Variability in some texture characteristics and chemical composition of common beans (*Phaseolus vulgaris* L.)

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Abstract: The increase in the consumption of pulses in developed countries is strongly related to the availability of varieties with high-quality sensory attributes. Local varieties show variability of this characteristic but the extent is unknown. This study aims to assess the variability in texture and chemical composition among traditional Spanish varieties of common beans. Texture differences among varieties found by panellists correspond to chemical variation, although chemical differences within varieties seem greater than those reported in sensory analyses. It seems reasonable to screen existing information on the chemical composition of common beans to identify promising varieties to be tested in sensory trials. Nevertheless, selection within varieties should be performed only after sensory tests on the degree of differences shown by extreme genotypes for components such as protein or starch.

Keywords: common bean; variability; texture; chemical composition

INTRODUCTION

Breeding grain pulses for improved organoleptic quality would increase their consumption, and provide a healthier diet in countries where proteins come mainly from meat. Texture characteristics are very important in determining the organoleptic value of grain pulses, while taste is mainly provided by accompanying products in the cooked dish (like in Italian pasta). As far as texture is concerned, perception of the seed-coat and degree of creaminess of the whole-seed are important characteristics easily perceived by consumers in common beans (*Phaseolus vulgaris* L.). To date, little information on organoleptic attributes in grain pulse species has been published.[1,2] Moreover, although some correlations between texture and chemical composition of the seed have been reported on dry beans (*Phaseolus vulgaris* L),[3] it is still necessary to use sensory panels for variety characterization or texture breeding, which is very time consuming.

In Spain, a secondary centre of diversity of *Phaseolus vulgaris* L.,[4] many local varieties (usually linked to traditional dishes and/or to a presumed high organoleptic quality) have been preserved by regular cultivation and consumption. Such autochthonous traditional varieties, clearly out-yielded by modern improved varieties, remain in commercial cultivation due to their supposedly superior organoleptic quality. The most appreciated local varieties Faba Granja, Tolosa and Ganxet, with a total yield of about 2000 tons per year, are priced between 8 and 15 euros per kg.

In this context we aim to (1) analyse differences in texture and in chemical composition of four varieties of bean, both from the sensory and chemical points of view, and (2) apply the same approach to investigating the variability within the Ganxet local variety, one of the most promising Spanish varieties from an organoleptic point of view.

MATERIAL AND METHODS

Plant material

For the inter-variety study, three Spanish local varieties of common bean (Ganxet, Genoll de Crist, Castellfollit del Boix) and a well-known improved commercial variety (Canela) were used. For the intra-variety study, 21 inbred lines were chosen, all of which had the typical Ganxet morphology (highly hooked, much more so than kidney beans) but still presenting agronomic and chemical variability.[5]

Field trials

Field trials were performed at a single location (La Roca del Vallès, north-east Spain) where all

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the germplasm had previously proved to grow satisfactorily. The crop was planted in early July and harvested in November, according to the tradition of the area. A randomised block design (two blocks) with 80 plants per plot was used in both trials.

Sensory and chemical analysis

The material from the inter-variety trial was assessed for chemical and organoleptic characteristics. For the intra-variety trial, 21 lines from the Ganxet variety were assessed for chemical variables. Sensory evaluations were performed only in five Ganxet lines, those representing the maximum variability for the chemical variables related to seed-coat perception and whole-seed creaminess.

Sensory analysis

Each sample of 250 g of beans was soaked in 1250 mL of low mineralised water for 12 h, at a temperature of 20 °C. The soaked beans were placed in 1.5 L cold water and cooked on low heat until tender. Shortly before the beans were done, 2.5 g NaCl was added. Twelve trained panellists evaluated the cooked seeds in a multi-comparison trial, performed in a duplicate session in a fully equipped sensory laboratory. Each panellist was provided with 50 g beans per sample, served at a temperature of 70 °C. Three sensory attributes were evaluated on unstructured scales: (1) seed-coat perception in the mouth when eaten, on a scale from zero (not perceptible) to 5; (2) seed-coat roughness measured by the tip of the tongue on a scale from zero (completely smooth) to 5; and (3) whole-seed creaminess on a scale from zero (high dispersion of the bean-mass in the mouth at the lowest pressure) to 5 (the perception of granules).

The panel was previously trained using various foods with extreme and intermediate textures and finally with beans. Before the present experiment, the panel was evaluated by means of a three-session taste test using four different varieties of beans (different from those employed in this experiment). In the evaluation, for all texture variables considered in this experiment, the variety effect was statistically significant in the ANOVA, while the observer effect and observer × variety effect were not.

Chemical analysis

Seed-coat and whole-seed chemical analyses were performed in duplicate on uncooked material from each plot. The chemical compounds chosen had previously been related with seed-coat perception[6–8] and with texture of the whole seed.[3,9–12]

Crude protein. The crude protein was determined using the Kjeldahl method,[13] quantifying the amount of nitrogen by selective ammonium electrode. Crude protein content was calculated as %N × 6.25.

Dietary fibre and uronic acids. Total, soluble and insoluble dietary fibre were determined by means of the Englyst Fiberzym colorimetry kit (Novo Nordisk Bioindustries Surrey, UK n° 7 367 722). This method measures dietary fibre as non-starch polysaccharides (NSPs) using enzymatic–chemical methods and has evolved from the principles laid down by Southgate.[14] Starch is hydrolysed enzymatically, NSPs are isolated by precipitation in ethanol then hydrolysed by sulfuric acid. The constituent neutral sugars and uronic acid (UAc) were measured by colorimetry.

Starch content. Starch content was determined using the AOAC method.[15] The glucose obtained was determined by high-performance liquid chromatography (HPLC). The total starch was calculated as glucose ×0.9.

Amylose and amylopectin. Amylose content was analysed using the methodology proposed by Juliano *et al.*[16] The complex coloration amylase/iodide was determined colorimetrically using a UV–visible spectrophotometer ($\lambda = 620$ nm). The amylopectin content was calculated as the difference between the starch content and amylose content.

Calcium and magnesium. The analysis was performed on the ash extract (dissolution in 2 mol L^{-1} HNO_3). Ca and Mg were quantified by atomic spectrophotometry.

Statistical analysis

The data for each chemical variable were studied by means of ANOVA using the SAS[17] statistical package according to the linear model $x_{ij} = \mu + g_i + \varepsilon_{j(i)}$, where x_{ij} is any individual value, μ is the mean, g_i is the effect of bean type and $\varepsilon_{j(i)}$ is the residual.

Data recorded in the sensory analysis were studied by means of ANOVA using the SAS statistical package according to the linear model, $x_{ij\,k} = \mu + g_i + d_j + p_k + g_i d_j + g_i p_k + \varepsilon_{ijk}$, where $x_{ij\,k}$ is any individual value, g_i is the effect of bean type, d_j is the effect of day of evaluation, p_k is the effect of the panellist and ε_{ijk} is the residual.

RESULTS AND DISCUSSION

Inter-variety analysis

Sensory approach

The three texture attributes considered presented significant differences between varieties (Table 1).

Table 1. Inter-variety study. Mean values of the texture attributes on cooked seeds, measured by panellists on a scale 0 to 5

Variety	Seed-coat perception	Seed-coat surface roughness	Whole-seed creaminess
Ganxet	1.1^b	3.4^a	3.7^a
Castellfollit	1.2^b	1.4^b	2.4^b
Genoll de Crist	2.1^ab	1.3^b	0.8^c
Canela	3.0^a	2.6^b	1.0^c

Values followed by the same letter are not significantly different (Newman–Keuls test, $P \leq 0.05$).

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The other effects (day of evaluation and panellist) and interactions, were not significant ($P = 0.05$). The set of local varieties encompasses a wide range of organoleptic variation for these attributes. Castellfollit del Boix and Genoll de Crist showed the smoothest surface of the seed-coat, while Ganxet was the creamiest and had the least perceptible seed-coat (Table 1). It seems that selection has kept a large amount of variability for the main texture attributes, although consumers generally associate high quality with low perception of the seed-coat and high creaminess. Seed-coat surface roughness would be of lesser importance from the gastronomic point of view. Canela, included in the experiment as a representative of successful commercial improved varieties, showed the highest seed-coat perception, the second highest seed-coat surface roughness, and shared with Genoll de Crist the last position in creaminess (Table 1).

Chemical approach

All variables considered presented significant differences between varieties, except for Mg content in the seed coat (Tables 2 and 3). Protein and/or amylose/amylopectin ratio, previously reported[3] to be related with creaminess in beans, also showed significant variability (Table 3). The coefficients of correlation between seed creaminess and protein content, starch, amylose, amylopectin and amylose/amylopectin ratio were 0.89 ($P = 0.10$), −0.92 (0.07), −0.91 ($P = 0.09$), −0.91 ($P = 0.09$) and 0.87 ($P = 0.12$), respectively. The chemical and sensory approaches were consistent in that the creamiest varieties were those with the highest protein content, although the role of the amylose/amylopectin ratio was not clear. Regarding seed-coat perception, the content of uronic acid (correlation coefficient with seed-coat perception of −0.95, $P = 0.05$) seems to be a better indicator than Ca or Mg content (no significant correlation with seed-coat perception $P = 0.35$) (Tables 1 and 2), as previously reported.[8]

Much variability in protein content has been reported in a wide range of local varieties throughout the world.[18] If our findings held true for all varieties of the common bean, it would seem reasonable to scan some selected chemical components in traditional varieties to look for germplasm with superior texture properties.

Intra-variety analysis

Chemical approach

Ganxet was chosen to study variability for sensory related attributes within a local variety, as it had the best organoleptic qualities among the varieties considered (Tables 1, 2 and 3), according to consumers' preferences. The 21 Ganxet lines selected showed significant variability for both seed-coat and whole-bean chemical compounds (Tables 4 and 5), except for total uronic acids (TUAc), soluble uronic acids (SUAc) and Mg content of the seed coat. So, despite the morphological similarity of the lines selected (only very hooked beans which presented similar seed weight), a high genetic variability in the Ganxet variety was found. These results suggest that the Ganxet bean, originally introduced in Catalonia, spontaneously intermated with other varieties, and, in later generations, successful selection for the distinctive hooked trait was easily achieved by farmers.

The Ganxet lines with extreme values for the variables most related to seed-coat perception and whole-seed creaminess were submitted to the sensory analysis (Tables 6 and 7).

Sensory approach

The panellist effect in the attributes seed-coat perception and seed-coat surface roughness was the

Table 2. Inter-variety study. Mean values ($g\,kg^{-1}$) of the seed-coat chemical variables

Variety	Protein	TNSP	INSP	SNSP	NCP	Cellulose	TUAc	IUAc	SUAc	Ca	Mg
Ganxet	52.7^{a}	713^{a}	513^{b}	200^{a}	326^{b}	388^{a}	193^{a}	93^{a}	100^{b}	4.7^{c}	4.3^{a}
Castellf. del Boix	46.7^{b}	671^{b}	571^{a}	99^{c}	368^{a}	303^{d}	198^{a}	80^{b}	118^{a}	11.6^{a}	3.4^{a}
Genoll de Crist	48.9^{ab}	677^{b}	483^{c}	194^{a}	339^{b}	338^{b}	146^{b}	53^{d}	93^{b}	4.7^{c}	4.2^{a}
Canela	46.6^{b}	635^{c}	469^{d}	166^{b}	308^{c}	326^{c}	135^{d}	62^{c}	73^{c}	6.7^{bc}	2.4^{a}

TNSP: total non-starch polysaccharides; INSP: non-soluble non-starch polysaccharides; SNSP: soluble non-starch polysaccharides; NCP: non-cellulosic polysaccharides; TUAc total uronic acids; IUAc: non-soluble uronic acids; SUAc: soluble uronic acids.
Values followed by the same letter are not significantly different (Newman–Keuls test, $P \leq 0.05$).

Table 3. Inter-variety study. Mean values ($g\,kg^{-1}$) of the chemical and physical characteristics of whole seeds

Variety	Protein	Starch	Amylose	Amylopectin	Aml/Amp	Seed-coat proportion
Ganxet	257^{a}	359^{b}	94^{b}	265^{b}	0.36^{a}	90^{a}
Castellfollit Boix	223^{b}	436^{a}	102^{a}	334^{a}	0.31^{ab}	77^{b}
Genoll Crist	219^{b}	449^{a}	106^{a}	343^{a}	0.31^{ab}	63^{d}
Canela	221^{b}	454^{a}	102^{a}	352^{a}	0.29^{b}	73^{c}

Aml: amylose; amp: amylpectin.
Values followed by the same letter are not significantly different (Newman-Keuls test, $P \leq 0.05$).

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and lower perception of the seed coat in Ganxet, but the improvements obtained are not likely to be noticed by the consumer.

Although consumers prefer low seed-coat perception and high creaminess when beans are eaten alone, the persistence in the market of appreciated local varieties with opposite characteristics is probably related to the different dishes in which they are used. Creamy varieties with low seed-coat perception are used mainly in simple dishes like salads or as side vegetables of main courses. The other extreme is represented by varieties with a very strong taste, floury texture and generally high perception of the seed coat. In Spain, these varieties are used in more complex dishes, such as those cooked with meat, shellfish and all kinds of sauces.

It seems reasonable to screen existing information on the chemical composition of common beans to identify promising varieties to be tested in sensory trials. Nevertheless, selection within varieties should be performed only after sensory tests on the degree of differences shown by extreme genotypes for significant molecules.

Taking Ganxet as a model, and given the joint evolution of local varieties and related traditional dishes, it seems very difficult to improve sensory quality within a local variety. Undoubtedly, much more can be accomplished by breeding the local varieties with superior organoleptic attributes for agronomic traits and improving the gastronomic quality of commercial varieties of beans.

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REFERENCES

1 Wassimi NN, Hostfield GL and Uerbersax MA, Inheritance of physico-chemical seed characters related to culinary quality in dry bean. *J Am Soc Hortic Sci* **115**:492–499 (1990).
2 Sanz-Calvo M and del Rey JA, Sensory analysis of beans. *Biotechnol Agron Soc Environ* 3:201–204 (1999).
3 Pujolà M, Casañas F, Bosch L, Almirall A, Sánchez E and Nuez F, Creaminess and chemical composition in dry beans (*Phaseolus vulgaris* L.): the roles of protein and starch, in *5th European Conference on Grain Legumes. Conference Handbook.* Dijon, ed. by AEP (European Association for Grain Legume Research). 12 Avenue George V, 75008 Paris, France. p. 424 (2004).
4 Santalla M, Rodiño AP and de Ron AM, Allozyme evidence supporting southwestern Europe as a secondary center of genetic diversity for the common bean. *Theor Appl Genet* **104**:934–944 (2002).
5 Casañas F, Bosch L, Pujolà M, Sanchez E, Sorribas X, Baldi M, *et al*, Characteristics of a common bean landrace (*Phaseolus vulgaris* L.) of great culinary value and selection of a commercial inbred line. *J Sci Food Agric* **79**:693–698 (1999).
6 Quenzer NM, Fuman VL and Burns EE, Some factors affecting pinto bean quality. *J Food Sci* **43**:1059–1061 (1978).
7 Wang CR, Chang KC and Grafton K, Canning quality evaluation of pinto and navy beans. *J Food Sci* **53**:772–776 (1998).
8 Casañas F, Pujolà M, Bosch L, Sanchez E and Nuez F, Chemical basis for low sensory perception of Ganxet bean (*Phaseolus vulgaris* L.) seed coat. *J Sci Food Agric* **82**:1282–1286 (2002).
9 Ong MH and Blanxhard JMV, Texture determinants in cooked parboiled rice. I: Rice starch amylase and the fine structure of amylopectin. *J Cereal Sci* **21**:251–260 (1995).
10 Ramesh M, Bhattacharya KR and Mitchell JR, Developments in understanding the basis of cooked-rice texture. *Crit Rev Food Sci Nutr* **40**:449–460 (2000).
11 Champagne ET, Bett-Garber KL, McClung AM and Bergman C, Sensory characteristics of diverse rice cultivars as influenced by genetic and environmental factors. *Cereal Chem* **81**:237–243 (2004).
12 Park JK, Kim SS and Kim KO, Effect of milling ratio on sensory properties of cooked rice and on physicochemical properties of milled and cooked rice. *Cereal Chem* **78**:151–156 (2004).
13 Association of Official Analytical Chemists, *Official Methods of Analysis*, 15th edition. AOAC, Arlington, VA (1990).
14 Southgate DA, Determination of carbohydrates in foods. I. Available carbohydrates. *J Sci Food Agric* **20**:326–330 (1969).
15 Association of Official Analytical Chemists, *Official Methods of analysis*, 20th edition. AOAC, Arlington, VA (1997).
16 Juliano BO, Perez CM, Blakeney AB, Castillo T, Kongseree N, Laignelet B, *et al*, International cooperative testing on the amylase content of milled rice. *Starch/Stärke* **33**:157–162 (1981).
17 SAS Institute, *SAS User's Guide: Statistics.* SAS Institute, Cary NC (1985).
18 Baudoin JP and Maquet A, Improvement of protein and amino acid contents in seeds of food legumes. A case study in *Phaseolus. Biotechnol Agron Soc Environ* **3**:220–224 (1999).