International Journal of Gastronomy and Food Science 11 (2018) 25–30

Contents lists available at ScienceDirect

International Journal of Gastronomy and Food Science

journal homepage: www.elsevier.com/locate/ijgfs

Scientific paper

Evaluation of chemical composition and sensory profile in Jerusalem artichoke (*Helianthus tuberosus* L) tubers: The effect of clones and cooking conditions

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ARTICLE INFO

Keywords:
Jerusalem artichoke
Sensory evaluation
Panel
PCA

ABSTRACT

Jerusalem artichoke (*Helianthus tuberosus L.*) (JA) produces ground artichokes, is resistant to most parasites, diseases and tough conditions such as frost and drought.

It has many applications including biofuels or bio-chemicals that do not compete with food supply. Improving the genetic diversity would help meet food demand.

Four clones of the JA were studied to determine sensory attributes, facilitate the characterization of each clone and promote a better use and consumption.

The sensory attributes of raw and boiled JA tubers have been identified by a trained panel, in compliance with the UNI EN ISO13299: 2010 standard; the geometric mean (M) has been applied to reduce the number of descriptors in order to produce a sensory assessment sheet for tests. The principal component analysis (PCA) of the average values was applied to the data to evaluate the importance of each selected attribute in the samples identification.

The results clearly showed that the 16 attributes selected for raw and 14 for cooked are useful for discriminating the 4 clones.

Knowledge of the sensory characteristics of different clones of raw and cooked tubers of Jerusalem artichoke can be used to inform consumers about the right choice of Jerusalem artichoke tubers for their needs and therefore increase consumption of this vegetal, which has many beneficial effects on human health.

Introduction

Jerusalem artichoke (*Helianthus tuberosus L.*) is a species of the Asteraceae family, genus Helianthus, known for the remarkable genetic variability of its clones and genotypes (Puttha et al., 2013; Rossini et al., 2012). It consists of 66 species native to the United States and south east of eastern and central Canada: it is an old species, originally grown mainly in North America and later in Europe where it can grow in nature (Balogh, 2008; Slimestad et al., 2010).

The taxonomic classification of the topinambur is uncertain and widely discussed (Filep et al., 2010); however, the numerous varieties of Helianthus tuberosus L. were classified by Cockerell (1919) as follows: var. *typicus*; var. *nebrascensis;* var. *alexandri*; var. *purpurellus*; var. *fusiformis*; var. *albus;* var. *purpureus*; var. *multituberculatus*.

In Mediterranean regions it spontaneously grows virtually everywhere and does not require any kind of fertilizer or organic matter and should not be subjected to pesticides. Its rapid and vigorous growth allows good natural control against weeds, which hardly exceed the plant (Rosati, 2010).

In fact, JA is mainly cultivated for use as green or brackish fodder as crops in marginal areas, in particular in relation to hardiness and low production costs (Shanzhao et al., 2013) and for the production of sugars (in particular fructose) and soluble fiber (inulin). The plant is also an excellent resource for bioenergy production, such as bioethanol, methane, anaerobic digestion and biogas from pyrolysis (Kim and Kim, 2014).

JA can be appreciated not only as a biomass crop resource but also for its nutritional and medical qualities as an accessible source of protein and essential amino acids (Cieślik et al., 2011), minerals (Somda et al., 1999; Takeuchi and Nagashima, 2011; Terzić et al., 2012) and a number of functional ingredients such as inulin, oligofructose and fructose.

In addition, it has both nutritional and functional attributes, particularly beneficial for individuals with type 2 diabetes and obesity (Saengthongpinit and Sajjaanantakul, 2005; Yang et al., 2015).

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https://doi.org/10.1016/j.ijgfs.2017.11.001
Received 24 August 2017; Accepted 3 November 2017
Available online 07 November 2017

In particular, inulin is the main preservative carbohydrate in JA (10–20% by weight of fresh tubers) and is used for the production of dietary fibers, feed, high carbohydrate fructose syrup, bioethanol or biochemical materials by fermentation of microorganisms (Mee-Jin et al., 2016).

It is a food fiber not degraded by digestive enzymes and has been shown to have a prebiotic effect on humans (Kleessen et al., 2007; Ramnani et al., 2010). Some studies also report that tuber was used in the past in popular medicine for the treatment of diabetes and rheumatism (Kays and Nottingham, 2007).

Jerusalem artichoke (JA), as a source of food, was well-known to American Indians long before the arrival of the white man (Cockerell, 1918).

Recently JA has become very popular especially in France, Italy and Germany. There are several ways that can be consumed: raw, cooked, stewed, soup or salad, cooked or pure.

Tuber is well-known in restaurants in Northern Europe, where it is generally served in raw, boiled, pure or soup salad. However, the use of JA in domestic cooking is limited because the product is poorly available on the market. For this reason, the quality of available clones and their ability to be marketed must be considered more closely.

Greater knowledge of sensory properties, gourmet quality, and suitability for JA tubes are needed to meet consumer demand and increase consumption.

High inulin content in the tubers makes them particularly suitable for creams and purees; in fact, inulin mixed with water creates a soft and creamy gelatin texture (Franck, 2002).

Many researchers have focused on the sensory description of different plant species, aimed at comparing or characterizing products according to several variables, such as geographic origin, cultivation method, system, or conservation time. Sometimes, the sensory profile has been centered exclusively on the aromatic description of the product or its different cultivars, or in the description of the modifications required by the cooking techniques. Some examples of this type of work are Di Salvo et al. (2014) on a DOP artichokes; Arvanitoyannis et al. (2008) about two cultivars of raw and cooked potatoes; Smith et al. (2006), with a pepper study and finally a comparison of 5 varieties of sweet potato (Leighton et al., 2010).

Since very few studies have examined the sensory characteristics of both JA raw and cooked tubers (Bach et al., 2012, 2013a, 2013b), our work seeks to examine the new JA clones use for food purposes.

Developing an appropriate vocabulary allows you to evaluate both the sensory quality of the tubers as well as the identification of some sensory attributes, predictors of the specific suitability of the various JA clones in cooked and raw gourmet preparations.

So, it is hoped that this knowledge will increase demand and will be an attractive source of food in the future.

Materials and methods

Plant material

Four clones of the Jerusalem artichoke (JA) tubers were selected for sensory and chemical analysis. The genotypes were grown in the Experimental Farm (EF) of the University of Tuscia, located in Viterbo, Central Italy (42°42'N, 12°08'E, altitude: 326 masl). Tested in a previous study (Rossini et al., 2012), they have proven to be suitable for the Mediterranean environment.

The clones (Fig. 1), K8, D19-Blanc precoce, CU3B-Hungarian clones, selected from the EF collection (Bizzarri et al., 2011; Gutierrez Pesce et al., 2011) were chosen to include a large variation in sensory characteristics and compared with Violet de Rennes cv, from the same collection, commercially used.

Tubers of 30–45 g size and free from defects were used for the chemical and sensory analysis. After harvesting, the tubers were washed, dried, sealed in polypropylene bags (PP approved by FDA/USDA), and maintained at 4 °C ± 2 and ≥98% relative humidity until analysis (maximum 1 week).

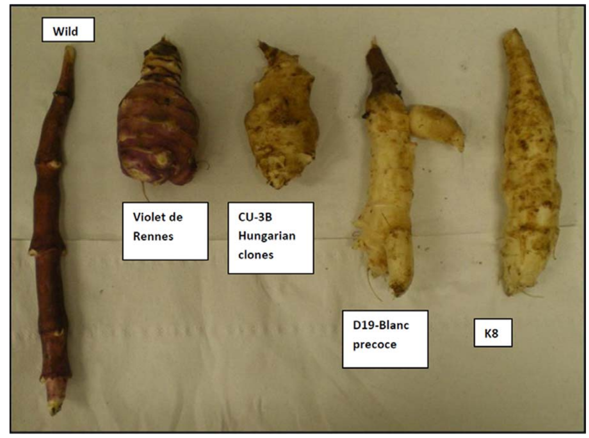

Fig. 1. Tuber shapes of Jerusalem artichoke from *Tuscia University* collection.

Chemical analyses

Chemical analyses of Jerusalem artichoke tubers was determined by standard methods (AOAC, 1999). For moisture content and ash measurement, standard gravimetric method was used. The amount of protein was determined by the Kjeldahl method and calculated as the nitrogen content×6.25 (Takeuchi and Nagashima, 2011). The determination of total sugar was determined using a refractometer (ATAGO PR-32α-Palette series).

All chemical analysis were performed in triplicate for each preparation.

Sample preparation

Before the analysis, the Jerusalem artichoke tubers were hand peeled and diced into 2 cm × 2 cm cubes. For the boiled preparation, 200 g of Jerusalem artichoke cubes were placed in a beaker together with 200 mL of water, and covered with perforated Parafilm.

The different samples were boiled in a microwave oven at 750 W for 5 min, then cooled in iced water, drained and finely chopped to make a puree. Then they were stored at room temperature before the test that was performed about 15 +/− 1 min later.

Sensory analysis

The sensory analysis was performed on any clone of the Jerusalem artichoke tubers, both raw and boiled, by a trained sensory panel composed by twelve judges (eight women and four men) aged between 25 and 55 years.

All the assessors had already eaten topinambur, were familiar with it, and did not object to eating it.

For the development of the lexicon, a well-known (University of Tuscia) expert sensory assessor, trained and monitored according to ISO 8586-1, 2012 was selected.

The profiling of the JA was performed in a sensory evaluation laboratory that conforms with the international standards (ISO 8589, 1988). Before the official test, two preliminary sessions were carried out to allow the assessors to become familiar with the product.

The development of the lexicon for the JA sensory evaluation was completed in three sessions, according to ISO 11035 (1994), with modification in M value reduction.

At the beginning, the panelists evaluated the raw and cooked samples (Test 1), presented in a monadic sequential order, to individually recognize the attributes that best described each sample.

All the descriptors were collected into a list that was then reduced

Table 1
a/b Descriptors and geometric mean values (M) for raw tuber (1a) and for boiled tuber (1b).

1a

Descriptors	**M**		**M**
Sweet	0,70	RawCarrot	0,80
Sour	0,52	Green Peas	0,62
Astringency	0,48	Raw potato	0,60
Salty	0,45	Lettuce	0,50
Bitter	0,40	Apple	0,48
Umami	< 0,3	Rawartichoke	0,42
		Fennel	0,40
		Hazelnut	0,38
		Walnut	0,38
		Almond	0,35
		Earthy	0,32
		Walnuthusk	< 0,3
		Boiledartichoke	< 0,3
		Boiled potato	< 0,3
		Pear	< 0,3
		Caki	< 0,3
		Coconut	< 0,3
		Pepper	< 0,3
		Herbs	< 0,3
		Tea	< 0,3
		Hay	< 0,3
		Mushroom	< 0,3
		Green wood	< 0,3
		Wood	< 0,3
		Driedleafs	< 0,3
		Sulfur	< 0,3
		Rancidity	< 0,3

1b

Descriptors	**M**		**M**
Sweet	0.70	Apple	0.80
Salty	0.68	Earthy	0.79
Bitter	0.54	Boiledartichoke	0.70
Sour	0.48	Rawcarrot	0.69
Astringency	0.35	Hazelnut	0.68
Umami	< 0,3	Almond	0.68
		Walnut	0.56
		Boiled potato	0.48
		Lettuce	0.42
		Rawartichoke	< 0,3
		Pear	< 0,3
		Caki	< 0,3
		Coconut	< 0,3
		Tea	< 0,3
		Hay	< 0,3
		Mushroom	< 0,3
		Green wood	< 0,3
		Wood	< 0,3
		Driedleafs	< 0,3
		Sulfur	< 0,3
		Rancidity	< 0,3
		Pepper	< 0,3
		Herbs	< 0,3
		Walnuthusk	< 0,3
		Green peas	< 0,3
		Raw potato	< 0,3
		Fennel	< 0,3

by eliminating the inappropriate terms and by grouping synonymous and descriptors which unequivocally referred to the same characteristic.

The list was then abridged to 33 terms which were then discussed with the assessors to be sure that they could share the correct meaning of each descriptor.

Finally the assessors, in two separate sessions, evaluated the four clones (raw and boiled), using the 33 identified descriptors, according to a linear intensity scale from 0 to 9, where (0) was absence and (9) was high intensity.

The results were collected and calculated using the geometric mean (M), according to the UNI EN ISO13299, 2010:

M=√F*I

"F" is the ratio between the number of times a descriptor is mentioned, and the maximum number of times this descriptor could be mentioned;

"I" is the ratio between the intensity given a descriptor by the panel and the maximum possible intensity for the same descriptor.

Descriptors presenting geometric mean values lower than 0.3 were discarded (Table 1a/b).

Subsequently, a further test (Test 3) was carried out in order to determine the adequacy of the attributes that should be significant to discriminate samples, according to Pereira et al. (2015).

The evaluation of raw and boiled JA tubers was performed separately in two following sessions.

Sample preparation for sensory analysis

Test 1: the samples prepared as described above, were given to all assessors in a group session. For the raw sample, three cubes of each encoded sample were served on plastic disposable plates. The boiled sample were 5 g of minced JA, served in plastic cups (80 mL) with a lid.

For tests 2 and 3 the samples, prepared as in test 1,were coded with three digit numbers and served to each assessor, in a random order, in the sensory booths, and at room temperature.

The samples were evaluated using the list of selected attributes (Table 2), on a linear scale of 10 points from 0 to 9, where 0 corresponded to the absence of perception and 9 to the maximum intensity.

Prior to the test, evaluators were calibrated to reference standards, according to the different intensity level for at least two points on the scale as reported by Di Salvo et al. (2014).

All the assessors were provided with mineral water to cleanse their palates between testing.

All data was registered on a computerized system.

Statistical analysis

The analysis of variance (ANOVA) was performed on the data to verify the differences between the clones for each variable and the means were separated using Fisher's least significant differences (LSD) at $P = 0.05$. Data analysis was performed using the software R 3.3.2 (R Project for Statistical Computing).

The principal components analysis (PCA) was used to analyze the sensory data collected from Test 3, and to study how important the attributes are to evaluate JA clones.

PCA was performed and figures were drawn using Unscrambler ® Camo Software AS v.9.7.

Results

Chemical characteristics of the clones

The moisture content, total sugar, protein and ash were determined on raw tubers as it can be seen in Table 3. The moisture content was between 797.61 and 812.51 g kg^{-1} tuber, the amount of ash in the tubers ranged from 16.22 to 19.56 g kg^{-1} tuber, which is similar for the dry substance levels. The D19 clone had the highest protein content (32.62 g kg^{-1}) and the lowest sugar (10.85° Brix).

Sensory analyses

By applying the procedure to reduce the terms freely generated by the assessors, and following a further reduction on the basis of the values of $M > 0.3$ (arbitrary point of cutting), the final list was

Table 2
List of selected sensory attributes.

Sensory attributes	Definition	Reference
Sour	Fundamental taste factor associated with a citric acid solution	Citric acid solution
Sweet	Fundamental taste factor of which sucrose is typical	Sucrose solution
Bitter	Fundamental taste factor associated with a caffeine solution	Caffeine solution
Salty	Fundamental taste factor of which sodium chloride is typical	Sodium chloride solution
Astringency	Taste sensation found in green tea/black tea	Green tea/black tea
Apple	Flavour raw apple	Sliced raw apple
Hazelnut	Flavour of green, unripe hazelnut	Minced unripe hazelnut
Almond	Flavour of green, unripe almond	Minced unripe almond
Walnut	Flavour of green, unripe walnut	Minced unripe walnut
Raw potato	Flavour of raw potato	Sliced raw potato
Boiled potato	Flavour of boiled potato	Purée of boiled potato
Green Peas	Flavour of green peas	Green peas
Raw Artichoke	Flavour of boiled of artichoke	Bracts of artichoke
Boiled Artichoke	Flavour of raw of artichoke	Boiled artichoke
Raw Carrot	Flavour of raw carrots	Minced carrot
Lettuce	Flavour of fresh lettuce	Leaf of lettuce
Fennel	Flavour of fennel	Leaf of fennel
Earthy	Flavour of eartly, mushroom or forest bed	1-Octen−3-ol solution

Table 3
Contents of moisture, ash, protein and sugar in raw Jerusalem artichoke tubers.

Clones	Moisture (g/Kg of tuber)	Ash (g/Kg of tuber)	Protein (g/Kg of tuber)	Sugar (° Brix)
K8	812.51	18.257	23.11	13.57
D19	832.23	16.225	32.62	10.85
CU3B	819.72	17.415	28.06	22.57
VR	797.61	19.564	25.38	13.97

composed of about 16 attributes for raw tuber and 14 for boiled tuber (Table 4a/b).

After the terms were reduced, the 16 variables for raw JA and the 14 variables for boiled JA were used for the qualitative and quantitative evaluation of the clones. The collected data was processed by multivariate analysis PCA.

The clones have provided a good amount of materials with consistent sensory differences, thus allowing to identify different sensory attributes, available in the aroma of the Jerusalem artichoke tubers; moreover, it was possible to test the ability to distinguish them.

Figs. 2a and b show the evaluation results of the trained sensory panel on different clones of raw and boiled Jerusalem artichoke tubers.

There were differences between the raw and boiled evaluations of each clone.

According to Bach et al. (2013a), the aroma of the topinambur is mainly represented by descriptors belonging to the fruity family, which includes fresh and dried fruit, - in particular, apple, hazelnut, almond and walnut fragrances - and vegetables (potatoes, green peas, carrot, lettuce, fennel, and artichoke.)

The boiled tubers were characterized by similar sensory aromatic notes; however in particular cases aromas of boiled vegetables such as potato and artichoke replaced fresh vegetable fragrances.

The list of identified attributes, related to the topinambur aroma, did not include negative descriptors as reported in other works (Bach et al., 2012) such as fungus, linseed oil, stale aroma and iron flavour, probably developed during the storage period; the earthy aroma, that included mushroom or forest bed, was anyway reported.

All the clones are strongly characterized by the attributes selected by the judges, as displayed using PCA.

Loadings of each variable to each PC and the communalities from two PCs are presented in Table 4a/b.

Using two sets of variables selected, 82% and 90% of the total variance was explained by the two PCs respectively for raw and boiled JA.

Indeed, in the case of raw samples, the map clearly shows that the flavour of clone CU3B is closer to apple, potatoes and a sweet flavour, D19-Blanc precoce is described by the smell of carrot, K8 is characterized by a strong vegetal note of artichoke and peas, while the VR is identified by the flavour of dried fruit and salty notes.

Many of the attributes found in raw tubers have not been found in boiled tubers (*b*).

The CU3R*b* clone was strongly identified with the sensory cooked

Table 4
a/b Final list of 16 attributes for raw tuber (4a) and 14 attributes for boiled tuber (4b). Loadings of each variables to each PC and the communalities (CM) from two PC (PC01 and PC02) are presented.

4a

	Variables	PC 01	PC 02	CM
1	EA	−0.0023	0.1170	0.0136
2	SO	0.0685	−0.2590	0.0718
3	SW	0.2090	0.4060	0.2085
4	BIT	0.0275	−0.2860	0.0825
5	SA	−0.0474	−0.0519	0.0049
6	AS	0.0435	−0.3550	0.1279
7	AP	0.1440	0.2260	0.0718
8	HA	0.0644	−0.4080	0.1706
9	AL	- 0.0575	−0.2200	0.0517
10	WA	- 0.1150	−0.0472	0.0154
11	PO	0.1170	0.3160	0.1135
12	GP	−0.1460	0.3570	0.1488
13	AR	−0.1260	0.1700	0.0448
14	CA	0.9170	−0.0197	0.8413
15	LE	0.1080	−0.1090	0.0235
16	FE	0.0469	−0.0823	0.0090

4b

	Variables	PC 01	PC 02	CM
1	SO	- 0.0555	0.2010	0.0434
2	SW	0.3500	0.09993	0.1325
3	BIT	0.0182	0.08322	0.0397
4	SA	−0.2610	−0.1180	0.0820
5	AS	−0.0232	−0.01010	0.0006
6	AP	0.5970	−0.1260	0.3723
7	HA	0.0349	0.4470	0.2010
8	AL	−0.0091	0.5100	0.2602
9	WA	−0.0319	−0.2890	0.0845
10	PO	0.0820	0.2700	0.0796
11	AR	−0.4130	0.4260	0.3520
12	CA	0.2380	−0.0019	0.0566
13	LE	−0.1890	−0.1970	0.0745
14	EA	−0.4210	−0.2750	0.2529

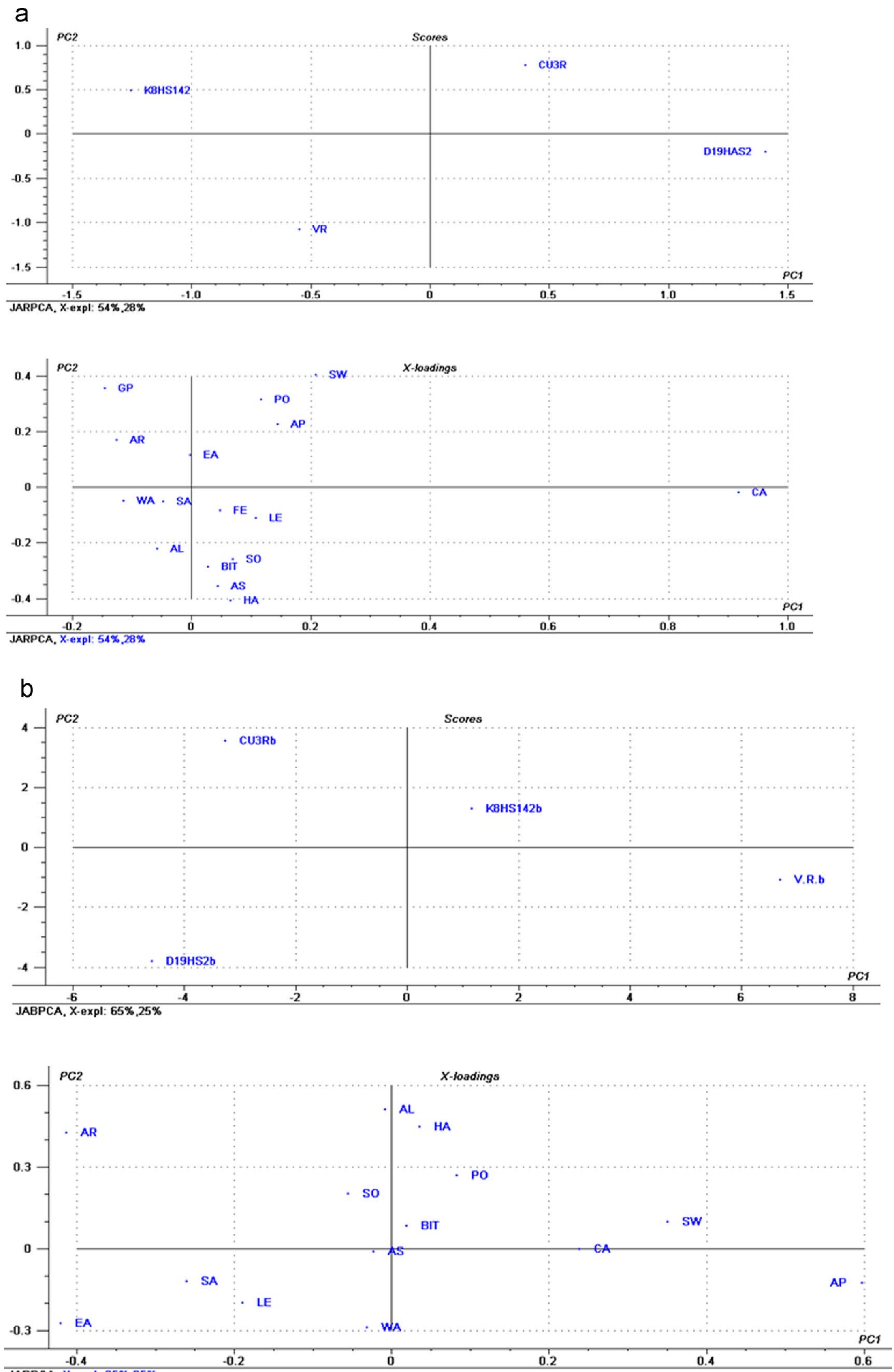

Fig. 2. a. Biplots of Principal Component Analysis (PCA) for identified sensory attributes of raw JA tubers. **b.** Biplots of Principal Component Analysis (PCA) for identified sensory attributes of boiled JA tubers.

artichoke, a typical attribute of this product (Jerusalem artichokes), the D19*b* maintained an intense flavour with notes of herbs and earth, the K8*b* was characterized by boiled potatoes and dried fruit notes, while the VR*b* shows a sweetish fragrance of apple and carrot.

These results confirm the suitability of the selected vocabulary to describe the sensory characteristics of JA, either raw or boiled.

Discussion

The present study allows us to establish the lexicon to describe the sensory characteristics of raw or boiled Jerusalem Artichoke tubers. Discrimination observed when our judges use the identified sensor descriptors seems to be appropriate to define the profile of the products.

The selected descriptors show that not all the available products have the same sensory characteristics; in particular, the flavour of artichokes, which is commonly attributed to boiled JA, does not have the same intensity in all clones. Moreover, notable sensory differences were found between raw and cooked tubers.

Identify the sensory attributes to describe the aroma in fresh vegetables is quite difficult because of the scarcity of aromatic notes, compared to processed, fermented or seasoned products where the aromatic complexity is extraordinarily large.

Suffice to say that for a brewed coffee there are 127 descriptors (Hayakawa et al., 2010), 88 attributes have been identified for the soy sauce, (Imamura, 2016), while 24 are used for cashew nuts (Griffin et al., 2017), 11 for asparagus (Cuppet et al., 1997), 7 and 8 for Galician potato respectively raw and cooked (Montouto-Grana et al., 2002), 10 for two potatoes during a storage period of time (Arvanitoyannis et al., 2008), 13 for the sweet potato (Leighton et al., 2010), 7 for a PDO artichoke (Di Salvo et al., 2014), and many others.

Correct information about the different sensory attributes of any different clone can be used to guide consumers in their choice of the Jerusalem artichoke tubers for their different purposes, thereby increasing the consumption of this product which has many beneficial effects on human health.

Conclusion

The development of a lexicon to assess the sensory characteristics of different clones of raw and cooked tubers of the Jerusalem artichoke can be used to help retailers and consumers make the most appropriate choice and encourage the consumption of this nutritious plant.

In addition, some sensory attributes can be used as predictors of the suitability of the different Jerusalem artichoke tuber clones in both cooked and raw gourmet preparations. So, it is hoped that this knowledge will increase demand and constitute an attractive source of food in the future.

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