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First sensory analysis of soybean drinks made from commercial grain grown in Mexico

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Abstract: In Mexico there is an important production of soybeans; however, no evidence of the analysis of organoleptic attributes in Mexican soybean products was found, so the objective of this work was to sensorially characterise soymilk made from commercial beans grown in northern Mexico based on seven organoleptic attributes. A panel of trained judges evaluated 11 soymilks made from commercial soybeans grown in Mexico, two soymilks made from commercial soybeans reported to be free of lipoxygenases, and one control soymilk. Evaluated flavour attributes were beany, milky, greasy, toasted, bitter, metallic and rancid. The results showed that the soymilks from the JP 30790 and JP 28955 genotypes generated low beany notes. The Mexican variety Guayparime S-10 obtained the lowest beany flavour note. Among Mexican soybeans, the soymilks of Huasteca 700 and Vernal varieties got the highest values of the milky flavour and the JP 30790 and JP 28955 materials obtained intermediate values in this attribute; in the rancid attribute, the zero value was given to all the soymilks. The scarce beany notes and the high milky attribute, as well as the zero value in the rancid attribute favour an acceptable flavour in the soymilks.

Keywords: beany flavour; descriptive analysis; lipoxygenase; soymilk

Soybean (*Glycine max*/L./Merr.) is the most popular legume in the food industry due to the amount of oil and protein present in the grain (Vázquez-Frias et al. 2020). The most demanded soybean products are oil, texturised products, sauces and soymilk, however, some of them have a beany flavour due to the action of the lipoxygenase present in the grain; this enzyme is responsible for generating volatile compounds such as hexanal aldehyde and producing the unpleasant flavour (Moreano et al. 2017). The characteristic of beany flavour has affected the acceptance of soybean products because consumers demand better foods with the most palatable flavour characteristic (Rochín-Medina et al. 2015). Currently, soymilks are made from selected soybeans (Ma et al. 2015) and genetic improvement has played an important role (Wang et al. 2020) as it has allowed selecting grains free of lipoxygenases (Ma et al. 2015). The Lox1, Lox2 and Lox3 genes synthesise the expression of the enzymes lipoxygenase-1, lipoxygenase-2 and lipoxygenase-3 (Yang et al. 2015). The identification of point mutations in Lox genes in native and wild materials has led to the genetic improvement and selection of grain (Wang et al. 2020).

In the north of Mexico, there is a significant soybean production; however, most of the national consumption is imported from the USA (Rivera de la Rosa and Ortíz 2017). Soybean imports into the country benefit industrialists by importing improved grain with better sensory characteristics (Start et al. 1986; Torres-Penaranda and Reitmeier 2001). Adapted and genetically improved

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soybean materials in Mexico have not been modified to achieve acceptable sensory attributes in food products made from the grain (Maldonado-Moreno et al. 2019), neither is there any evidence that products made from soybeans produced in the country have been analysed for their organoleptic attributes, so the objective of this work was to sensorially characterise soymilks made from commercial soybeans grown in northern Mexico based on seven attributes of flavour.

MATERIAL AND METHODS

In the present study 14 soymilks were analysed; 11 made from commercial soybeans grown in Mexico (Table 1) developed by the National Institute of Forestry, Agriculture and Livestock Research of Mexico (INIFAP) and 2 materials provided by the National Institute of Agrobiological Sciences (NIAS) Japan, reported as free of lipoxygenases or triple null in Lox genes (NARO 2022) and a commercial soymilk ADES® brand produced in Mexico (Table 1).

Soymilk processing. The methodology reported by Chong et al. (2019) was used with some modifications; 140 g of soybeans were soaked in water overnight (8 h), the water was drained and the grain was ground using a blender (Oster Duralast Classic BLSTCGCBG000; Oster, USA) with the addition of 1 L of purified water, the raw liquid was then extracted with 200-micron food grade nylon mesh and heated to the boiling point, 1 g of salt was added and removed from the fire. To stop the degradation kinetics of the lipoxygenase, the liquid was placed in a cold-water bath until it reached room temperature (25 °C), and then the additives shown in Table 2 were added as emulsifier, stabiliser and thickener, stirring constantly, finally the soymilks were stored at 4 °C until analysis.

Descriptive sensory analysis. Seven sensory attributes were analysed: beany, bitter, metallic, milky, rancid, greasy and toasted (Table 3) using the Quantitative Flavour Profiling Technique (Murray et al. 2001). In the first phase of the analysis, five expert judges (Mérieux NutriSciences Silliker Mexico Laboratory) evaluated the control drink (commercial soymilk ADES® brand manufactured in Mexico). The judges assigned a value to each attribute on a scale of 0 to 9, where: 0 – lower intensity or not perceived and 9 – higher intensity of perception of the evaluated attribute (Yang et al. 2015). In the second phase the judges evaluated 13 soybean materials, with each judge evaluating the samples independently, each sample consisted of 15 mL of soymilk of each material in triplicate (samples were randomly coded) and the assigned intensity value for each attribute was on the same scale used to evaluate the control drink.

Statistical analysis. Sensory attribute values were used for statistical analysis of variance (ANOVA) and the comparison of means was carried out by Tukey's test ($P < 0.05$). A principal component analysis (PCA) was done to detect clustering and elucidate possible correlations between the different sensory parameters of the soymilks (Deng et al. 2016). The statistical analysis was carried out using the statistical program InfoStat v. 2019. In the ANOVA analysis, the attributes rancid, greasy and bitter were not considered because they presented zero values on the evaluation scale.

Table 1. Soybean materials used in sensory evaluation

Number	Material	Origin	Adaptation	Progeny
1	JP 30790	USA	USA	unknown
2	JP 28955	USA	USA	unknown
3	Vernal	Mexico	north of Tamaulipas	D77-12244 × Bedford
4	Huasteca 100	Mexico	south of Tamaulipas	Santa Rosa × Júpiter
5	Huasteca 200	Mexico	south of Tamaulipas	F815344 × Santa Rosa
6	Huasteca 300	Mexico	south of Tamaulipas	H82-1930 × H80-2535
7	Huasteca 400	Mexico	south of Tamaulipas	individual selection DM301
8	Tamesi	Mexico	south of Tamaulipas	Santa Rosa × H80-2535
9	Huasteca 600	Mexico	south of Tamaulipas	H88-1880 × H88-3868
10	Huasteca 700	Mexico	south of Tamaulipas	Santa Rosa × F81-5517
11	Nainari	Mexico	Sonora	derived from Suaqui 86
12	Suaqui 86	Mexico	Sonora	(Rad × Cajeme) × (Tetabiate × Cajeme)
13	Guayparime S-10	Mexico	Sonora	Nainari × PI-171443

Source: Maldonado-Moreno et al. (2009, 2010, 2017), Maldonado-Moreno and Ascencio-Luciano (2010a, 2010b, 2012), Rodríguez-Cota et al. (2017), NARO (2022) and National Service of Seed Inspection and Certification (2022)

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Table 2. Formulation for 1 L of soymilk

Component	Quantity
Soybean	140.0 g
Water	1.0 L
Salt	1.0 g
Calcium carbonate	3.0 g
Sodium citrate	1.8 g
Xanthan gum	0.4 g
Soy lecithin	1.2 g
Maltodextrin	2.0 g

Table 3. Attributes evaluated in 11 Mexican commercial soybean drinks, two lipoxygenase-free soymilks and one control drink made in Mexico (commercial soymilk ADES® brand)

Flavour attributes	Description of the attribute
Beany (cereal grain or legume)	flavour associated with grains and cereals, grass flavour (Torres-Penaranda and Reitmeier 2001; Childs et al. 2007)
Bitter	basic bitter taste stimulated by alkaloids (Childs et al. 2007)
Metallic	a sensation factor on the tongue stimulated by metal or aromatic compounds associated with metals (Childs et al. 2007)
Milky	attribute perceived to be like characteristics of milk of animal origin, such as density (N'Kouka et al. 2006)
Rancid	unpleasant flavour caused by compounds formed by the oxidation or hydrolysis of fats (Lawrence et al. 2016)
Greasy	sensorial property related to the quantity and quality of the fat in the product (Merieux NutriSciences Silliker Mexico)
Toasted	attribute originated by the formation of chemical compounds such as pyrazines, furans, pyrroles and phenols (Merieux NutriSciences Silliker Mexico)

RESULTS AND DISCUSSION

Analysis of variance (ANOVA). ANOVA showed highly significant differences ($P < 0.0001$) for all the attributes analysed.

Tukey's test showed that the control drink had the highest value of the milky attribute, showing significant differences ($P < 0.05$) from the rest of the beverages analysed. In the notes for the beany, toasted and metallic attributes, however, the soymilks from Mexican grain were significantly ($P < 0.05$) better than the control soymilk, the Guayparime S-10 variety (0.2) stands out in the beany attribute which showed the lowest value for this attribute. Soymilks from the lipoxygenase-free materials had an average value of 1.4 (Table 4).

Sensory analysis. The results of the sensory analysis of 14 soymilks showed that six materials cultivated in Mexico obtained low scores for the beany attribute, improving the flavour of the beverage, with the Guayparime S-10 variety standing out (0.2) (Table 4); these results are different from those published by Navicha et al. (2018), who reported higher values in beverages made from roasted beans (110 °C per 60 min) of Heinong material (5.9) and the control soymilk (7.9) and the results reported by Torres-Penaranda and Reitmeier (2001) in lipoxygenase-free materials (28–44) and the results reported by Chambers et al. (2006) in soymilks made from commercial soybeans (Table 5). The lipoxygenase-free materials JP 28955 (1.3) and JP 30790 (1.7) analysed in this study showed better beany notes than the values reported for lipoxygenase--free materials analysed by Torres-Penaranda and Reitmeier (2001) (Tables 4, 5). In this study, nine samples presented beany notes with low values (0.3–2.3) and five showed beany notes with high values (3.3–8.0), this proportion of results was like those obtained by Torres--Penaranda and Reitmeier (2001), Chambers et al. (2006), and Navicha et al. (2018) (Table 5). Removing soybean lipoxygenases affects the sensory attributes, particularly the soybean beany flavour, and apparently it depends on the soybean product, for example, Torres-Penaranda et al. (1998) reported that soymilk made from grain without lipoxygenase had less aroma and beany flavour than that produced from the normal line, showing no difference in tofu; in other studies, the lipoxygenase-free soybeans showed no effect on breads and meat pies (King et al. 2001; Liu et al. 2008). Thus, Yang et al. (2015) considered that the beany flavour in certain soybean products may be masked by stronger sensory notes. Ma et al. (2015), in evaluating 70 soybean materials, including near isogenic lines with and without lipoxygenases, observed no significant effect of the absence of lipoxygenases on the taste of soymilk. In this work, the soybean materials free of lipoxygenases (JP 30790 and JP 28955) significantly improved the beany notes in relation to the control, however, three

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Table 4. Comparison of Tukey's means of four sensory attributes in 11 Mexican commercial soybean drinks, two lipoxygenase-free soymilks and one control drink made in Mexico (commercial soymilk ADES® brand)

Material	Milky		Beany		Toasted		Metallic	
	mean ± SD	(%)	mean ± SD	(%)	mean ± SD	(%)	mean ± SD	(%)
Control	$8.1^{a} \pm 0.2$	90.0	$0.6^{i} \pm 0.2$	6.7	$2.5^{a} \pm 0.5$	27.8	$1.0^{a} \pm 0.3$	11.1
*JP 30790 Cypress	$3.8^{f} \pm 0.2$	42.2	$1.7^{g} \pm 0.5$	18.9	$0.0^{b} \pm 0.0$	0.0	$0.9^{b} \pm 0.1$	10.0
*JP 28955 Imperial	$4.5^{d} \pm 0.8$	50.0	$1.2^{h} \pm 0.4$	13.3	$0.0^{b} \pm 0.0$	0.0	$0.6^{c} \pm 0.1$	6.7
Vernal	$6.0^{c} \pm 0.0$	66.7	$7.0^{b} \pm 0.4$	77.8	$0.2^{b} \pm 0.3$	2.2	$0.0^{d} \pm 0.0$	0.0
Huasteca 100	$1.5^{i} \pm 0.5$	16.7	$8.0^{a} \pm 0.4$	88.9	$0.2^{b} \pm 0.4$	2.2	$0.5^{c} \pm 0.5$	5.6
Huasteca 200	$1.7^{h} \pm 0.5$	18.9	$4.7^{c} \pm 0.7$	52.2	$0.4^{b} \pm 0.5$	4.4	$0.0^{d} \pm 0.0$	0.0
Huasteca 300	$4.5^{d} \pm 0.0$	50.0	$3.2^{e} \pm 0.5$	35.6	$0.0^{b} \pm 0.0$	0.0	$0.0^{d} \pm 0.0$	0.0
Huasteca 400	$1.2^{i} \pm 0.4$	13.3	$2.2^{f} \pm 0.6$	24.4	$0.4^{b} \pm 0.8$	4.4	$0.0^{d} \pm 0.0$	0.0
Tamesi	$4.0^{e} \pm 0.5$	44.4	$1.0^{h} \pm 0.0$	11.1	$0.4^{b} \pm 0.8$	4.4	$0.0^{d} \pm 0.0$	0.0
Huasteca 600	$4.7^{d} \pm 0.4$	52.2	$1.0^{h} \pm 0.0$	11.1	$0.2^{b} \pm 0.4$	2.2	$0.0^{d} \pm 0.0$	0.0
Huasteca 700	$6.7^{b} \pm 0.7$	74.4	$1.0^{h} \pm 0.0$	11.1	$0.0^{b} \pm 0.0$	0.0	$0.0^{d} \pm 0.0$	0.0
Nainari	$1.5^{i} \pm 0.0$	16.7	$4.2^{d} \pm 0.4$	46.7	$0.0^{b} \pm 0.0$	0.0	$0.9^{b} \pm 0.1$	10.0
Suaqui 86	$2.2^{h} \pm 0.5$	24.4	$2.2^{f} \pm 0.4$	24.4	$0.2^{b} \pm 0.4$	2.2	$0.9^{b} \pm 0.3$	10.0
Guayparime S-10	$3.2^{g} \pm 0.6$	35.6	$0.2^{j} \pm 0.2$	2.2	$0.0^{b} \pm 0.0$	0.0	$0.0^{d} \pm 0.0$	0.0

[a–j]Different letters in the same column indicate significant differences ($P < 0.05$); *genotypes from the National Institute Agrobiological Sciences (NIAS) Japan, reported as lipoxygenase-free in mature grain Lox genes (NARO 2022)

materials (Tamesi, Huasteca 600 and Huasteca 700) considered as normal were better in flavour and a fourth material (Guayparime S-10) was significantly better in taste even than the commercial control soymilk.

In the milky attribute, the lipoxygenase-free materials did not improve the milky appearance of the soymilk, showing intermediate values in this attribute, Huasteca 700 and Vernal varieties presented the highest values for this attribute, but lower values than those shown for the control drink (Table 4). Chambers et al. (2006) reported intermediate values for the milky attribute in ready-to-drink commercial soymilks. Per Chambers et al. (2006), the beany and milky attributes have a positive inverse relationship in soymilk, the less the beany flavour, the greater the milky flavour. This behaviour between the beany and milky flavour was observed in most of the samples evaluated in this work, including the control, with the exception

Table 5. Compendium of results of the effect of sensory attributes in soymilk reported in this work and work reported by other authors

Attribute	This work	Torres-Penaranda and Reitmeier (2001)	Navicha et al. (2018)	Chambers et al. (2006)
Measuring scale				
	0 to 9	0 to 100	0 to 15	0 to 15
Range of values				
Beany	Guayparime S-10 (2.7%) Huasteca 100 (88.9%)	lipoxygenase-free soybean (28% to 44%)	Heinong (39.5%) control (52.7%)	soybean varieties (23.3% to 40%)
Milky	Huasteca 400 (13.9%) Huasteca 700 (75%)	NA	NA	commercial drinks (13.3% to 40%)
Metallic	Vernal (0 %) control (11.1%)	commercial (0%) lipoxygenase-free soybean (54%)	NA	NA
Toasted	JP 30790 (0%) control (27.8%)	NA	control (29.3%) Heinong (62.3%)	NA

NA – not applicable

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of Vernal variety, which showed a higher beany value compared to the milky one (Table 4). In the toasted, metallic, rancid, greasy and bitter attributes, most of the samples showed low positive values, even better than the control sample (Table 4), in the rancid attribute, the results were significantly better than those found by Chambers et al. (2006).

Principal component analysis (PCA). In order to observe the association between sensory parameters and soymilks, PCA and biplot graph were developed (Gabriel 1971). Orthogonality of principal components (PC) showed that PC1 separated soymilks containing sensory parameters of milky, rancid (neutral for all), greasy, toasted and metallic attributes showing a positive correlation in these parameters, these sensory parameters generated the greatest variation between the soymilks analysed (PC1, 48%) (Table 6). PC2 separated the soymilks containing the sensory parameters of beaniness and bitterness showing a positive correlation in these parameters, these sensory parameters generated the greatest variation in PC2 between the soymilks analysed (24%) (Table 6).

The control soymilk showed the highest association in the milky, greasy, toasted and metallic parameters, when in this drink high positive values were observed for milky attribute, high negative values for metallic and toasted attributes. Huasteca 600, Huasteca 700, Tamesi, Guayparime S-10, JP 28955 and JP 30790 have a high positive association and value with milky flavour (Table 4, Figure 1). The biplot graph showed a negative correlation between the sensory parameters milky and beany and bitter, and a positive correlation between bitterness and beaniness. The negative correlation between beany flavour and milky flavour was observed by Chambers et al. (2006) in their results on ready-to-drink soymilks, indicating that the milkier the flavour, the less beany flavour is perceived or inversely, the soymilks from Huasteca 600, Huasteca 700, Tamesi, Guayparime S-10, JP 28955, JP 30790 and the control soymilk show this characteristic while the drinks from Nainari and Vernal show negative high beany values and low and high milky value, respectively (Figure 1).

The results in the PCA biplot graph of Lawrence et al. (2016) in the sensory analysis of flavouring-free soymilks indicated a positive correlation between

Table 6. Principal component analysis (PCA) for seven sensory attributes in 11 Mexican commercial soybean drinks, two lipoxygenase-free soymilks and one control drink made in Mexico (commercial soymilk ADES® brand)

Variable	PC		
	PC1	PC2	PC3
Milky	**0.67**	–0.10	**0.69**
Rancid	**–0.85**	0.38	0.25
Greasy	**0.97**	0.17	–0.03
Toasted	**0.90**	0.18	–0.06
Beany	–0.45	**0.74**	–0.03
Bitter	–0.24	**0.81**	0.38
Metallic	**0.64**	0.41	–0.48
Total variance explained (%)	48.0	24.0	14.0
Cumulative variance (%)	48.0	72.0	86.0

PC – principal component; bold values indicate the variables with the highest descriptive value

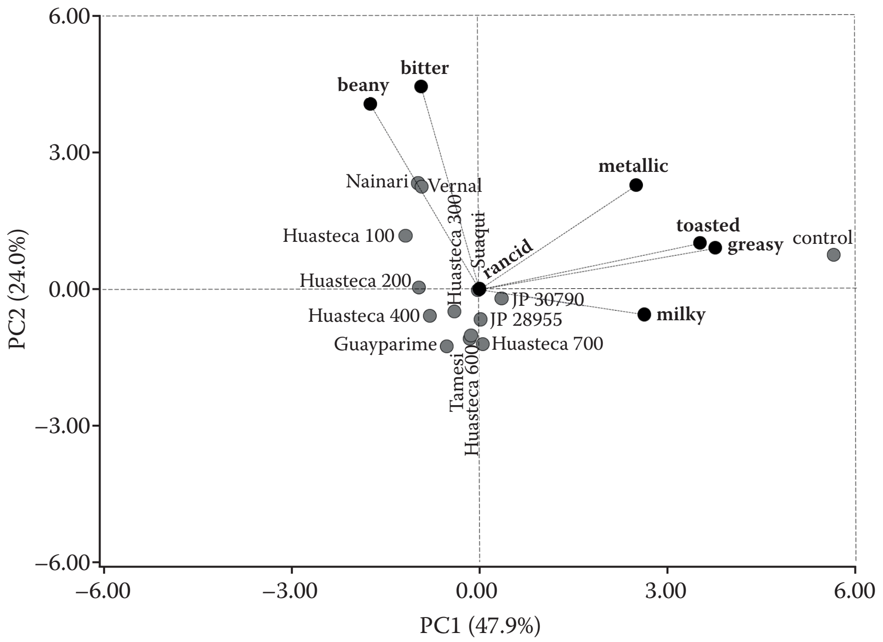

Figure 1. Principal components analysis (PCA) for seven sensory attributes in 11 Mexican commercial soybean drinks, two lipoxygenase-free soymilks and one control drink made in Mexico (commercial soymilk ADES® brand)

PC – principal component

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beany and bitter taste. In the metallic, greasy and toasted attributes, all the samples had a negative association, presenting low positive values for these attributes. In the case of commercial drinks, the metallic, greasy and astringent flavours of soymilks can be masked by the addition of maltodextrin and flavourings, as referred Torres-Penaranda and Reitmeier (2001). For the toasted flavour attribute, soymilks presented a negative association, having low positive values because the grain was not toasted for beverage production, contrary to what was observed by Navicha et al. (2018), who obtained high values in this attribute.

CONCLUSION

This study has shown that commercial soybean varieties grown in northern Mexico have contrasting organoleptic characteristics affecting the palatability of the soymilk obtained from them. Soymilks of genotypes JP 30790 and JP 28955 generated scarce beany notes, although these drinks were expected to show no significant difference compared to the control drink because they are reported as lipoxygenase-free soybean by the NIAS Japan Soybean Germplasm Bank. The Mexican variety Guayparime S-10 obtained the lowest positive score in the beany attribute with a significant difference compared to the control, which improves the flavour of the soymilk. The soymilks from Huasteca 700 and Vernal varieties got higher positive values for milky flavour and the JP 30790 and JP 28955 materials obtained intermediate values for this attribute. In all soymilks, zero values were given to the rancidity attribute, which is positive for the flavour of the drink.

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