

Agro-morphological Characteristics and Sensory Evaluation of Native Peruvian Chili Peppers

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Abstract: In this work, 31 native Peruvian chili peppers were evaluated for their agro-morphological characteristics and sensory attributes. The descriptive sensory analysis (DSA) was used to evaluate the 31 chili pepper samples based on their acid, bell pepper, sweet, tomato, apple, citrus, fruity, herbal, oregano and passion fruit attributes. The data obtained from the DSA enabled the grouping of these 31 chili peppers into six groups based on their different sensory attributes, such as fruity, bell pepper and herbal. The most abundant group (12 of the 31) had the bell pepper, apple, herbal, fruity and sweet attributes. Each group contained different species and different physical appearances, indicating that species or different forms of chili pepper do not define that sensory attribute. Considering the fact that Peruvian peppers are in high demand, the results achieved would be useful for growers, producers and chefs, as well as for further breeding activities.

Key words: Chili peppers, Peru, sensory analysis, agro-morphological characteristics.

1. Introduction

Peru possesses the highest diversity of cultivated chili peppers in the world and is one of the few countries where all five domesticated species are cultivated and used in local diet [1]. Peruvian chili peppers with their great diversity have an increasing popularity internationally; especially, a rise in Andean style restaurants has led to the need of research in understanding their flavour and aroma.

There are limited studies on Peruvian chili peppers. One paper reports the effect of different environments on the chemical attributes, indicating that due to the change in meteorological conditions and agricultural practices, there was a difference in the phytochemical profiles [2]. A study on 147 dry pepper samples from Peru quantified their content of flavonoids, fat vitamin C and extractable color [1]. Another study on 32 different accessions of native Peruvian *Capsicum*

pubescens (Rocoto) concluded that their phytochemical composition was less diverse, as compared to other four Peruvian domesticated *Capsicum* species [3]. A most recent study on Peruvian chili peppers showed the volatile composition of 50 fresh samples, which were clustered into groups based on hydrocarbons, esters, terpenes, aldehyde and ketones composition [4].

Very few studies have reported the sensory attributes that contribute to the flavor of *Capsicum* species. For green bell peppers (*C. annuum*), grassy, cucumber and green bell pepper attributes were reported; whereas red bell peppers were reported to have sweet, sour and red bell pepper aroma attributes [5]. Analysis of *C. chinense* from Brazil showed high pepper-like and green-note compounds [6]. Two Andean species of chili peppers, *C. baccatum* (Ají) and *C. pubescens* (Rocoto), had an earthy/vegetable/bell pepper like aroma with a distinct cucumber odor [7]. Sensory analysis showed that elite sweet pepper (*C. annuum*) lines and hybrids from a

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commercial breeding program in Netherlands had sensory attributes such as sweet and fruity apple [8].

To our knowledge, there is no information on fresh Peruvian chili peppers regarding their flavor. Considering the increase in their popularity, especially to gastronomy, it is important to understand their unique flavor and sensory attributes. Therefore, the main purpose of this study was to evaluate the agro-morphological characteristics and sensory properties of 31 Peruvian chili peppers, as well as to group the chili peppers based on their sensory evaluation.

The overall outcome of this research could be a starting point towards the directed flavor breeding in chili peppers. The results highlight the individual flavor and sensory attributes of Peruvian chili peppers and this may lead to a further increase in their demand in the international markets.

2. Materials and Methods

2.1 Chili Pepper Samples

Chili peppers samples were collected in January and February 2015 from four locations representing the different environments where chili peppers are grown, namely, (1) a farm located in a gorge of Grocio Prado district in Chincha province (dry flat area), (2) a farm in the city of Pucallpa in Coronel Portillo province (mountain wet area), (3) the agricultural station of Instituto Nacional de Innovacion Agraria (INIA) located in Huaral, North Lima (dry flat area) and (4) *C. pubescens* "Rocoto" samples were collected from the department of Pasco in the district of Villa Rica (forest region).

Agro-morphological characterization was performed using descriptors for the plant and fruit, as established by the International Plant Genetic Resources Institute (IPGRI) [9]. Habit of growth was observed for each variety at the time of start of first fruit ripening in 50% of growing plants. Plant height and the number and total weight of fruits per plant were calculated as the average of data obtained from

five samples. Each fruit is described based on their color, shape, length, diameter and weight observed, when each of them reached full physiological ripeness. Performance was expressed as the weight of fruit per hectare.

2.2 Descriptive Sensory Analysis (DSA)

The 31 fresh chili pepper samples were evaluated by five trained panelists. Training of the candidates for a 10-month duration resulted in a selection of five final panelists from 75 candidates, according to the procedures given by the NTP-ISO 6564 [10] and NTP-ISO 6658 [11]. Panelists' selection criteria were based on pepper eating habits, sensibility to basic tastes and smells, as well as individual reproducibility and degree of agreement with the rest of the members. Four flavor (acid, bell pepper, sweet and tomato) and six aroma (apple, citrus, fruity, herbal, oregano and passion fruit) descriptors, as well as references for lower and upper limits, were defined by consensus. All tests were carried out in individual booths under controlled lighting (white, green, red and purple) and temperature (22 °C). Whole peppers were given in plastic cups coded with three-digit random numbers, and each sample was analyzed three times in different sessions. Cold water and cream crackers were served to eliminate aftertaste and reduce pungency. First, the panelists analyzed aroma by making a longitudinal cut of the fruit, then flavor was assessed by cutting a piece of pericarp. All impressions were registered on a horizontal 10 cm line scale marking near the lower or upper limit depending on whether the sample was more similar to each respective reference.

2.3 Statistical Analysis

Data from the sensory analysis of chili pepper samples are reported as mean ($n = 3$). Differences were considered to be significant at $P \leq 0.05$. Data were analyzed by one way ANOVA (sample) using XLSTAT (version 2015.3.01, Addinsoft SARI, Paris, France).

3. Results and Discussion

The agronomical information of the 31 chili peppers studied is shown in Table 1 and Fig. 1. The fruit morphological features, such as color, fruit form and size, were determined on five ripe fruits. In all accessions, the fruit color at the ripe stage was red, but the level of red varied from dark red, e.g., in “Ají Montaña” (1: *C. chinense*) to clear red, such as in “Ají Dulce Rojo” (72: *C. chinense*). Several accessions had fruit with special colors (Fig. 1), such as orange (193), brown (354), lemon yellow (10ica) and yellow orange

(13p). The fruit shapes and sizes varied in the samples studied. Based on the criteria, they can be grouped in different types, such as bell shaped, triangular, almost round and elongated. The bell shaped fruit type generally had similar fruit length and diameter. Several samples had an almost round shape (12p, 13p and 1ica) and all belonged to *C. frutescens*. There was a great diversity in fruit length (6-122 mm), fruit diameter (6-64 mm), fruit weight (0.3-90.2 g), number of fruits per plant (16-905) and plant height (27-183 cm).

Table 1 Agro-morphological characteristics of 31 Peruvian chili peppers.

Code	Species	Accession name	Color	Fruit form	Length (mm)	Diameter (mm)	Fruit weight (g)	No. of fruits per plant	Plant height (cm)
1	<i>C. chinense</i>	Aji Montaña	Dark red	Bell shaped	33	23	5.8	157	126
7	<i>C. baccatum</i>	Tomatito Rojo	Red	Triangular	29	22	4.5	52	27
10	<i>C. baccatum</i>	Aji Limo Rojo	Dark red	Triangular	56	28	14.1	107	28
18	<i>C. baccatum</i>	Puca Limo	Dark red	Triangular	56	28	14.1	117	28
29	<i>C. frutescens</i>	Aji Pipi Rojo	Red	Elongated	24	6	0.3	615	144
38	<i>C. chinense</i>	Picante Rojo	Red	Bell shaped	28	20	3.8	212	142
40	<i>C. chinense</i>	Aji Dulce Rojo	Red	Bell shaped	38	18	4.7	227	134
72	<i>C. chinense</i>	Aji Dulce Rojo	Clear red	Elongated	39	11	2.2	544	119
175	<i>C. baccatum</i>	Aji Uña de Gavilan	Red	Elongated	64	20	7.5	80	77
184	<i>C. annuum</i>	Aji Cerezo	Dark red	Triangular	26	26	8.7	16	32
191	<i>C. frutescens</i>	Aji Pinchito Rojo	Clear red	Elongated	21	7	0.5	905	138
193	<i>C. baccatum</i>	Escabeche	Orange	Elongated	104	27	21.4	28	125
203	<i>C. chinense</i>	Aji Rojo	Dark red	Triangular	23	12	3.3	185	134
339	<i>C. annuum</i>	Aji Macruzori Picante	Red	Elongated	98	10	1.6	163	119
354	<i>C. chinense</i>	Aji Panca	Brown	Elongated	80	25	14.0	59	100
374	<i>C. frutescens</i>	Asna Uchu	Clear red	Elongated	26	9	0.8	440	183
377	<i>C. chinense</i>	Asna Uchu Grande	Dark red	Elongated	95	25	19.9	72	123
401	<i>C. frutescens</i>	Aji Mono	Red	Triangular	24	11	1.3	92	168
10ica	<i>C. chinense</i>	Miscucho	Lemon yellow	Triangular	51	29	10.3	56	106
11ica	<i>C. chinense</i>	Corazon de Paloma Rojo	Red	Triangular	21	13	1.6	89	43
12p	<i>C. frutescens</i>	Charapita Rojo	Red	Almost round	8	10	0.4	111	117
13p	<i>C. frutescens</i>	Charapita Amarillo	Yellow orange	Almost round	6	9	0.3	127	106
16p	<i>C. chinense</i>	Pucunucho	Yellow orange	Triangular	50	17	3.2	70	75
1ica	<i>C. frutescens</i>	Charapon	Red	Almost round	14	16	1.2	39	131
1vr	<i>C. pubescens</i>	Rocoto Rojo	Red	Bell shaped	55	50	53.6	34	169
2vr	<i>C. pubescens</i>	Rocoto Amarillo	Pale yellow orange	Bell shaped	75	64	90.2	26	156
4ica	<i>C. baccatum</i>	Aji Amarillo	Yellow orange	Elongated	122	32	38.8	27	122
5ica	<i>C. baccatum</i>	Ayuello	Red	Bell shaped	33	17	3.7	45	86
6ica	<i>C. baccatum</i>	Challuaruro	Clear red	Elongated	58	13	3.4	162	65
7ica	<i>C. chinense</i>	Limo	Red	Triangular	58	33	9.5	81	86
9ica	<i>C. chinense</i>	Corazon de Paloma Amarillo	Yellow orange	Triangular	21	14	1.6	78	36

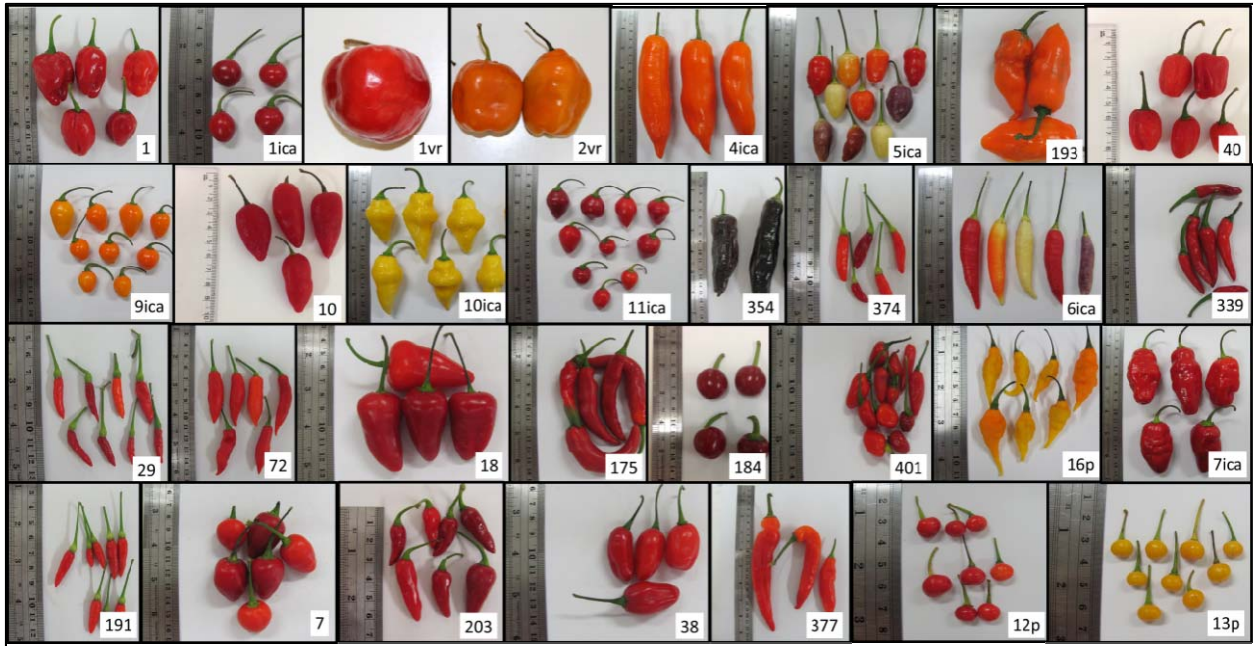


Fig. 1 Representative variation in fruit color and shape among 31 chili peppers.

The numbers in this figure corresponds with code of different chili peppers.

The sensory quality of different cultivars of chili peppers was evaluated through DSA. The panelists identified a total of four flavor (acid, bell pepper, sweet and tomato) and six aroma (apple, citrus, fruity, herbal, oregano and passion fruit) attributes. Citrus attribute was described by tangerine, orange and lime references, while fruity attribute was described by pear, banana, papaya, apricot, pineapple and mango references. Oregano attribute was different from the herb attribute; the reference for the latter was grass, chamomile, lemon verbena, mint and parsley. The attribute acidity was referenced by green pepper, watermelon and green and red apple. Aji Amarillo (*C. baccatum*) and bell pepper were the reference for the sweet attribute. The average mean results for the sensory analysis of 31 chili peppers are shown in Table 2. Significant differences among the 31 chili peppers were established for all the 10 attributes (Table 3). All sensory attributes were highly significantly different ($P < 0.001$) among the chili peppers samples. The 31 chili pepper samples were relatively dispersed, indicating variation in terms of

sensory profiles, as shown in Fig. 2 and Table 4. Group A (9ica, 13p and 401) was perceived to be higher in fruity, passion fruit and citrus notes. Group C (16p, 374 and 191) also perceived a fruit note, with a high score on the apple descriptor. Group B (354 and 29) was differentiated by herbal and oregano notes. Group D (4ica, 38, 175, 1 and 7), group E (2vr, 1vr, 184, 339, 203 and 377) and group F (7ica, 18, 40, 1ica, 5ica, 11ica, 6ica, 12p, 72, 10ica, 193 and 10) all had a bell pepper note presence; but group D has a sweet note, group E had a herbal note and group F had an apple, herbal, sweet and fruity note.

On the basis of the sensory results (Tables 2-4 and Fig. 2), the sensory profiles of these 31 chili peppers can be grouped into three large categories broadly related to fruity (group A and C), herbal (group B) and bell pepper (group D, E and F). The 31 chili pepper samples (Groups A-F) are comprised of several different chili peppers species and physical appearances (Table 4 and Fig. 2), suggesting that species or physical forms of chili peppers do not govern sensory attributes.

**Agro-morphological Characteristics and Sensory Evaluation of
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Table 2 Mean scores of sensory descriptors of 31 chili pepper samples.

Code	Species	Accession name	Sensory descriptors*									
			Acid	Citrus	Sweet	Fruity	Herbal	Apple	Passion fruit	Oregano	Bell pepper	Tomato
1	<i>C. chinense</i>	Aji Montaña	2.51	3.47	6.61	5.91	5.71	6.09	2.67	3.84	5.59	3.43
7	<i>C. baccatum</i>	Tomatito Rojo	2.79	3.97	8.99	5.67	5.14	4.22	2.97	3.64	6.32	3.63
10	<i>C. baccatum</i>	Aji Limo Rojo	3.65	4.25	5.80	4.77	5.91	3.84	3.18	4.48	5.81	4.07
18	<i>C. baccatum</i>	Puca Limo	3.17	4.47	6.24	6.27	5.52	4.79	3.48	3.79	7.33	4.34
29	<i>C. frutescens</i>	Aji Pipi Rojo	3.57	2.08	1.59	4.03	4.13	3.11	1.09	3.99	2.97	1.65
38	<i>C. chinense</i>	Picante Rojo	3.46	7.63	7.16	5.61	4.56	4.17	2.22	3.15	6.33	4.90
40	<i>C. chinense</i>	Aji Dulce Rojo	3.00	4.86	6.11	6.16	4.72	4.76	4.17	3.69	6.36	4.81
72	<i>C. chinense</i>	Aji Dulce Rojo	3.46	3.37	3.96	6.14	5.47	4.97	2.79	3.68	6.56	4.45
175	<i>C. baccatum</i>	Aji Uña de Gavilan	2.34	3.53	6.09	5.43	4.92	4.31	2.00	2.66	6.20	3.72
184	<i>C. annuum</i>	Aji Cerezo	3.59	2.33	4.44	4.17	3.67	2.48	0.75	2.19	6.09	3.27
191	<i>C. frutescens</i>	Aji Pinchito Rojo	4.56	3.42	1.61	5.99	5.34	4.87	2.09	2.92	1.89	1.21
193	<i>C. baccatum</i>	Escabeche	2.87	4.24	5.83	5.42	5.70	5.00	3.51	3.84	4.27	3.74
203	<i>C. chinense</i>	Aji Rojo	2.27	3.37	5.19	4.97	4.85	3.81	1.83	4.20	4.60	1.72
339	<i>C. annuum</i>	Aji Macruzori Picante	3.70	3.36	3.23	3.85	5.26	2.37	2.09	3.96	4.55	2.35
354	<i>C. chinense</i>	Aji Panca	2.51	1.75	2.40	4.29	5.91	3.43	0.45	3.95	3.91	4.09
374	<i>C. frutescens</i>	Asna Uchu	3.24	4.80	2.43	7.48	4.89	6.43	2.07	4.89	2.21	2.03
377	<i>C. chinense</i>	Asna Uchu Grande	1.37	1.25	5.95	4.25	5.95	3.45	1.00	4.12	6.25	3.12
401	<i>C. frutescens</i>	Aji Mono	3.37	4.33	2.77	7.97	5.23	5.70	5.40	3.70	3.17	2.73
10ica	<i>C. chinense</i>	Miscucho	3.12	4.54	4.80	5.39	4.70	4.16	4.11	3.17	4.14	3.72
11ica	<i>C. chinense</i>	Corazon de Paloma Rojo	4.51	5.51	5.35	6.81	4.43	4.81	3.33	3.81	5.81	3.91
12p	<i>C. frutescens</i>	Charapita Rojo	3.38	4.21	3.80	6.32	4.36	4.31	3.36	2.61	5.01	3.38
13p	<i>C. frutescens</i>	Charapita Amarillo	3.66	4.95	2.57	6.24	4.98	4.54	4.54	3.35	2.40	2.54
16p	<i>C. chinense</i>	Pucunucho	2.25	4.32	2.96	5.61	3.82	4.20	3.00	1.96	2.84	2.55
1ica	<i>C. frutescens</i>	Charapon	3.38	4.98	5.04	6.76	5.39	4.28	4.11	3.77	6.52	3.37
1vr	<i>C. pubescens</i>	Rocoto Rojo	2.12	2.45	3.79	3.63	3.98	3.51	0.27	1.99	3.51	3.15
2vr	<i>C. pubescens</i>	Rocoto Amarillo	2.75	2.91	5.10	4.63	4.24	3.79	0.91	1.86	4.45	3.55
4ica	<i>C. baccatum</i>	Aji Amarillo	3.15	5.72	7.92	7.76	4.25	4.90	4.92	2.60	5.35	4.49
5ica	<i>C. baccatum</i>	Ayuello	3.63	4.86	5.19	6.62	4.06	5.50	2.58	2.81	5.42	3.90
6ica	<i>C. baccatum</i>	Challuaruro	4.11	4.26	3.99	6.49	4.37	4.67	3.13	2.59	5.41	4.07
7ica	<i>C. chinense</i>	Limo	3.24	4.52	5.58	6.10	4.95	5.28	2.68	3.08	7.18	4.62
9ica	<i>C. chinense</i>	Corazon de Paloma Amarillo	3.25	5.40	4.89	6.85	4.89	4.42	6.21	2.92	4.31	3.49

* Scores of sensory descriptors were evaluated on a 0-10 scale.

Table 3 Results of sensory descriptive analysis for 31 chili peppers.

Attribute	Minimum	Maximum	Mean	SD
Acid	1.37	4.56	3.16	0.69
Citrus	1.25	7.63	4.04	1.29
Sweet	1.59	8.99	4.75	1.79
Fruity	3.63	7.97	5.73	1.14
Herbal	3.67	5.95	4.88	0.65
Apple	2.37	6.43	4.39	0.93
Passion fruit	0.27	6.21	2.80	1.44
Oregano	1.86	4.89	3.33	0.77
Bell pepper	1.89	7.33	4.93	1.51
Tomato	1.21	4.90	3.42	0.95

SD: standard deviation. Scores of sensory descriptors were evaluated on a 0-10 scale. Differences among sensory attributes were statistically significant ($P < 0.001$).

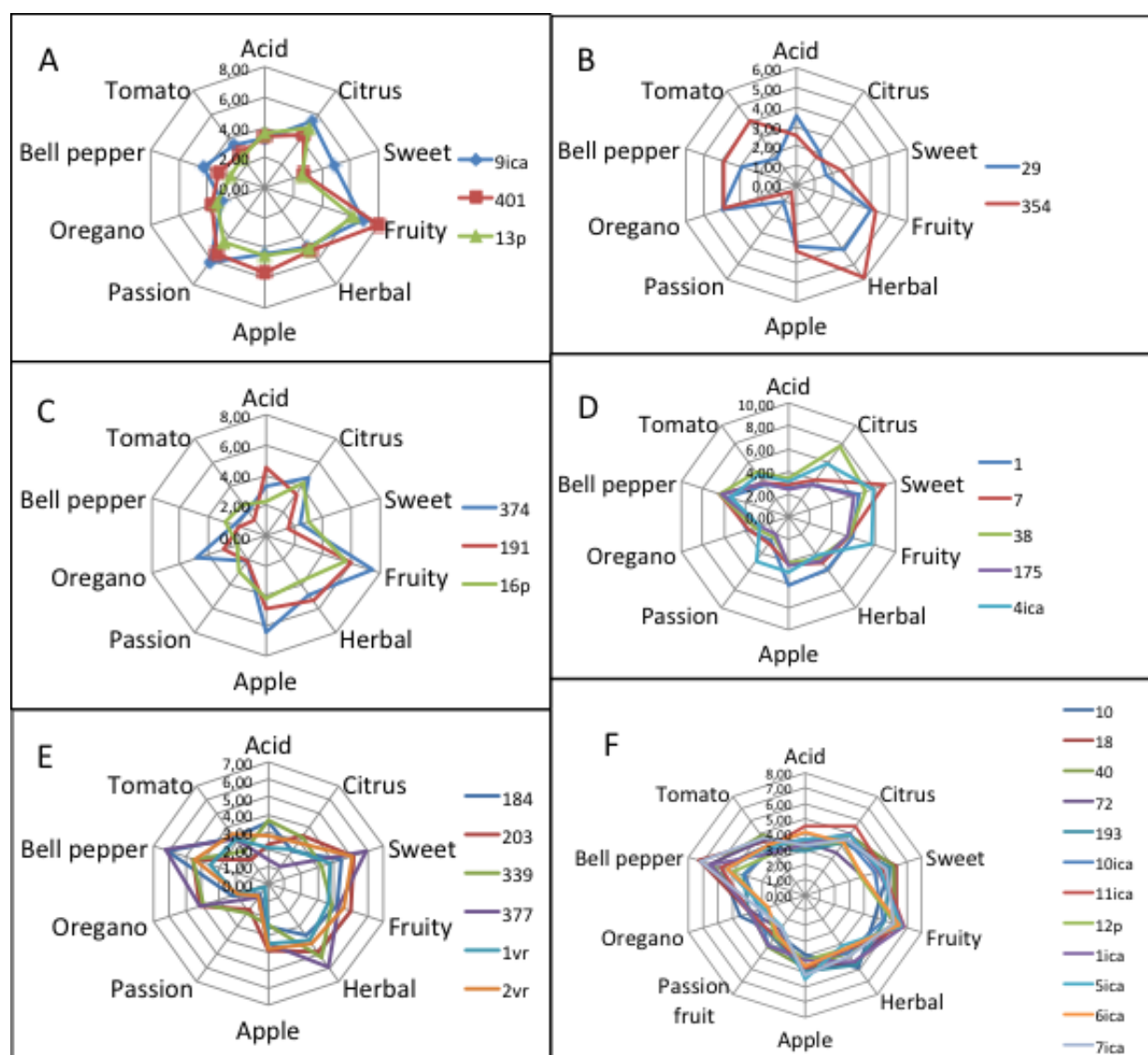


Fig. 2 Descriptive sensory analysis of 31 chili peppers and grouping according to their sensory profiles.

Table 4 Sensory analysis and morphological characteristics of different chili pepper groups.

Group	Sensory attribute	Code	Species	Accession name	Color	Fruit form
A	Fruity, passion fruit, citrus	9ica	<i>C. chinense</i>	Corazon de Paloma	Yellow orange	Triangular
		401	<i>C. frutescens</i>	Aji Mono	Red	Triangular
		13p	<i>C. frutescens</i>	Charapita Amarillo	Yellow orange	Almost round
B	Herbal, oregano	29	<i>C. frutescens</i>	Aji Pipi Rojo	Red	Elongated
		354	<i>C. chinense</i>	Aji Panca	Brown	Elongated
C	Fruit, apple	374	<i>C. frutescens</i>	Asna Uchu	Clear red	Elongated
		191	<i>C. frutescens</i>	Aji Pinchito Rojo	Clear red	Elongated
		16p	<i>C. chinense</i>	Pucunucho	Yellow orange	Triangular
D	Bell pepper, sweet	1	<i>C. chinense</i>	Aji Montaña	Dark red	Bell shaped
		7	<i>C. baccatum</i>	Tomatito Rojo	Red	Triangular
		38	<i>C. chinense</i>	Picante Rojo	Red	Bell shaped
		175	<i>C. baccatum</i>	Aji Uña de Gavilan	Red	Elongated
		4ica	<i>C. baccatum</i>	Aji Amarillo	Yellow orange	Elongated

(Table 4 continued)

Group	Sensory attribute	Code	Species	Accession name	Color	Fruit form
E	Bell pepper, herbal	184	<i>C. annuum</i>	Aji Cerezo	Dark red	Triangular
		203	<i>C. chinense</i>	Aji Rojo	Dark red	Triangular
		339	<i>C. annuum</i>	Aji Macruzori Picante	Red	Elongated
		377	<i>C. chinense</i>	Asna Uchu Grande	Dark red	Elongated
		1vr	<i>C. pubescens</i>	Rocoto Rojo	Red	Bell shaped
		2vr	<i>C. pubescens</i>	Rocoto Amarillo	Pale yellow orange	Bell shaped
F	Bell pepper, apple, herbal, fruity, sweet	10	<i>C. baccatum</i>	Aji Limo Rojo	Dark red	Triangular
		18	<i>C. baccatum</i>	Puca Limo	Dark red	Triangular
		40	<i>C. chinense</i>	Aji Dulce Rojo	Red	Bell shaped
		72	<i>C. chinense</i>	Aji Dulce Rojo	Clear red	Elongated
		193	<i>C. baccatum</i>	Escabeche	Orange	Elongated
		10ica	<i>C. chinense</i>	Miscucho	Lemon yellow	Triangular
		11ica	<i>C. chinense</i>	Corazon de Paloma Rojo	Red	Triangular
		12p	<i>C. frutescens</i>	Charapita Rojo	Red	Almost round
		1ica	<i>C. frutescens</i>	Charapon	Red	Almost round
		5ica	<i>C. baccatum</i>	Ayuello	Clear red	Bell shaped
6ica	<i>C. baccatum</i>	Challuaruro	Clear red	Elongated		
7ica	<i>C. chinense</i>	Limo	Red	Triangular		

4. Conclusions

The present study investigated the agro-morphological characteristics of 31 native Peruvian chili peppers. These peppers showed a great diversity in fruit length, fruit diameter, fruit weight, number of fruits per plant, plant height and color. Various shades of red and yellow, along with colors like orange and brown, were present. The sensory properties of these 31 native Peruvian chili peppers were determined by DSA. This is the first detailed study on the sensory attributes of fresh chili peppers from Peru, a country with a long history in the culinary use of these spices. The results from the DSA differentiated the 31 chili peppers into six groups based on their sensory attributes. The majority of them (12 out of 31) had a predominant bell pepper attribute (groups D, E and F), while the remaining was either fruity (groups A and C) or herbal (group B). Each group included different *Capsicum* species with different agro-morphological characteristics, indicating that sensory attribute is not specific to one species or one form of chili pepper. These four flavor (acid, bell-pepper, sweet and tomato) and six aroma

(apple, citrus, fruity, herbal, oregano and passion fruit) attributes were all significantly different among the 31 chili peppers. These sensory attributes and overall results will be helpful for producers and the gastronomy sector for the selection of desirable chili peppers in order to increase consumer satisfaction.

Acknowledgments

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