Research article

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Physicochemical and sensorial characterisation of Argentine ciders

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This work reports the physicochemical and sensorial characteristics of industrial and artisanal ciders from the Patagonia and Cuyo region of Argentina. Argentine cider has been undervalued by consumers in recent years and the academic and manufacturing sectors are looking to respond to this challenge . A novel sensorial panel for evaluating Argentine cider was developed, which to our knowledge is the first o f its kind for cider. Principal components analysis of the physicochemical data grouped the ciders by their manufacturing type (industrial or artisanal). Cluster analysis identified three groups of ciders defined by their alcohol and reducing sugar content. Most of the industrially made ciders were sweetened whereas the artisan ciders generally had the lowest sugar content. Correspondence analysis of the sensorial data revealed that the assessors found more differences in aroma than in taste. On tasting, alcoholic and oxidation notes differentiated 56.5 and 60.9% of the ciders respectively.

Keywords: Argentine ciders; Upper Valley of the Río Negro and Neuquén; sensorial analysis

Introduction

The Upper Valley of the Río Negro and Neuquén (hereafter referred to as the Upper Valley), a fertile region of northern Patagonia, is home to some 85% of Argentina's apple production. The remaining 15% is distributed between the Uco Valley (Province of Mendoza), the town of 25 de Mayo (Province of La Pampa) and the Tulum Valley (Province of San Juan). The total area under apple cultivation exceeds 27,000 ha.

The National Institute of Industrial Technology (Instituto Nacional de Tecnología Industrial) reported that ~35% of Argentine apples are sold fresh for eating, 17% are exported and the remaining 48% are processed industrially (i.e. fruit that does not meet the size or appearance requirements for sale to consumers). Of this latter fraction, 83% is used to make concentrated juice, 5% to make dehydrated apple (in addition to other products derived from grinding) and 12% to make cider.

According to the Ministry of National Agribusiness, 860,000 tonnes of commercial apples were harvested in 2013, falling to 640,000 tonnes in 2015. This decline was due to adverse weather conditions (including hail, which has become more frequent in recent years) and a fall in the profitability of fruit and vegetable growing in the area (apples were being sold at low prices, and trees were replaced with pear trees as pears demand a higher price on international markets).

Argentina produced some 900,000 hL of cider in 2017. Production in Europe, which is centred on carbonated cider, was around 10,000,000 hL, led by the UK with 5,800,000 hL, and followed by France (1,300,000 hL), Germany (1,100,000 hL) and Spain (800,000 hL). The USA is a promising producer of cider (620,000 hL reported in 2012) *(1)*. In the Americas, cider is also produced in Canada, Chile and Mexico. Argentina mostly produces carbonated cider; in other countries with a longer tradition of production (such as Spain), natural cider may also be produced.

The Argentine Ministry of Agriculture, Livestock and Fisheries records that, in recent years, Argentina has exported cider to the Mercosur (Brazil) and ALADI (Paraguay, Uruguay, Chile, Bolivia, Peru and Venezuela) organisations. To a lesser extent it has also exported to the European Union (Spain, Germany and Italy), the NAFTA block (USA, Canada, and Mexico), Asia (China, Malaysia), Oceania (Australia) and the Middle East (Israel). The largest importer of Argentine cider is Brazil; high freight costs make it difficult to export to the Northern Hemisphere and compete with countries such as Spain. Argentina also imports cider, especially from Spain, and to a lesser extent from Belgium and France, although these imports have decreased since 2000.

In 2015, cider consumption in Argentina was recorded at 0.017 hL per person per year, with about 80% is consumed during the Christmas holidays. The largest producers, some of which handle around 15,000,000 kg of apples every year, are seeking to promote the consumption of cider at other times of the year in order to compete with wine and beer, the most consumed alcoholic beverages in the country.

During handling, the apples used to make Argentine cider at an industrial scale, where the processing of fruit ranges from 300 kg to more than 10,000,000 kg, suffer a risk of exposure to the sun and microbial (especially fungal) contamination. Large scale processing

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involves a number of operations: transport, fruit reception, washing, grinding, pressing and juice extraction, sulphiting, clarification, alcoholic fermentation, racking, sulphiting and stabilisation of the base cider, transport in tankers to the bottling plant, filtering, sulphiting, sweetening (sucrose and/or high fructose corn syrup and/or concentrated apple juice), acidification (citric acid, tartaric acid or malic acid), pasteurisation or sterile filtration, carbonation and bottling (Fig. 1a and b). According to the Argentine Food Code, base cider can contain up to 10% fermented pear juice. Only one of the eight large industrial plants in the Upper Valley area bottles its cider. The remaining plants send their cider by tanker for bottling in Buenos Aires, as this a cheaper option.

In recent years, the production of artisanal cider has been boosted by entrepreneurs new to the sector. This type of cider making typically involves the processing of 200–300 kg of good quality fruit (mouldy and/or damaged apples are rejected). The

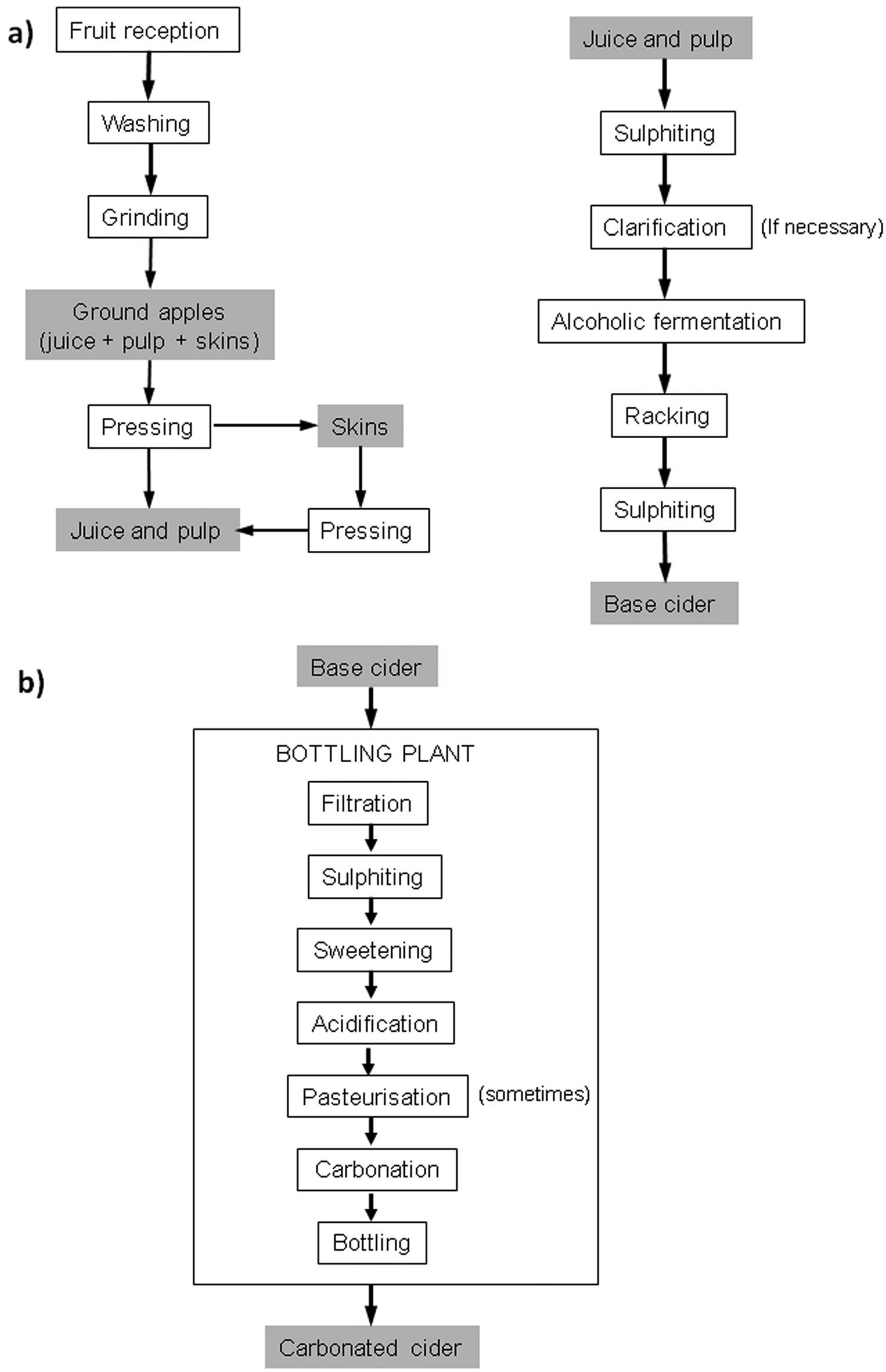

Figure 1. Flow chart for 'industrial'/large-scale cider making. (a) Extraction of juice and production of the base cider. (b) Production of carbonated cider.

apples come from specially designated orchards, and bottling is performed on site. The Upper Valley region is currently home to four producers of artisanal cider and one large-scale producer producing sparkling cider by the Champenoise method.

Cider production has a long history. In 1911 and 1927 respectively, Barker *(2)* and Bufton *(3)* outlined the process of cider making in the UK and the various challenges. Beech *(4)* published a review about cider making focusing on the fermentation of apple juice, describing innovations such as the inoculation of pure yeast cultures, the adoption of improved fermenting vessels and the use of sterile concentrate. Williams *(5)* surveyed the state of the cider industry and the research being conducted to give the manufacturer tools to control the cider flavour so as to produce better ciders.

Leguérinel *et al.* *(6)* developed a method for the evaluation of ciders based on instrumental analysis and applied multiple linear regression models to correlate sensory profile analysis data to the concentrations of compounds such as glucose, fructose, malic, lactic and acetic acids, isobutanol, ethyl acetate, 2,3-butandiol, amyl alcohols, ethanol and titratable acidity. In further work, Leguérinel *et al.* *(7)* compared ciders fermented using a pure culture of *Saccharomyces uvarum* with natural ciders, and assessed the role of the yeast strain in the formation of flavour components and the role of fermentation temperature in the flavour development of ciders.

Fan *et al.* *(8)* developed a method for the quantification of volatile compounds in ciders using stir bar sorptive extraction followed by gas chromatography coupled to mass spectrometry. They detected 54 compounds in Chinese cider samples, mainly alcohols, acids, esters, terpenoids and aromatics. Antón *et al.* *(9)* studied the aromatic profile of Asturian ciders using gas chromatography coupled with olfactometry and sensory analysis. Zhao *et al.* *(10)* studied the volatile composition of ciders after the alcoholic fermentation detecting 51 compounds, most of them described as contributors to the fruity notes of fermented beverages *(11–13)*. Symoneaux *et al.* *(14)* assessed the effect of the apple procyanidins on the sensory perception in ciders regarding their concentration and degree of polymerisation. Verdu *et al.* *(15)* reported that procyanidins and their degree of polymerisation are responsible for the bitterness and astringency in ciders, while the colour is due to their enzymatic oxidation. According to Herrero *et al.* *(16)* hydroxycinnamic acids can be precursors of volatile molecules involved in cider aroma. Symoneaux and colleagues *(17)* studied the incidence of cider aroma on taste sensations and the effect of carbon dioxide on different matrix components of cider such as fructose, organic acids, phenols and ethanol together with the perceived sensory impression *(18)*.

Picinelli *et al.* *(19)* chemically characterised Asturian ciders and Le Quéré *et al.* *(20)* reported the sensorial, chemical and

Table 1. Aroma descriptors used in the sensorial analysis

Descriptor	Recognition of the descriptor via:	Group	Descriptor	Recognition of the descriptor via:	Group
Sherry	sample test	Ox-H-D	Sulphite, sulphur dioxide	sample test	Ox-H-D
Sweetness	sample test	Os	Citrus	sample test	Os
Acetic acid	pure compound	Ox-H-D	Red apple (Red Delicious)	natural standard	F
Acetaldehyde	pure compound	Ox-H-D	Green apple (Granny Smith)	natural standard	F
Ethyl acetate	pure compound	Ox-H-D	Fresh fruit	sample test	F
Fresh	sample test	F	Ripe apple	natural standard	F
Dried apple	natural standard	F	Syrup	sample test	Os
Apple	natural standard	F	Quince	sample test	F
Apple seed	natural standard	Ox-H-D	Concentrated apple juice	natural standard	Os
Apple pulp	sample test	F	Lactic acid, dairy	pure compound	Os
Almond	natural standard	Os	Reduction, hydrogen sulphide	sample test	Ox-H-D
Apple juice	natural standard	F	Sulphited base cider	natural standard	Ox-H-D
Fermented apple juice	sample test	F	Burned rubber	sample test	Ox-H-D
Base cider	natural standard	A	Dregs	sample test	Ox-H-D
Red apple juice	natural standard	F	Rotten	sample test	Ox-H-D
Ethanol	pure compound	A	Soil	natural standard	Os
n-Butanol	pure compound	A	Apple stalk	natural standard	Ox-H-D
Amyl alcohol	pure compound	A	Yeast, bread	natural standard	Os
Compote	natural standard	Os	Banana	natural standard	F
Candy	sample test	Os	Moisture	natural standard	Ox-H-D
Oxidation	sample test	Ox-H-D	Ketone	pure compound	A
Vintage	sample test	Ox-H-D	Overripe apple	natural standard	Os
Herbaceous	natural standard	Ox-H-D	Fungi	sample test	Ox-H-D
Geranium	natural standard	Ox-H-D	Olive	sample test	F
Metallic	sample test	Os	Pear	natural standard	F
Fruity	sample test	F	Antibiotic	sample test	Ox-H-D
Tutti-frutti	sample test	F	Preservative	sample test	Ox-H-D
Pineapple	natural standard	F	Smoke	sample test	Os
Cider alcohol	natural standard	A	Wood	sample test	Os

Abbreviations: F, fruity descriptor; A, alcoholic descriptor; Ox-H-D, oxidation/herbaceous notes/defects; Os, others (pungency included).

technological analysis of French ciders. Carter *et al.* *(21)* used isotopic analysis to study the chemical composition of European, Australian and New Zealand ciders obtaining a data bank as a tool to differentiate in terms of regions and cider-making countries. Clément *et al.* *(22)* reported the use of simple laboratory tests plus fluorescence and infrared spectroscopy for the authentication of ice ciders while Qin *et al.* *(23)* characterised the flavour profiles of commercial UK and Scandinavian apple ciders via sensory profiling and analysis of their volatile and non-volatile (residual sugars, titratable acidity and organic acids) components. Nicolini *et al.* *(24)* characterised single variety still ciders from the Italian Alps and found their elemental composition differed from that of French ciders. Moreover, several aroma compounds differed from the *Saccharomyces cerevisiae* strain used for the fermentation, while apple variety and processing contributed to differences in their methanol content.

The present work characterises Argentine ciders physicochemically and sensorially. The goal is to repeat this work annually so as to build up information for use by cider makers. No prior reports on the sensory and chemical aspects of Argentine ciders have been published.

Materials and methods

Samples

Twenty-two Argentinian ciders were examined (six bottles for each type), 21 from the Upper Valley area and one from the Province of Mendoza. Ten were purchased in supermarkets and 12 were provided by their producers. All were stored at 4°C until analysis.

Physicochemical analyses

Titratable acidity, free, bound and total sulphur dioxide, volatile acidity, pH and the reducing sugars, alcohol, dried extract, reduced dried extract and ash contents were analysed according to standard Argentine National Institute of Viniculture methods for alcoholic beverages; based on the norms of the Office Internationale de la Vigne et du Vin (Paris) *(25)*. Titratable acidity was measured by titration with a NaOH 0.1 M solution with bromothymol blue as indicator. Free and bound sulphur dioxide was analysed by the Rippert method, volatile acidity by the Jaulmes method, pH by potentiometry and reducing sugars by the Fehling method. The alcohol degree was determined using distillation and measurement of the distillate density, dried extract by heating in a boiling water bath, the reduced dried extract by subtracting reducing sugars from the dried extract and ash by heating the cider at 525°C. All determinations were made in at least duplicate. The total polyphenol index was measured (in triplicate) using the Folin–Ciocalteau micro method proposed by Waterhouse *(26)* and based on that used by Slinkard and Singleton *(27)*.

Sensorial analysis

Reagents. Anhydrous caffeine (*purissimum*; bitter taste), sodium chloride (analytical grade; salty taste), sodium glutamate hydrate

Table 2. Taste descriptors used in the sensorial analysis

Descriptor	Recognition of the descriptor via	Group	Descriptor	Recognition of the descriptor via:	Group
Pineapple	sample test	F-S-Sp	Syrup	sample test	F-S-Sp
Pear	sample test	F-S-Sp	Candy	sample test	F-S-Sp
Sherry	sample test	Ox-St-A	Overripe apple	sample test	F-S-Sp
Almond	sample test	F-S-Sp	Rotten apple	sample test	Ap-Ac
Vinegar	sample test	Ap-Ac	Quince	sample test	Os
Ketone	sample test	Ox-St-A	Ethanol	sample test	T
Solvent	sample test	Ox-St-A	Amyl alcohol	sample test	Ox-St-A
Apple	sample test	Ap-Ac	Dregs	sample test	Os
Green apple (Granny Smith)	sample test	Ap-Ac	Watery	sample test	T
Apple juice	sample test	Ap-Ac	Fruit juice	sample test	F-S-Sp
Apple seed	sample test	Ap-Ac	Leafy	sample test	Os
Apple peel	sample test	Ap-Ac	Herbaceous	sample test	Os
Apple stalk	sample test	Ap-Ac	Fermented apple juice	sample test	Ox-St-A
Compote	sample test	F-S-Sp	Red apple (Red Delicious)	sample test	F-S-Sp
Sulphite, sulphur dioxide	sample test	F-S-Sp	Grape	sample test	F-S-Sp
Sulphited base cider	sample test	F-S-Sp	Acrid	sample test	T
Base cider	sample test	T	Woody	sample test	Os
Sweet acidulated	sample test	T	Soil	sample test	Os
Fruity	sample test	T	Ginger	sample test	Os
Fresh	sample test	T	Cheesy	sample test	Os
Citrus	sample test	F-S-Sp	Fungi	sample test	Os
Rubber	sample test	Os	Yeast	sample test	Os
Medicine, cough syrup	sample test	F-S-Sp	Olive	sample test	Os

Abbreviations: T, taste; Ap-Ac, apple, defective apple and vinegar notes; F-S-Sp, fruity, sulphite and syrup notes; Ox-St-A, oxidation, solvent and alcoholic notes; Os, other notes.

Table 3. Values of physicochemical variables for the different ciders

Ciders	SD1	SD2	SD3	SD4	SD5	SD6	SD7	SD8	SD9*	SD10	SD11
Titratable acidity (g tartaric acid/L)	5.33 ± 0.05	5.89 ± 0.11	4.56 ± 0.03	4.46 ± 0.00	4.14 ± 0.03	4.71 ± 0.03	3.60 ± 0.00	3.68 ± 0.00	6.02 ± 0.03	6.77 ± 0.03	4.63 ± 0.03
Free sulphur dioxide (mg/L)	7.1 ± 0.8	28.0 ± 0.3	55.4 ± 0.0	38.0 ± 0.0	78.8 ± 0.8	7.1 ± 0.8	12.5 ± 0.8	7.6 ± 0.0	7.6 ± 0.0	8.7 ± 0.0	8.2 ± 0.8
Bound sulphur dioxide (mg/L)	46.7 ± 0.0	69.6 ± 1.5	76.1 ± 0.0	78.2 ± 4.6	67.9 ± 0.8	58.7 ± 1.5	56.0 ± 0.8	67.9 ± 3.8	25.5 ± 0.8	70.6 ± 0.0	100.0 ± 0.0
Total sulphur dioxide (mg/L)	53.8 ± 0.8	97.6 ± 1.8	131.5 ± 0.0	116.3 ± 4.6	146.7 ± 0.0	65.8 ± 2.3	68.5 ± 0.0	75.5 ± 3.8	33.1 ± 0.8	79.3 ± 0.0	108.1 ± 0.8
Volatile acidity (g acetic acid/L)	0.20 ± 0.09	0.30 ± 0.03	0.55 ± 0.23	0.88 ± 0.16	0.30 ± 0.07	0.51 ± 0.19	0.10 ± 0.06	n.d.	1.07 ± 0.07	0.08 ± 0.18	0.48 ± 0.01
Reducing sugars (g/L)	116.39 ± 1.06	77.10 ± 0.93	95.47 ± 2.14	75.55 ± 3.13	69.66 ± 1.14	84.31 ± 1.11	37.12 ± 0.22	17.71 ± 0.98	60.42 ± 3.14	90.28 ± 3.83	74.55 ± 0.87
pH	3.4 ± 0.0	3.5 ± 0.0	3.5 ± 0.0	3.6 ± 0.0	3.6 ± 0.0	3.4 ± 0.0	3.9 ± 0.0	3.7 ± 0.0	3.8 ± 0.0	3.3 ± 0.0	3.5 ± 0.0
Alcohol content (% v/v)	4.5 ± 0.2	5.8 ± 0.2	4.5 ± 0.0	4.3 ± 0.1	4.8 ± 0.0	5.1 ± 1.3	5.9 ± 0.1	6.3 ± 0.1	6.9 ± 0.0	5.9 ± 0.2	4.4 ± 0.4
Dried extract (g/L)	139.23 ± 6.11	130.69 ± 1.25	122.95 ± 3.46	94.16 ± 4.30	93.32 ± 2.93	101.81 ± 3.30	86.92 ± 2.04	72.50 ± 0.07	84.75 ± 6.29	87.17 ± 1.38	111.84 ± 1.23
Reduced dried extract (g/L)	22.84 ± 7.17	53.59 ± 2.18	27.47 ± 5.60	18.61 ± 7.43	23.66 ± 4.07	17.50 ± 2.19	49.80 ± 1.82	54.79 ± 0.91	24.33 ± 3.14	n.d.	37.29 ± 0.36
Ash (g/L)	2.50 ± 0.13	3.40 ± 0.06	2.79 ± 0.54	2.47 ± 0.24	3.21 ± 1.08	2.29 ± 0.13	1.86 ± 0.04	2.08 ± 0.02	1.91 ± 0.01	3.38 ± 0.44	2.49 ± 0.33
Total phenol index (mg. gallic acid/L)	327.8 ± 20.2	359.2 ± 35.9	308.9 ± 15.3	215.4 ± 19.0	401.5 ± 40.4	366.7 ± 21.3	240.4 ± 23.0	219.0 ± 15.2	301.3 ± 34.3	353.5 ± 66.9	300.6 ± 90.8

Ciders	SD12	SD13*	SD14	SD15	SD16	SD17	SD18	SD19	SD20*	SD21*	SD22
Titratable acidity (g tartaric acid/L)	4.43 ± 0.00	5.76 ± 0.24	4.95 ± 0.11	5.08 ± 0.03	4.54 ± 0.05	4.84 ± 0.05	4.09 ± 0.05	4.58 ± 0.00	5.06 ± 0.05	4.91 ± 0.05	4.86 ± 0.03
Free sulphur dioxide (mg/L)	65.8 ± 2.3	11.1 ± 0.0	8.3 ± 0.0	5.5 ± 0.0	7.4 ± 0.0	22.6 ± 0.6	38.2 ± 1.9	115.6 ± 0.0	534.0 ± 39.2	43.0 ± 1.4	7.2 ± 2.0
Bound sulphur dioxide (mg/L)	94.5 ± 0.0	85.7 ± 0.0	122.0 ± 8.5	87.5 ± 0.0	63.1 ± 0.7	62.2 ± 0.7	67.2 ± 1.3	285.1 ± 23.6	696.3 ± 23.0	130.4 ± 0.7	112.7 ± 2.7
Total sulphur dioxide (mg/L)	160.3 ± 2.3	96.7 ± 0.0	130.3 ± 8.5	93.0 ± 0.0	70.5 ± 0.7	84.7 ± 0.0	105.5 ± 3.3	400.7 ± 23.6	1230.3 ± 16.2	173.4 ± 0.7	119.9 ± 0.7
Volatile acidity (g acetic acid/L)	n.d.	0.26 ± 0.01	0.66 ± 0.01	0.59 ± 0.03	0.77 ± 0.01	0.28 ± 0.01	0.21 ± 0.03	0.95 ± 0.02	n.d.	n.d.	0.36 ± 0.09
Reducing sugars (g/L)	44.77 ± 0.47	32.81 ± 0.84	57.66 ± 1.82	53.06 ± 0.44	82.76 ± 1.07	36.14 ± 2.04	87.58 ± 1.20	84.24 ± 11.03	13.77 ± 0.15	14.56 ± 0.66	58.25 ± 2.66
pH	3.5 ± 0.0	3.8 ± 0.0	3.6 ± 0.0	3.4 ± 0.0	3.7 ± 0.0	3.7 ± 0.0	3.6 ± 0.0	3.5 ± 0.0	3.6 ± 0.0	3.7 ± 0.0	3.3 ± 0.0
Alcohol content (% v/v)	5.4 ± 0.1	7.4 ± 0.1	5.5 ± 0.0	4.3 ± 0.1	6.2 ± 0.0	7.3 ± 0.1	4.6 ± 0.0	4.5 ± 0.1	7.6 ± 0.3	9.5 ± 0.1	4.6 ± 0.1
Dried extract (g/L)	106.58 ± 0.33	71.30 ± 2.55	131.41 ± 1.62	89.14 ± 2.38	143.74 ± 3.35	53.66 ± 2.80	113.65 ± 2.24	93.56 ± 2.28	25.81 ± 0.31	36.16 ± 0.48	95.55 ± 2.35

(*Continues*)

Table 3. *(Continued)*

Ciders	SD12	SD13*	SD14	SD15	SD16	SD17	SD18	SD19	SD20*	SD21*	SD22
Reduced dried extract (g/L)	61.81 ± 0.14	38.48 ± 3.40	73.74 ± 0.21	36.08 ± 2.82	60.98 ± 2.27	17.52 ± 4.84	26.06 ± 1.31	9.32 ± 3.31	12.04 ± 0.16	21.60 ± 1.15	37.30 ± 5.01
Ash (g/L)	2.16 ± 0.15	3.36 ± 0.07	3.70 ± 0.02	3.35 ± 0.00	2.40 ± 0.15	3.04 ± 0.07	2.10 ± 0.30	1.89 ± 0.62	3.05 ± 0.23	2.83 ± 0.62	2.94 ± 0.40
Total phenol index (mg. gallic acid/L)	375.2 ± 37.0	320.7 ± 53.3	319.4 ± 9.7	257.4 ± 63.5	368.8 ± 8.9	397.7 ± 6.6	246.0 ± 6.7	292.0 ± 64.3	623.9 ± 85.2	450.4 ± 46.3	193.2 ± 25.5

Note: ciders marked with an asterisk are artisanal.

(purissimum; umami taste), ferrous sulphate heptahydrate (analytical grade; metallic taste), aluminium sulphate octadecahydrate (analytical grade; astringent taste) and anhydrous citric acid (analytical grade; sour taste) were purchased from Biopack (Buenos Aires, Argentina). Commercial sucrose (sweet taste) was obtained from Ingeniero Ledesma SAAI (Province of Jujuy, Argentina).

Sensorial training and cider evaluation. Twelve volunteers from academia and industry (professors, students, cider makers and other professionals) were trained in sensory evaluation by experts at the National Institute of Industrial Technology following the recommendations of the Argentine Institute of Rationalization of Materials (Norm IRAM 20005–1: Sensorial analysis. Complete guide for the selection, training and monitoring of the evaluators. Part 1: Selected evaluators).

Training was accomplished as follows:

(1) The volunteers were asked to confirm that they drank cider, and for details of their diet (for health reasons), medication, possible illnesses and their lifestyle followed by attendance at a seminar on sensorial analysis.
(2) Three ciders and three base ciders were tasted for the volunteers to become acquainted with the product.
(3) Training to recognise basic tastes (sweet, sour, salty and bitter) and non-basic tastes (e.g. astringent, metal and umami) was provided, followed by tests to confirm the correct identification.
(4) This was followed by 'triangular tests' with the basic tastes (i.e. tests with three samples of two products to identify the odd one out).

This was followed by:

(5) Smell recognition training;
(6) Training in colour scaling;
(7) Training using concentration scales.

The volunteers then:

(8) Assessed cider samples by taste and smell to establish descriptors and finally performed
(9) Evaluation of cider samples.

At the start of each evaluation session (n = 3 or 4 samples; with 9–12 evaluators attending; step 9), odour standards – amyl alcohol (*n*-butanol), acetaldehyde, ethyl acetate (solvent, ketone), almond, alcoholic (6% (v/v) ethanol in water), cider alcohol and dairy (diluted lactic acid) – were presented in 30 mL screwcap candycoloured bottles. The panel were also presented with fresh Red Delicious apple, over-ripe Red Delicious apple, fresh Granny Smith apple, pear, pineapple, grass, soil, yeast, apple stalk, apple seeds, highly sulphited base cider and cider lees. A total of 58 olfactory descriptors were examined (Table 1). The frequency of detection of these descriptors by the tasters was recorded. This provided a final data matrix of 23 ciders (cider SD19 was evaluated twice) × 59 variables (the 58 descriptors plus an estimate of pungency, i.e. itching in the nose caused by carbon dioxide).

Tasting involved 52 variables, of which 46 were proposed during the descriptor search (step 8; Table 2) and six corresponded to pungency and flavours (sweet, sour, bitter, astringent and metallic). The detection frequency (as a percentage) was determined, producing a data matrix of 52 variables for the 23 ciders.

All cider samples (30 mL) were tested using standard wine glasses with an aluminium lid. All sensory evaluations were performed with the cider at 12–13°C.

Sensorial data collection. The evaluators recorded the sample code, visual characteristics (sparkling, foam, bubble size, colour, brightness and clarity) and descriptors for taste and aroma. Frequencies of detection were then determined using the following formula:

$$\text{Frequency}\ (\%) = \frac{\text{no.of evaluators who detected a sensory feature}}{\text{no.of total evaluators}} \times 100$$

The frequency values determined for each cider generated its sensory profile.

Statistical analysis. Statistical treatment of the physicochemical and sensorial data was performed using Statgraphics Centurion XVI software (Statgraphics Technologies Inc., The Plains, Virginia, USA).

Results and discussion

Table 3 shows the physicochemical data for the ciders. None of the ciders exceeded the legal volatile acidity limit (2.50 g/L) with all values ≤1.07 g/L. The alcohol content complied with the Argentine Food Code (4.3–7.4% v/v for carbonated ciders and 7.3–9.5% v/v for sparkling ciders) and all ciders complied with the regulations for ash content. A total of 95% of the samples met the legal requirements for free and total sulphur dioxide and 90% those for reduced dried extract content. Among the variables not subject to legislation by the Argentine Food Code, the reducing sugar concentration was higher in most of the industrial ciders (mean 62.0 g/L) than in the artisanal ciders (mean 30.4 g/L).

Principal components analysis extracted four principal components that explained 82.23% of the variance and revealed eight of the 22 ciders (36.4%) to be similar (SD7 and SD8, SD9 and SD5, SD18 and SD19, and SD22 and SD6). This analysis also differentiated industrial and artisanal ciders (Fig. 2). Indeed, two of the artisanal ciders (SD20 and SD21) had the lowest concentration of reducing sugars (13.8 and 14.6 g/L, respectively) and the highest alcohol content (7.6 and 9.5% v/v respectively; Table 3). However, the SD20 cider had an excessive concentration of sulphur dioxide (534 mg/L) which was over five times the maximum level allowed by legislation (100 mg/L). On consulting with the producer, this was reported as an error with an experimental and non-commercial cider.

For the ciders, the best correlations were found with reducing sugar with alcohol ($r = -0.71$) and dry extract ($r = 0.78$) and alcohol with dry extract ($r = -0.67$; $p < 0.05$). The correlation between the reducing sugar and alcohol was inverse, indicating that ciders with higher alcohol content had a lower residual reducing sugar content. However, Argentine ciders are sweetened prior to bottling, modifying the concentration of residual sugars after fermentation. Indeed, this negative correlation can be largely explained by the artisanal ciders SD20 and SD21, which had the highest alcohol content and the lowest reducing sugar. The reducing sugar and the dry extract content showed a strong positive correlation as the latter increases as a consequence of the sweetening operation.

Cluster analysis using the *k*-means conglomeration method produced four apparent clusters of ciders. The reducing sugar and alcohol content were the variables that best discriminated between them (Fig. 3). Cluster 1 comprised 11 industrial ciders – SD1, SD4/5/6, SD10, SD11, SD15, SD18, SD19 and SD22 – with

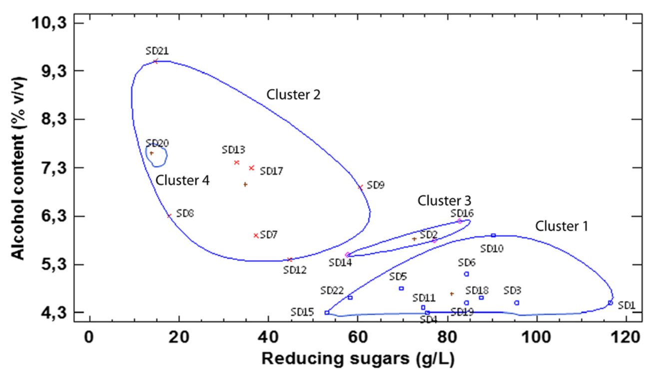

Figure 3. Cluster scattering graph showing three groups of ciders (ciders marked with and asterisk are artisanal). [Colour figure can be viewed at wileyonlinelibrary.com]

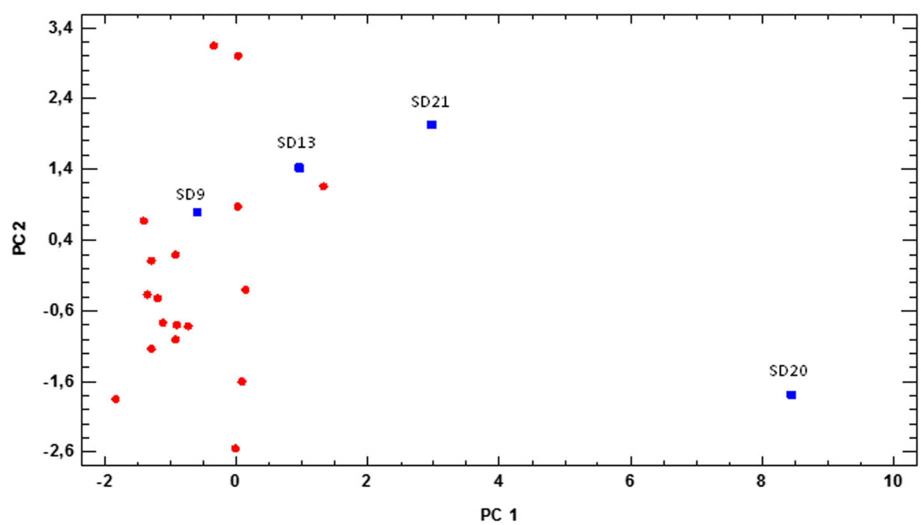

Figure 2. Principal components analysis: 2D graph grouping the industrial and artisanal ciders (, industrial ciders; , artisanal ciders). [Colour figure can be viewed at wileyonlinelibrary.com]

the highest reducing sugar and lowest alcohol contents. Cluster 2 comprised seven ciders with the lowest reducing sugar and the highest alcohol contents – SD7/8/9, SD12, SD13, SD17 and SD21. Of these, SD9, SD13 and SD21 were artisanal ciders. Cluster 3 included three ciders of industrial origin with intermediate sugar and alcohol content (SD2, SD14 and SD16). Cluster 4 contained only one cider, SD20 (artisanal with a low reducing sugar and a high alcohol content), but it cannot be differentiated from Cluster 2.

The colour and clarity of the ciders were tested by sensorial analysis. These parameters gave more consistent results than factors such as foam and bubble size which varied significantly within the same sample. For more than 50% of the evaluators only three of the 22 ciders (SD7, SD13 and SD14) were clear, two (SD8 and SD15) were gold and three (SD12, SD17 and SD20) were pale. Thirteen ciders were bright for 100% of the evaluators and six were assessed to be 100% clear by all evaluators. Many ciders were considered to be either hazy or cloudy. This may be due to a lack of filtration, poor stabilisation or aging over lees as was the case for artisanal ciders SD20 and SD21.The correspondence analysis of the aroma data was divided into four independent analyses given the large number of variables (59). This was run for (a) fruity descriptors, (b) alcoholic descriptors, (c) oxidation/herbaceous notes/defects and (d) others (Table 1). On performing the analysis for fruity descriptors, the first two dimensions explained 33.9% of the variance, differentiating 17.4% of the samples (SD1, SD9, SD13 and SD16). The most discriminating variables were apple pulp and dried apple (Fig. 4a). When performing the analysis for alcoholic descriptors, the first two dimensions explained 64.8% of the variance, differentiating 56.5% of the ciders (SD8/9/10/11/12/13/14, SD16/17/18/19, SD21 and SD22). The most discriminating variables were *n*-butanol, cider alcohol and amyl alcohol (Fig. 4b). When performing the analysis for oxidation, herbaceous notes and defects, the first two dimensions explained 37.8% of the total variance, differentiating 60.9% of the ciders (SD2, SD6, SD8, SD9/10/11, SD13, SD15/16/17/18 and SD20/21/22). The most discriminating variables were those related to oxidation, stalk, herbaceous, acetaldehyde, preservative, geranium, antibiotic, burnt rubber and ethyl acetate (Fig. 4c). SD21 and SD22 resembled each other, containing notes of dregs and sulphited broth. Finally, when performing the analysis for other descriptors, the first two dimensions explained 39.1% of the variance, differentiating 13.0% of the ciders (SD9, SD11 and SD13). The most discriminating variables were citrus and metallic notes (Fig. 4d).

The correspondence analysis of the taste data had to be divided - given the large number of variables - into five independent analyses. This was for (a) taste , (b) apple, defective apple and vinegar notes, (c) different fruity, sulphite and syrup notes, (d) oxidation, solvent and alcoholic notes and (e) other notes or descriptors (Table 2). The sweetness and sourness data was included in groups (c)–(e) given the number of zero entries in these groups. When performing the analysis for taste, the first two dimensions explained nearly 50% of the total variance and differentiated 34.8% of the ciders (SD7/8/9, SD11, SD13, SD17, SD20 and SD21). The variables that best discriminated these ciders were fruity, fresh, acrid, astringent, ethanol, bitterness, watery and metallic (Fig. 5a). When performing the analysis for apple, defective apple and vinegar notes, the first two dimensions explained 51.3% of the variance, differentiating 21.7% of the samples (SD8, SD9, SD13, SD20 and SD21). The most discriminating variables were vinegar, apple peel and rotten apple (Fig. 5b). Ciders SD6 and SD17 showed an accentuated Granny Smith apple character, excluding them from the latter group. Indeed, SD17 was a monovarietal sparkling cider made using the Champenoise method. When performing the analysis for different fruity, sulphite and syrup notes, the first two axes explained 36.8% of the variance, differentiating 13.0% of the ciders

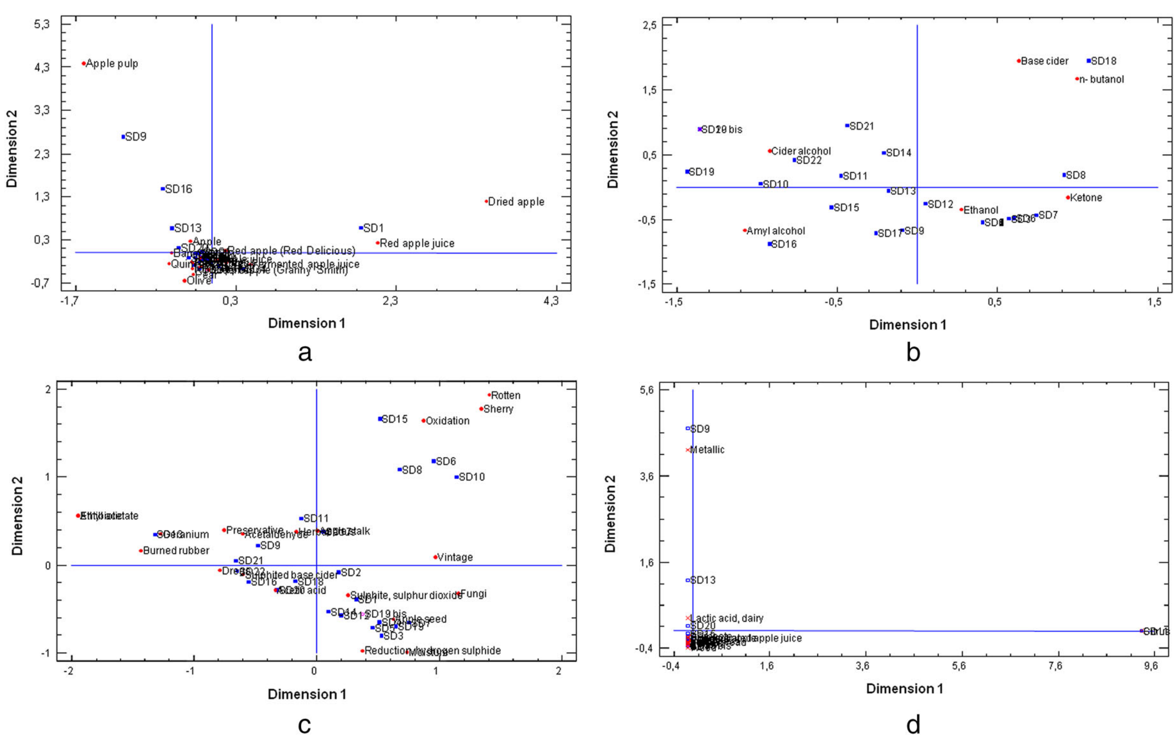

Figure 4. Correspondence analysis for (a) fruity descriptors (F), (b) alcoholic descriptors (A), (c) oxidation, herbaceous and defects descriptors (Ox-H-D) and (d) other descriptors (Os). [Colour figure can be viewed at wileyonlinelibrary.com]

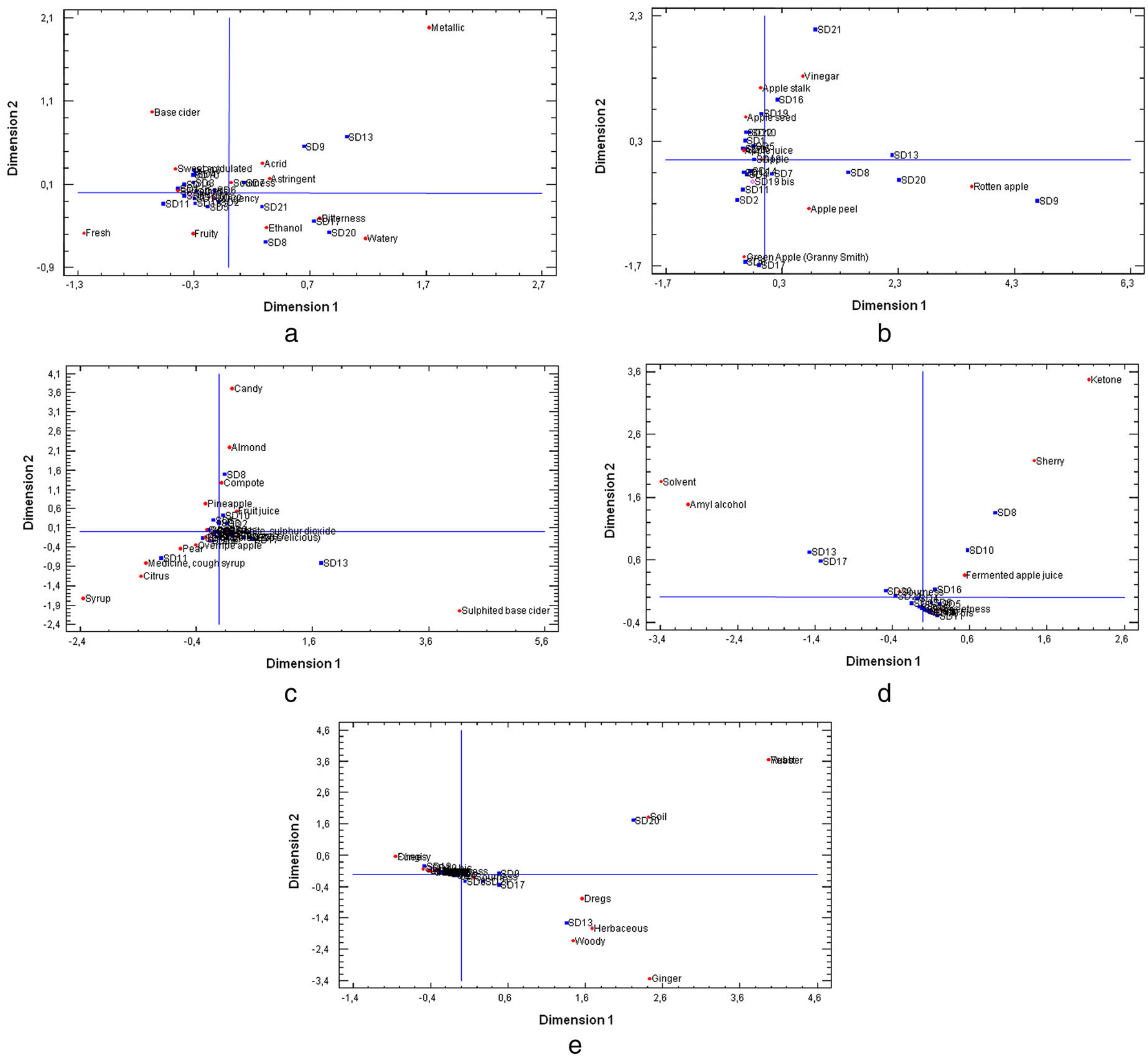

Figure 5. Correspondence analysis for (a) taste (T), (b) apple, defective apple and vinegar notes (Ap-Ac), (c) fruity, sulphite and syrup notes (F-S-Sp), (d) oxidation, solvent and alcoholic notes (Ox-St-A) and (e) for the other descriptors (Os). [Colour figure can be viewed at wileyonlinelibrary.com]

(SD8, SD11 and SD13). The variables that best discriminated these samples were syrup, citrus, cough syrup, compote, almond, candy and sulphited base cider (Fig. 5c). When performing the analysis for oxidation, solvent and alcoholic notes, the first two dimensions explained 57.9% of the variance, differentiating 17.4% of the ciders (SD8, SD10, SD13 and SD17). The variables that best differentiated these ciders were solvent, amyl alcohol, fermented apple juice, sherry and ketone (Fig. 5d). Finally, for the analysis for the other descriptors, the first two dimensions explained 54.0% of the variance, differentiating 8.6% of the samples (SD13, SD20). The most discriminating variables were rubber, yeast, soil, dregs, herbaceous, woody and ginger (Fig. 5e).

These results show that the evaluators were able to differentiate ciders better in the aroma phase than in the taste phase. Indeed, the olfactory descriptors related to alcohol notes, and oxidation/defects/herbaceous notes, differentiated 56.5 and 60.9% of the ciders, respectively. In the olfactory phase, apple and apple juice were the descriptors most commonly recorded, together with sulphite, and to a lesser extent, alcohol, geranium, herbaceous, dregs, fruity, soil, moisture, fungi and yeast (data not shown). Less sulphite might be used in the future in a drive to improve quality; herbaceous notes and those reminiscent of dregs, soil, moisture and fungi may therefore disappear. In terms of taste, sweet was the most frequently recorded, followed by bitter, sour, apple juice and pungency (data not shown). This is explained by the traditional sweetening of the ciders prior to bottling.

Conclusions

The ciders reported here showed an acceptable degree of compliance with the Argentine Food Code. Principal components analysis showed a difference between the industrial and artisanal ciders. Two of the four artisanal ciders were made with just one variety of apple (Granny Smith or Pink Lady) and were sparkling ciders. Other variables such as reducing sugar and alcohol content further distinguished the four artisanal ciders from the other ciders. A good correlation was found between the reducing sugar content and both alcohol and dried extract; a moderate correlation was also found between alcohol and dried extract content. Cluster analysis showed the variables that best differentiated the three groups of ciders to be reducing sugars and alcohol content. The assessors were more able to differentiate the ciders by aroma than taste. Apple and apple juice were the most commonly recorded aroma descriptors, together with sulphite. Less sulphite might be used in the future in order to improve quality. The descriptors apple and apple juice might be better brought out through improved apple selection and changes to the cider making process. Sweet was the most commonly noted taste (although some consumers have begun to prefer more balanced ciders with lower sugar concentrations). A future goal of sensorial analysis is to test Argentine ciders using evaluators trained in the use of quantitative scales for different descriptors. We also hope to record data for the volatile and phenolic compound compositions of these ciders.

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