Tarragona)	Ceba Morada d'Amposta
BGV011504	Santa Fe (Granada)	Cebolla Recas
BGV011932	Pintanos (Zaragoza)	Cebolla Chata de Pintanos

Table 2. Results of sensory analyses for different accessions and preparation in the process of fine-tuning the method of 'calçot' sample preparation.

Population	Preparation	Sweetness	Fiber	Off flavour
1	Fragments	5.95 ± 0.39	1.08 ± 0.32	1.38 ± 0.44
	Purée	6.00 ± 0.13	1.13 ± 0.11	1.28 ± 0.11
	Defrosted purée	5.95 ± 0.09	1.18 ± 0.10	1.31 ± 0.14
	LSD	0.52	0.43	0.47
	Mean	5.97[b]	1.13[b]	1.32[b]
2	Fragments	8.05 ± 0.38	2.70 ± 0.44	2.48 ± 0.42
	Purée	8.00 ± 0.09	2.79 ± 0.08	2.55 ± 0.11
	Defrosted purée	8.03 ± 0.07	2.76 ± 0.11	2.52 ± 0.08
	LSD	0.49	0.60	0.57
	Mean	8.03[a]	2.75[a]	2.52[a]

Values are mean ± standard deviation. Means of population in a column sharing the same letter are significantly different by least significant difference (LSD) (P≤0.05).

Fine-tuning the method of sample preparation

The panel's scores for the sensory attributes of the two accessions studied did not differ significantly when the samples were presented as fresh 'calçot' fragments, freshly elaborated purée, and frozen and defrosted purée (Table 2). However, when samples were presented as fragments, the values for the three attributes were much more widely dispersed (Table 2).

Training and validation of a specialized panel

In the trials carried out during the training sessions for the discrimination of the attributes sweetness, fiber and off flavors, only the factor accession was significant. Values for all three of the attributes were significantly different among the four purées used in the training sessions (Table 3). As expected the reference purées chosen for the extreme values for each of the three attributes scored near the extremes of the scale (0 and 10) (Table 3).

In the sessions carried out to validate the panel, neither the factor panelist nor the interaction panelist x accession were significant. For the attribute sweetness, panelists' evaluations established three statistically different groups: 'calçots' from Tarragona, Lleida, and La Masó were the sweetest, followed by those from Tordera and those from Cabrils were the least sweet (Table 4). For the attribute fiber, evaluations also established three statistically different groups, although the second group, 'calçots' from La Masó, overlaps with the 'calçots' from two locations comprising the group with the most fiber (Table 4). Fiber perception was highest in 'calçots' from Cabrils and from Lleida, followed by those from La Masó and Tarragona, and was lowest in those from Tordera (Table 4). Finally, two clearly different groups were established for the presence of off flavors: 'calçots' from

Table 3. Results of sensory analyses for each group of reference material used to establish the evaluation scales.

Accession	Fiber	Accession	Sweetness	Accession	Off flavour
Leek and celery	8.24 ± 0.44	Calçot + sugar	9.12 ± 0.21	Moldy onion	9.68 ± 0.19
Leek	5.20 ± 0.44	Sweet onion	6.54 ± 0.31	Spinach	5.34 ± 0.33
Calçot	4.90 ± 0.26	Calçot	3.74 ± 0.28	Calçot	0.85 ± 0.21
Spinach	1.14 ± 0.30	No sweet onion	1.51 ± 0.22	Leek	8.54 ± 0.24
LSD	0.56	LSD	0.61	LSD	0.64
P	*		*		*

Values are mean ± standard deviation; LSD, least significant difference (P≤0.05). *Significant at P<0.001.

Table 4. Results of sensory analysis in the three attributes for 5 accessions of 'Ceba Blanca Tardana de Lleida' onion landrace cultivated in their locations of origin.

Accession	Sweetness	Fibre	Off Flavour
La Masó	7.13 ± 0.25	6.35 ± 0.39	1.22 ± 0.30
Lleida	7.04 ± 0.28	6.61 ± 0.23	6.00 ± 0.31
Tarragona	6.78 ± 0.27	5.39 ± 0.32	1.48 ± 0.26
Tordera	5.25 ± 0.29	3.83 ± 0.24	1.75 ± 0.33
Cabrils	3.22 ± 0.30	7.22 ± 0.39	5.83 ± 0.28
LSD	0.88	0.96	0.87
P	*	*	*

Values are mean ± standard deviation; LSD, least significant difference (P≤0.05). *Significant at P<0.001.

Cabrils and those from Lleida had intermediate values for this attribute, whereas the remaining accessions had very low values (Table 4).

Study of the variability

Whereas the landrace effect was significant for all three sensory attributes, the interaction panelist x landrace was not significant for any attribute. The panelist effect was significant for the attributes sweetness and off flavors.

We found up to seven statistically different groups for the attribute sweetness (Table 5), although some groups overlap with others. 'Calçots' from the 'Ceba Blanca Tardana de Lleida' landrace (the landrace used in the PGI for 'calçots') have the highest values for sweetness (Table 5), together with the 'Ceba Morada d'Amposta', the 'Cebolla Babosa 2', and the 'Cebolla de Nerja'. The lowest values for sweetness corresponded to the landraces 'Cebolla Longa de Corón', 'Cebolla Blanca del Golosa', 'Cebolla de Betanzos', and 'Ceba de Figueres'.

'Calçots' from the 'Ceba Blanca Tardana de Lleida' landrace had the lowest scores for fiber perception. For this attribute, they were grouped with the landraces 'Cebolla de Nerja', 'Ceba Mallorquina', 'Ceba Morada d'Amposta', 'Cebolla de Betanzos', and 'Cebolla Amarilla de Ibarra'. The accessions with the highest scores for fiber perception were 'Cebolla Blanca del Goloso' and 'Cebolla del Terreno Blanca' (Table 5).

We found up to six statistically different groups for the attribute off flavors (Table 5), although given the overlapping these could be considered two large groups (those with values of three or four and the rest with higher values). 'Calçots' from the 'Ceba Blanca Tardana de Lleida' landrace have the second lowest scores for this attribute, and as in the other two attributes, these 'calçots' are near the ideotype elaborated by the preliminary advisory group.

We used the mean values of the agronomic, morphologic, and sensory traits of the varieties to calculate the genotypic correlations between traits (Table 6); the most significant correlations were weight with width (0.84), number of 'calçots' with length (0.72), and off flavors with fiber (0.83) (Table 6).

DISCUSSION

Sensory traits are often disregarded in breeding programs for various reasons. Before a breeding program aiming to improve sensory traits can be developed, it is necessary to define desirable attributes and develop strategies to overcome the difficulties involved in sampling and measuring these attributes as well as to explore the possibilities by the genetic variability and compatibility with important agromorphic traits. We sought to lay the groundwork for breeding programs to improve the sensory quality of 'calçots' by defining an ideotype to serve as a target, developing a simple and feasible method for measuring the traits defined in the ideotype, and exploring the genetic variability within the landrace defined in the protected geographical indication and in other Spanish landraces that might be suitable for cross-breeding.

Table 5. Results of sensory, morphological, and chemical analyses for 'calçots' obtained from prestigious Spanish landraces of onion.

Accession	Sweetness	Fiber	Off flavor	Width (cm)	Length (cm)	Weight (g)	Calçots
Ceba Blanca Tardana de Lleida	6.78 ± 0.35	1.38 ± 0.19	3.32 ± 0.64	22.82 ± 0.50	18.29 ± 0.15	100.41 ± 3.25	9.94 ± 1.07
CebaMoradad'Amposta	6.76 ± 0.42	2.53 ± 0.38	4.49 ± 0.62	15.95 ± 0.75	13.50 ± 0.45	68.48 ± 6.59	2.94 ± 0.36
Ceba de Figueres	6.34 ± 0.49	2.85 ± 0.59	5.09 ± 0.58	16.28 ± 0.94	12.96 ± 0.24	67.61 ± 7.79	3.00 ± 0.47
CebollaBabosa(b)	5.99 ± 0.57	3.70 ± 0.49	3.50 ± 0.67	16.33 ± 0.54	14.38 ± 0.26	75.37 ± 6.46	3.41 ± 0.67
Cebolla de Nerja	5.61 ± 0.57	2.69 ± 0.53	3.07 ± 0.63	15.60 ± 0.68	17.85 ± 0.27	72.00 ± 4.65	8.21 ± 1.60
CebaMallorquina	4.58 ± 0.44	2.41 ± 0.26	4.34 ± 0.78	16.21 ± 0.60	13.33 ± 0.14	89.18 ± 5.88	5.57 ± 0.61
CebollaBabosa (a)	4.52 ± 0.78	4.57 ± 0.64	5.86 ± 0.93	17.45 ± 0.51	14.21 ± 0.18	87.25 ± 4.87	4.85 ± 0.44
CebollaRecas	4.45 ± 0.53	3.28 ± 0.57	4.54 ± 0.90	26.02 ± 1.11	15.50 ± 0.64	165.43 ± 17.02	3.58 ± 0.45
Cebolla de Villafranca del Bierzo	4.40 ± 0.41	4.25 ± 0.50	4.20 ± 0.77	20.19 ± 1.70	12.34 ± 0.32	50.25 ± 4.16	3.10 ± 0.69
Cebolla del TerrenoBlanca	4.25 ± 0.56	6.37 ± 0.49	6.54 ± 0.49	23.85 ± 0.76	14.10 ± 0.19	144.21 ± 8.35	2.57 ± 0.36
CebollaAmarilla de Ibarra	4.05 ± 0.57	2.08 ± 0.41	3.65 ± 0.61	19.45 ± 0.39	15.05 ± 0.18	93.72 ± 3.96	8.57 ± 1.21
CebollaChata de Pintanos	3.65 ± 0.60	5.16 ± 0.33	5.65 ± 0.93	21.62 ± 1.35	15.36 ± 0.45	119.68 ± 16.4	3.30 ± 0.59
Cebolla de Betanzos	3.07 ± 0.47	2.57 ± 0.59	3.45 ± 0.94	16.73 ± 0.74	12.86 ± 0.18	59.32 ± 5.50	3.36 ± 0.41
CebollaBlanca del Golosa	2.82 ± 0.47	7.24 ± 0.36	7.15 ± 0.47	21.40 ± 0.92	13.80 ± 0.37	124.08 ± 9.25	6.72 ± 0.81
CebollaLonga de Coron	1.94 ± 0.36	3.04 ± 0.61	4.09 ± 0.71	16.69 ± 0.77	13.19 ± 0.27	64.26 ± 5.85	3.28 ± 0.52
LSD	1.5	1.14	1.69	3.81	0.81	20.81	2.41
P	*	*	*	*	*	*	*

Values are mean±standard deviation. LSD, Least significant difference (p≤0.05). *Significant at P < 0.001.

Sensory ideotype of the 'calçot'

Although, many traits were considered, the advisory group proposed high sweetness, low fiber perception, and low perception of off flavors to represent the ideal 'calçot'. This simple sensory ideotype complemented the agronomic (12 'calçots' per onion) and morphological (2 cm in diameter and 20 cm length of the edible part) ideotypes, providing a clear full target for breeding and agronomic management.

Fine-tuning the method of sample preparation

The mean values for the attributes measured in 'calçot' fragments did not differ from those measured in purées, and the dispersion of the values was much lower for the purées (Table 2). Therefore, we decided that puréeing was the best method of sample preparation because using 'calçot' fragments would require a much larger number of samples to be evaluated to enable a good estimate of the mean phenotypic value. The lack of significant differences between the freshly prepared purées and the frozen purées in the attributes evaluated (Table 2) enables greater flexibility in scheduling tasting sessions, making it possible to distribute the panel's work more conveniently. Furthermore, using frozen samples opens the possibility of comparing materials harvested at different times during a season or even during different seasons. Finally, puréeing is also suitable for sampling for chemical analysis, making it possible to perform both sensory and chemical analyses on the same sample. This method promises to be useful for evaluating the sensory and chemical characteristics of boiled or roasted onions as well as 'calçots'.

Training and validation of a specialized panel

No significant panelist effect or panelist x accession interaction was observed during the formal training process or during validation (Tables 4 and 5). These findings confirm that the panel was well trained, that the panelists had assimilated the scales, and that they had a clear idea of the attributes. Although differences between the samples of 'Ceba Blanca Tardana de Lleida' were expected to be minor, the panelists were able to establish statistically significant groups in all the evaluated attributes (Table 4).

It is important to note that the values for the different accessions do not represent the general traits of 'calçots' from each area; in fact, we sought out very different fields to ensure phenotypic variation for each sensory attribute. The aim of this trial was to develop a sampling method and to train a panel, rather than to study the effects of specific genetic and/or environmental factors on the sensory value of the'calçot'.

Table 6. Genotypic correlations between traits.

	Fiber	Off flavor	Width	Length	Weight	Calçots
Sweetness	-0.43	-0.31	-0.15	0.38	-0.15	0.18
Fiber		0.87***	0.38	-0.26	0.45	-0.32
Off flavors			0.38	-0.30	0.52*	-0.30
Width				0.31	0.84***	0.07
Length					0.34	0.72**
Weight						0.06

*, Significant at P<0.05; **, Significant at P<0.01; ***, Significant at P<0.001.

Study of the variability

The group of prestigious Spanish landraces had considerable variability for the three sensory attributes; however, the 'Ceba Blanca Tardana de Lleida' onion, the landrace traditionally used for the production of 'calçots', scored closest to the ideotype (Table 5). Nevertheless, the onion is an allogamous plant, and heterosis is expected when genetically distant varieties are crossed. Considering sensory, morphologic, and agronomic traits, 'Cebolla de Nerja' and 'Cebolla Amarilla de Ibarra' (Table 5) seem good candidates to be crossed with 'Ceba Blanca Tardana de Lleida' to generate a base population for breeding. Anyway, populations of allogamous plants are very heterogeneous, so studying the internal variability of the 'Ceba Blanca Tardana de Lleida' landrace and developing intravarietal breeding programs is likely to yield good results.

The lack of negative genotypic correlations (Table 6) suggests that breeding to reach agronomic, morphological, and sensory ideotypes is feasible. Furthermore, breeding for low fiber perception should also decrease off flavors as both traits have a high and significant positive correlation (Table 6).

The panelist effect was significant in this experiment. Though this effect did not prevent the panel from distinguishing between entries, it indicates that panelists' assimilation of the scales was insufficient when the variability of the attributes was increased (in the trial performed to validate the panel, in which only 'calçots' from 'Ceba Blanca Tardana de Lleida' onions were used, neither the panelist nor the interaction panelist x entry effect was significant for any attribute). This means that the panelists would need further training in the extremes of the scales if they were to continue to work with 'calçots' from onions with characteristics different from those typical of 'calçots' from 'Ceba Blanca Tardana de Lleida' onions.

Conclusion

The advisory group considered that the ideal 'calçot' should have a high level of sweetness, low fiber perception, and no off flavors. We propose a simple and standardized protocol for the preparation of samples: roasting samples of 50 commercial-size 'calçots' per entry at 270°C for 18 min, removing the two external leaves, cutting the 'calçots' to a length of 20 cm, and puréeing them for 2 min. This purée can be frozen at -20°C for further sensory analyses. The same method could be used to prepare samples of roasted or boiled onions.

Our investigations into the quality attributes of 'calçots' have yielded a simple ideotype and an easy, reproducible methods for preparing samples and training panels that will encourage breeders to include sensory attributes in their objectives. Our results suggest that breeding for improvements in sensory attributes is compatible with the agromorphologic ideotype, providing breeders with a clear full target.

We observed marked differences in all the traits studied between 'calçots' obtained from prestigious Spanish landraces of onion. Although none of the landraces clearly surpassed the 'Ceba Blanca Tardana de Lleida' onion, crosses between varieties could be useful to generate heterotic base populations for breeding. Given the variability among 'calçots' from different onions within 'Ceba Blanca Tardana de Lleida', selection within this population also seems to be an efficient approach to achieve the ideotype.

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