Research Article

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Intrinsic and extrinsic attributes related to the influence of growing altitude on consumer acceptability and sensory perception of fresh apple

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Abstract

BACKGROUND: Growing altitude might have an effect on the quality of fresh apple and therefore on the perception of sensory attributes and on acceptance by consumers. On the other hand, extrinsic information provided to the consumer might affect consumer acceptability and sensory perception of the fruit's main quality traits. The main objective of this work was to study the effect of the growing altitude on the physico-chemical attributes (soluble solid content (SSC), flesh firmness, fruit weight (g), and titratable acidity (TA)), consumer acceptability, and perception of the main sensory attributes (sweetness, acidity and texture) of two reference apple cultivars ('Golden D.' and 'Reineta') by using a panel of 195 consumers. A secondary objective was to study whether extrinsic information about cultivar and growing place have an effect on the consumer perception and acceptance of fresh apple.

RESULTS: Significant effects on physico-chemical and sensory attributes were found for 'Golden D.' and 'Reineta' apple cultivars due to the growing altitude, and they were perceived by consumers. Moreover, extrinsic information about the cultivar and the growing site influenced consumers' sensory perceptions significantly.

CONCLUSIONS: This work demonstrated that differences between apple fruit grown at different altitudes can be perceived by consumers. We demonstrated the importance of providing consumers with information about the cultivar and the growing place to increase their acceptance and support local produce.

Keywords: fruit quality; apple; hedonic evaluation; consumer acceptance; growing altitude

INTRODUCTION

In recent years, in different areas of the world such as Italy, France, Spain, and India, optimum apple growing conditions have been shifting and farmers have been moving their orchards to higher altitudes. Nowadays, apples are even cultivated at more than 3500 m elevation.[1,2] Previous studies have shown that long-term climate change has had a large impact on the alteration of phenology in apple cultivation,[3] the appearance of new diseases, premature defoliation, and changes in the texture and taste of the fruit.[4] Climate change is hindering apple production in low altitude regions and is creating, at the same time, new opportunities for apple cultivation at higher altitudes. Several studies have demonstrated the effect of altitude on the physiological mechanisms of fruit growth, ripening stage, chemical composition, and sensory quality.[1,5-7]

Consumer studies have been used widely to measure the effect of both intrinsic and extrinsic attributes on the consumer perception and liking for different food products such as milk, dairy products and apple juice.[8-10] These studies combine both sensory and extrinsic food attributes and compares blind and informed test of food products. Thus, they investigate whether and how the extrinsic information influences consumer linking. However, few authors have evaluated the effect of extrinsic attributes on the consumer acceptance of fresh fruit, and in particular, of apple. For apples, a few authors have observed the effect of external

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information about pesticide use, certification, origin, production method, and nutritional aspects.[11-14] These studies have shown that consumers are more inclined to reduce pesticide strategies, locally grown products and organic production, whereas price plays a minor role in their choice. However, most of those studies do not include a real tasting in their design. When investigating real products, and particularly fresh fruit, sensory attributes are key traits to be analyzed. There are only few examples of fresh products where the effect of intrinsic and extrinsic attributes on tasting has been studied.[12-15] As far as we are aware, there are no previous studies where the influence of information about the cultivar and the growing place on the sensory perception of consumers has been studied in apple.

The main goals of this work were: (i) to study the effect of growing altitude on the physico-chemical attributes of apple; (ii) to analyze the influence of intrinsic (sensory quality) and extrinsic information (about the cultivar and the growing site) on consumer acceptability and sensory perception of two reference apple cultivars ('Golden D.' and 'Reineta'), and (iii) to measure the importance of sensory attributes on consumers' overall liking of the two apple cultivars.

MATERIALS AND METHODS

Plant material

The first step of this study involved studying the effect of growing altitude on the fruit quality of 'Golden D.' and 'Reineta' apple cultivars (*Malus domestica* Borkh.). 'Golden D.' and 'Reineta' fruit were managed according to the regional guidelines for integrated fruit production and grown in a valley site (Ebro River valley, Zaragoza, Spain, ca. 300 m above sea level) and in a hilly site (Manubles River, Moros, Zaragoza, Spain, ca. 800 m above sea level) and were sampled during the 2019 harvesting season. The average air temperature in 2019 at the Ebro valley site at the Centro de Investigación y Tecnología Agroalimentaria de Aragón (CITA) was 16.7 °C (at 2 m), with a minimum of −4.9 °C and a maximum of 43.2 °C, 270.5 mm yearly rainfall and 2693 yearly sunshine hours. At the hilly site in Moros, in 2019, the average air temperature at 2 m was 13.8 °C with a minimum of −8.4 °C and a maximum of 41.3 °C, and 447.4 mm yearly rainfall and 2565 yearly sunshine hours were registered. We used climate data (daily temperature, precipitation, and sunshine duration) recorded at the Spanish Meteorological Agency (AEMET) observatories closest to the apple cultivation sites.

Apple cultivar selection

The cultivars selected to be inspected and tasted by the consumers included a reference apple cultivar ('Reineta'), typically grown in the area (Zaragoza, Spain), and a well known widely spread commercial cultivar ('Golden D.'). Moreover, the two apple cultivars selected have a different sensory profile, with different texture and flavor attributes.[16,17]

Fruit quality evaluation

Fruit was harvested at commercial maturity (according to visual evaluation of background color) and stored at 1.5 °C under normal atmosphere and 80% relative humidity (RH) for 4 ('Reineta') or 6 weeks ('Golden D.') until the evaluations. 'Golden D.' was harvested 2 weeks earlier than 'Reineta', so storage time was different for both cultivars tested. For the evaluations, 20 fruit from each cultivar and growing place combination (four combinations), were selected. Fruit weight, fruit firmness, and soluble solid content (SSC) were analyzed individually for each fruit. To measure fruit firmness, the top 1–2 mm of fruit skin and flesh surface were removed on opposite sides of the fruit using a stainless-steel blade. Once removed, puncture measurements were conducted manually using a 11 mm diameter probe to penetrate the apple flesh at a depth of 8 mm with a digital penetrometer (Fruit Firmness Tester, TR Turoni, Italy) mounted on a vertical rod, which could be adjusted for height. The force required to penetrate the fruit was averaged between both sides and expressed in Newtons (N). Then, on the same fruits, the SSC was measured with a digital refractometer. Soluble solid content was measured in each fruit by squeezing 2 mL of apple juice on a hand-held digital refractometer (PAL-1; Atago, Tokyo, Japan). To measure the pH and titratable acidity (TA) a homogenate sample was formed with a longitudinal edge of each fruit (20 edges per combination) and juice was extracted with a juice blender (Kenwood JE 850, Tokio, Japan). Then, juice TA was measured using 25 mL of juice diluted in 75 mL of deionized water (pH = 7.0) with an automatic titrator (785 DMP Titrino, Metrohm, Switzerland) using 0.1 mol/L sodium hydroxide (NaOH) as titrant. Initial pH, volume (mL) of 0.1 mol/L NaOH, and TA were calculated using an endpoint titration pH of 8.1 and an acid milliequivalent factor of 0.067 for malic acid, and expressed as a percentage of malic acid.

Sample preparation for sensory analysis

Samples were stored at room temperature (20 ± 1 °C) for 24 h prior to the consumer test. Before sensory evaluation, each fruit was cut from the stem end to the blossom end in eight slices with a stainless apple slicer-corer. Slices were then dipped in an antioxidant solution (0.2% citric acid, 0.2% ascorbic acid, 0.5% calcium chloride), and one slice per sample was served in a biodegradable palm-leaf dish labeled with three-digit random codes. Samples were prepared out of sight of the testing area. Sensory evaluations were performed within 30 min of sample preparation.

Participants

A total of 195 people older than 18 years (60% women and 40% men, with an average age of 50.6 years), and usually responsible for the grocery shopping in their homes, participated in this study (Table 1). The participants were recruited by the research team with the help of consumer associations and public institutions in different locations (universities, town hall learning centers, community activity centers, etc.), by personal on-site contacts, posters, and e-mail posting lists. Only people who purchase and consume fresh apples at home were invited to participate in the experiment. The experiment was organized in 20 working sessions of around ten participants and lasted approximately 1 h.

Consumer study

The experiment protocol for the consumer study was approved by the Ethical Committee of CITA. All participants voluntarily joined the sensory evaluations and before the experiment, they received information on the nature of the experiment and signed a form giving their informed consent for participation. To maintain anonymity, each participant was assigned an identification number upon arrival. They were not paid for their participation but received a gift voucher for a lunch or dinner in a city restaurant.

The consumer study was performed at different places in Zaragoza (a middle-sized town in the northeast of Spain, close to the two growing sites) from October to November 2019, when the apples were in season. The sessions were carried out either in the morning, mid-day, afternoon or evening. The evening times were chosen to allow working people to be able to take part in the study.

Table 1. Demographic characteristics of the fresh apple consumers

Characteristics	Sample (n = 195)	Population[a]
Gender		
Female	60.0	51.71[b]
Male	40.0	48.31[b]
Age (average, standard deviation)	50.6 ± 17.0	44.52[c]
18–34	21.0	20.61[b]
35–44	13.9	18.41[b]
45–54	23.1	18.71[b]
55–64	20.0	17.21[b]
≥65	22.0	25.11[b]
Studies level		
Primary	26.7	34.33[d]
Secondary	26.1	26.53[d]
Higher	47.2	39.53[d]
Income range		
≤1500 € month^{-1}	30.3	n.a.
1501–2500 € month^{-1}	18.5	n.a.
2501–3500 € month^{-1}	16.9	n.a.
>3500 € month^{-1}	8.7	n.a.
Do not know/refuse to answer	25.6	n.a.
Family size (average, standard deviation)	2.8 ± 1.1	n.a.
Children less than 18 years old		
0	69.0	n.a.
1	18.3	n.a.
2	11.3	n.a.
3	1.6	n.a.
Vegetarian	5.7	n.a.
Living in the region more than 20 years (%)	86.0	n.a.
Frequency of shopping for food		
Always	46.2	n.a.
Often	33.3	n.a.
Number of fresh fruits eaten daily (average, standard deviation)	2.6 ± 1.2	n.a.

Note: the percentage of respondents is shown, unless otherwise stated.
[a] Province where the town is located.
[b] INE (2019).[27]
[c] IAEST (2020).[28]
[d] EUROSTAT (2019).[29]

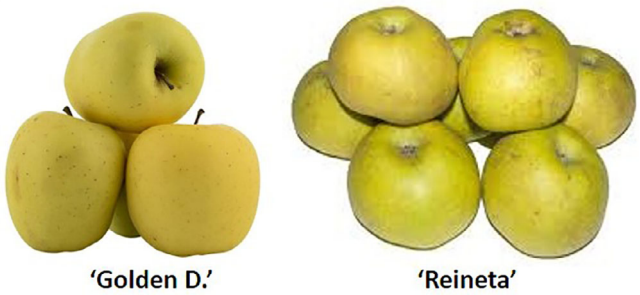

Figure 1. 'Golden D.' and 'Reineta' apple cultivars grown in the valley and hilly areas provided to the consumers in the consumer study.

The working session consisted of two parts: first a 'blind' test (without any external information) and then the 'info' tasting, where some information about the growing region and the cultivars was provided. The same monitor explained the general instruction of the sessions and guided participants to complete the different tests. The same two monitors conducted all the working sessions. The 'blind' test consisted of a sensory and hedonic evaluation of the four apple samples without any external information. Each participant received two apple slices from the same cultivar ('Golden D.'), one for each growing site (hilly and valley), and in a second round, the other two slices from the second cultivar ('Reineta'), presented in a different order using a balanced design (Fig. 1).

The descriptors were developed by the authors using consensus and taking into account their experience and the previous literature on the sensory analysis of apple. The resulting descriptors were: overall appearance, firmness, juiciness, mealiness, sweetness, and overall liking (Table 2). At the beginning of each session, the monitor explained the descriptors to the volunteers and answered any doubts about the traits and the test they may have had. The monitor also explained the difference among the sensory traits (objective) and the hedonic trait (subjective) that they had to rate. The consumers rated first the five sensory attributes (overall appearance, firmness, juiciness, mealiness and sweetness) and finally their degree of overall liking on a nine-point hedonic scale (1 = dislike extremely; 9 = like extremely).

After the 'blind' test, the 'info' test was performed. The consumers were provided with some information about the cultivars (they were identified by their names) and the growing sites ('hilly' for Manubles River and 'valley' for Ebro River) (Fig. 2). They were asked to read it carefully before proceeding with the test. Immediately after reading, consumers were asked to proceed with the evaluation. As in the 'blind' test, consumers rated first the five sensory attributes (overall appearance, firmness, juiciness, mealiness and sweetness) and finally their degree of overall liking on a nine-point hedonic scale (1 = dislike extremely; 9 = like extremely). In the first round of this informed test, each participant received two apple slices of 'Golden D.', one from each growing site (hilly and valley). In the second round, each participant received two apple slices of 'Reineta', one from each growing site (hilly and valley). In this 'info' test, the samples were named with the name of the cultivar and the growing site. No verbal instructions or information were provided during the 'info' test. Apple samples were prepared following the same procedure as in the 'blind' test. Finally, they should completed a brief questionnaire gathering information on economic

Table 2. Definitions of apple sensory traits used by consumers

Category	Attribute	Definition
Appearance	Overall appearance	Degree of liking for the fruits' shape, color, skin marks, and uniformity
Texture	Firmness	Initial force required when biting the sample with the front teeth
Texture	Juiciness	Amount of juice released during chewing
Texture	Mealiness	Degree of flesh breakdown into small dry particles during chewing
Flavor	Sweetness	Sweet taste sensation

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The Manubles River is located in the Celtibérica Serranía and comprises the municipalities of the province of Zaragoza, bordering Soria: Moros, Villalengua, Torrijo de la Cañada, Bijuesca, Berdejo and Torrelapaja. Water quality and height between 900 and 1,300 meters above sea level made this valley an important producer of high quality fruit.

The production of apple trees in low altitude areas implies climatic conditions characterized by high temperatures and low ambient humidity in the summer period, to which the apple tree has a poor adaptation, which results in problems of fruit quality, especially coloration and texture. Growing in higher altitude areas, with a higher oscillation of day/night temperatures, and lower maximum temperatures, favors the production of apples with higher quality.

Figure 2. Information provided to the consumers in the 'informed test'.

and socio-demographic characteristics (Table 1) as well as fruit and apple purchasing and consumption habits.

Statistical analysis

First, a one-way ANOVA was performed to evaluate the effect of the growing place (hilly or valley) on physico-chemical parameters (SSC, firmness, fruit weight, and TA), using International Business Machines Corporation (IBM) SPSS Statistics 21.0 software. *P* values equal to or lower than 0.05 were considered significant. Second, for the consumer data, initially, a two-way ANOVA test was performed to analyze the effect of the growing place and the supply of information about the cultivars on the sensory attributes and the overall liking for the two cultivars. The two-way ANOVA compares the average differences between groups that have been split on two independent factors (growing place and information about the cultivars tasted) with the primary purpose of understanding if there is an interaction between the growing place and the information on the sensory attributes. In the event that we found a statistically significant interaction between the two factors on the sensory attributes, the simple main effects were calculated to find out what these effects were. *P* values equal to or lower than 0.05 were considered significant. In the case that the interactions were not statistically significant, the main effects were interpreted. In a second step, the relation between overall liking and each of the sensory attributes evaluated (appearance, firmness, juiciness, mealiness, and sweetness) was studied using a Pearson correlation analysis to measure the influence of the different sensory attributes on the overall liking and their direction (positive or negative) and if this influence varies with the cultivar and the type of test (blind or informed test). These correlation coefficients were calculated for the two apple cultivars ('Golden D.' and 'Reineta') in the two growing sites (hilly and valley) and for the different information conditions ('blind' and 'info'). The consumer data analyses were performed using STATA 16.0 software.

RESULTS

Influence of growing altitude in the physico-chemical quality of fruit

There were significant differences when comparing fruit from valley and hilly areas for both 'Golden D.' and 'Reineta' cultivars (Table 3). Regarding fruit physico-chemical attributes, 'Golden D.' from the hilly site showed lower firmness and SSC than 'Golden D.' grown in the valley, although no significant differences were observed for fruit weight and TA. On the other hand, 'Reineta' fruit grown at the hilly site showed higher fruit weight and SSC than fruit from the valley, whereas no significant differences were observed for flesh firmness and TA.

Effect of growing altitude and extrinsic information on consumer perception

A two-way ANOVA was conducted on 195 individuals to examine the effect of the growing place and the information on the evaluation of sensory attributes (appearance, firmness, juiciness, mealiness and sweetness) and overall liking by consumers for the two cultivars (Table 4). For the Golden cultivar, there was no significant interaction between the effects of growing place and information on appearance and mealiness ($P = 0.7855$ and $P = 0.7847$, respectively). In both cases, no significant effect was observed when information was provided ($P = 0.1197$ and $P = 0.5866$, respectively) indicating that there was no significant difference in the consumers' evaluation between the 'blind' and 'info' conditions. On the other hand, there was a significant effect of growing place for both appearance and mealiness attributes ($P = 0.000$) indicating that fruit from the hilly site obtained a higher visual appearance score (6.78) and lower mealiness score (3.68) than fruit grown in the valley (5.82 and 4.55, respectively) (Table 5).

However, significant interaction effects between growing place and information on firmness, juiciness, sweetness, and overall

Table 3. Fruit initial physico-chemical traits at harvest from 'Golden D.' and 'Reineta' cultivars grown in valley and hilly environments. Average (ave) values and standard deviation (SD) are shown

	Firmness (N) ave ± SD	SSC (°Brix) ave ± SD	Fruit weight (g) ave ± SD	TA (g malic ac/100 g) ave ± SD
'Golden D.' (valley)	25.0 ± 2.1a	17.2 ± 0.8a	213.9 ± 22.3a	0.37 ± 0.02a
'Golden D.' (hilly)	22.3 ± 2.0b	15.2 ± 1.2b	241.7 ± 18.5a	0.44 ± 0.02a
'Reineta' (valley)	25.4 ± 7.9a	15.4 ± 1.8b	141.3 ± 11.2b	0.83 ± 0.04a
'Reineta' (hilly)	23.8 ± 7.6a	17.6 ± 2.9a	252.2 ± 21.9a	1.09 ± 0.05a

For each cultivar, different letters indicate significant differences for each attribute by one-way ANOVA at $P \leq 0.05$.
N, Newtons; SSC, Soluble Solids Content; TA, titratable acidity.

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Table 4. Two-way ANOVA results: F-value and significance (*P*-value) of the independent variables growing place, information and interaction effects on the sensory attributes for the two cultivars

	Growing place		Information		Growing place*information	
	F	*P*	*F*	*P*	*F*	*P*
'Golden D.'						
Appearance	60.21	0.0000*	2.43	0.1197	0.07	0.7855
Firmness	35.84	0.0000*	2.63	0.1053	14.14	0.0002*
Juiciness	53.35	0.0000*	1.51	0.2198	12.0	0.0006*
Mealiness	33.63	0.0000*	0.30	0.5866	0.07	0.7847
Sweetness	0.83	0.3615	0.06	0.8033	9.22	0.0025*
Overall liking	17.84	0.0000*	1.85	0.1737	6.80	0.0093*
'Reineta'						
Appearance	10.53	0.0012*	2.67	0.1026	2.95	0.0864
Firmness	103.84	0.0000*	2.52	0.1131	0.01	0.9361
Juiciness	0.03	0.8688	0.45	0.5031	2.65	0.1039
Mealiness	126.53	0.0000*	0.88	0.3492	0.02	0.8894
Sweetness	38.42	0.0000*	0.59	0.4438	0.00	0.9517
Overall liking	8.96	0.0028*	0.00	0.9777	0.00	0.9458

*The effect was significant for *P*-value less than 0.05.

liking were found (Table 4). It was observed that consumers reported greater firmness on the hilly fruit than on the valley fruit in the 'info' condition and the average evaluation of fruit from the hilly site significantly increased after providing the information about the growing places (Table 5). Similarly, consumers reported a higher juiciness in the fruit from the hilly places in both information

Table 5. Average values and *P* values for the simple effects test values on consumer evaluation of apple sensory attributes on the 'blind' and 'info'(extrinsic information) conditions and *P* values of the simple main effect tests when interaction between factors were found (see Table 4)

	'Golden D.'			'Reineta'		
Evaluation	Hilly	Valley	*P*	Hilly	Valley	*P*
Appearance						
Blind	6.78 ± 0.10	5.82 ± 0.12	—	5.72 ± 0.13	5.53 ± 0.13	—
Info	6.90 ± 0.12	6.03 ± 0.11	—	6.14 ± 0.12	5.51 ± 0.12	—
P	—	—		—	—	
Firmness						
Blind	6.61 ± 0.13	6.33 ± 0.15	0.1352	4.38 ± 0.17	6.13 ± 0.17	—
Info	7.34 ± 0.12	6.06 ± 0.13	0.0000*	4.67 ± 0.18	6.36 ± 0.16	—
P	0.0000*	0.1509		—	—	
Juiciness						
Blind	7.13 ± 0.12	6.65 ± 0.14	0.0106*	5.37 ± 0.16	5.63 ± 0.15	—
Info	7.43 ± 0.11	6.08 ± 0.13	0.0000*	5.71 ± 0.16	5.48 ± 0.15	—
P	0.086	0.0022*		—	—	
Mealiness						
Blind	3.68 ± 0.16	4.55 ± 0.17	—	6.71 ± 0.16	4.85 ± 0.17	—
Info	3.70 ± 0.16	4.73 ± 0.16	—	6.61 ± 0.16	4.69 ± 0.17	—
P	—	—		—	—	
Sweetness						
Blind	6.08 ± 0.15	6.61 ± 0.14	0.0066*	4.90 ± 0.19	3.84 ± 0.17	—
Info	6.47 ± 0.14	6.18 ± 0.14	0.1250	4.77 ± 0.18	3.69 ± 0.16	—
P	0.0519*	0.0193*		—	—	
Overall liking						
Blind	6.85 ± 0.11	6.66 ± 0.11	0.2522	5.61 ± 0.15	5.21 ± 0.13	—
Info	6.98 ± 0.11	6.22 ± 0.11	0.0000*	5.63 ± 0.15	5.20 ± 0.13	—
P	0.3716	0.0059*		—	—	

Note: ns denote that no significant interaction effects between growing place and information on sensory attributes were found at 5% significance levels (see Table 4). On the other hand, when significant interaction effects were detected, *P* values for the single main effects of the factor tests are displayed.
*The effect was significant for $P < 0.05$.

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conditions, and information significantly reduced the juiciness perception of the valley fruit. 'Golden D.' fruit from the valley was perceived as significantly sweeter than the 'Golden D.' from the hilly site, whereas the perception of consumers radically changed in the 'info' condition. The global acceptance result was significantly higher for 'Golden D.' fruit grown in the hilly site in the information scenario, and the acceptance of the fruit from the valley decreased significantly with the information provided to the consumers.

For the 'Reineta' cultivar, there were no significant interactions between the effects of growing place and information on any of the sensory attributes ($P > 0.05$). In all cases, there was no significant effect of information ($P > 0.05$) indicating that there was no significant difference in the consumers evaluations between the 'blind' and 'info' tests. On the other hand, there was a significant effect of growing place for all the attributes except for juiciness ($P = 0.869$) indicating that fruit from the hilly site obtained a similar score for juiciness and differences in average scores were found for the rest of attributes. In particular, consumers scored visual appearance higher for the fruit grown in the hilly site while firmness was perceived higher for fruit from the valley in the 'blind' and the 'info' tests. Mealiness, sweetness, and global acceptance were significantly higher in the fruit from the hilly site in both 'blind' and the 'info' tests, and no differences were induced by the information provided to the consumers.

Importance of sensory attributes in consumers overall liking

The correlation between the overall liking and the sensory attributes (Table 6) indicates that all the sensory attributes positively influenced overall liking except for mealiness, which only had a negative significant impact for the 'Golden D.' cultivar in the info condition. The firmness of the fruit had the least influence on the overall liking for the two cultivars in both information conditions and growing places. On the other hand, the influence of the appearance, juiciness and sweetness differs between apple cultivars, growing place and information condition. In the case of the commercial cultivar ('Golden D.'), the influences of these three attributes on the overall liking differed strongly between the blind and the info conditions and between the hilly and valley growing places. In the blind test, the most influential sensory attribute for the hilly fruit was the appearance, the sweetness and the juiciness, while different results were observed for the valley fruit. However, after information, sweetness was the sensory attribute with the greatest effect on the overall liking for 'Golden D.' grown in both sites although the influence of the three sensory attributes was quite similar. For the local cultivar, 'Reineta', the most influential sensory attributes on the overall liking were the juiciness and sweetness for the apple grown in the hilly while the sweetness and appearance were most influential for 'Reineta' from the valley. However, after information, appearance and juiciness were the most influential attributes on the overall liking for 'Reineta' apples grown both in the hilly area and in the valley, closely followed by sweetness.

Table 6. Pearson correlation coefficients between the overall liking and each of the apple sensory attributes before ('blind') and after ('info') providing information about the growing place of the cultivars (extrinsic information)

	'Golden D.'	'Reineta'		
Evaluation	Hilly	Valley	Hilly	Valley
Appearance				
Blind	0.4872*	0.2704*	0.3073*	0.3397*
Info	0.3550*	0.3778*	0.5976*	0.4112*
Firmness				
Blind	−0.0264	0.1315*	0.3134*	0.1817*
Info	0.1495*	0.2002*	0.2779*	0.1987*
Juiciness				
Blind	0.1748*	0.4465*	0.4444*	0.3295*
Info	0.3653*	0.3141*	0.5271*	0.4565*
Mealiness				
Blind	−0.0957	−0.0743	−0.1402	−0.0695
Info	−0.2075*	−0.2224*	−0.1355	0.0053
Sweetness				
Blind	0.3934*	0.3356*	0.4152*	0.4418*
Info	0.3867*	0.3857*	0.4828*	0.3893*

* denotes statistical significance at the 5% significance level.

DISCUSSION

Previous studies on different apple cultivars have demonstrated the effect of altitude on the fruit physico-chemical attributes.[1,5] However, the effect of altitude on these parameters was different depending on the cultivars tested. Iglesias *et al.*[1] and Donati *et al.*[18] reported greater firmness for different commercial cultivars when grown at higher altitudes, whereas Charles *et al.*[5] found the opposite effect on 'Golden D.'. The effect of altitude on SSC and TA also varied depending on the apple cultivar studied. In agreement with our results for 'Golden D.', Charles *et al.*[5] also reported higher SSC at higher altitude, and no significant effect on TA. These works also reported different effects of altitude on different cultivars depending on their harvest time, which may also explain the different effects of altitude in 'Golden D.' and 'Reineta' cultivars found in this work, as 'Reineta' reaches its commercial maturity around 2 weeks later than 'Golden D.' A possible explanation of different results observed in different studies is the high intrinsic variability, which is generally present in fruit and vegetable products, and it is a difficult variable to control.[12,19]

Consumer acceptance is influenced by several intrinsic factors, and texture (crunchiness, firmness and juiciness) and sweetness play a critical role.[19-23] In accordance with previous results, we have found that appearance, juiciness, and sweetness are the intrinsic attributes with higher influence on overall acceptance. However, we have demonstrated that the significance of each attribute on overall acceptance changes when extrinsic information regarding the growing place is provided to the consumers.

As observed in this work, sensory attributes have also been reported to be influenced by growing altitude in previous studies.[1,5] In contrast with our results on 'Golden D.', Charles *et al.*[5] reported a higher perception of juiciness and crunchiness and a lower mealiness at a lower altitude, and no significant effects on other sensory attributes such as firmness, sweetness, and sourness. On the other hand, Iglesias *et al.*[1] reported significant effects of altitude on most sensory attributes, whereas the effect depended on the cultivar studied. In several cultivars such as 'Golden Reinders®', 'Golden Smoothee®', 'Evelina®' and 'Brookfield® Gala', these authors reported higher firmness, crunchiness, and sourness at a higher altitude, whereas greater sweetness and mealiness was usually found at lower altitude, which is in agreement with our findings for 'Golden D.' However, these authors reported no significant improvement in the sensory attributes when growing late cultivars (harvested at the end of the apple

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season) such as 'Kiku® Fulbrax'[1] and 'Braeburn' at high altitude,[18] which is similar to our result with the late cultivar 'Reineta'.

The effect of altitude on the quality and sensory attributes of apple fruit seen in this and other works might be due to differences in temperature between growing places at different altitudes. Warrington *et al.*[24] demonstrated that different ranges of temperatures during fruit growth caused differences in fruit volume, weight, and quality traits in several apple varieties. These authors also reported higher SSC and a decrease in flesh firmness with higher temperatures. The different texture parameters reported by Charles *et al.*[5] at different altitudes in 'Golden D.' fruit were attributed to the lower cell numbers and percentage of intercellular spaces observed in fruit from higher altitudes. Temperature has been reported to be the climatic factor with a greater effect in the metabolic pathways of main fruit compounds such as sugars or organic acids, directly related with the fruit color, flesh texture and physico-chemical and sensory fruit attributes.[21] Lower temperatures at night during hot periods result in lower respiration rates, which means an increase in the carbohydrate pool available for those metabolic pathways.[22,23]

Several works have studied the effect of different extrinsic information on consumers' acceptance and perception of different food products combining blind and informed hedonic testing.[8-10] 10 All of them found positive and statistically significant effects of information on overall liking. Jiang *et al.*[10] also studied the consumer perception of different sensory attributes finding no statistically significant impact of information on some of them (appearance, aroma, sweetness and flavor) and a positive impact on overall taste and mouthfeel. In other words, the overall liking, overall taste, and mouthfeel scores were higher in the informed than in the blind condition. Similarly, in our case for apples, we found no statistically significant differences in sensory and overall liking between blind and informed conditions for some samples but a significant impact for others. In some cases, according to Jiang *et al.*,[10] the informed liking scores were statistically higher than the blind scores (firmness and sweetness for the hilly 'Golden D.'). On the other hand, the blind scores were higher than the informed scores for juiciness, sweetness, and overall liking for the 'Golden D.' grown in the valley. Consequently, previous findings and ours indicated that the effect of information on hedonic liking depends on products and sensory attributes.

Studies on apples where sensory analysis is performed and the extrinsic information effect was evaluated are scarce,[12,25,26] and, among them, different results are found depending on the type of information and the sensibility of consumers to the information given (mainly dependent on age and education). Other work, based on household surveys, has demonstrated stronger consumer preference and willingness to pay for locally grown apples as compared with apples from other regions.[11,14] However, there are no previous studies about the effect of information about cultivar (traditional versus commercial) and growing site on the sensory perception of apple consumers. Our work has demonstrated that consumer sensory perception was positively influenced when the cultivar was traditionally grown in the region and when it was grown in a recognized local production area, which provides an opportunity for producers and industry to capture and build their markets by offering the right information to consumers.

CONCLUSIONS

This study showed that the effect of growing at high altitude on the apple quality parameters depends on the cultivar, and that information about the cultivar and the growing site might influence consumer acceptance positively. By providing a better understanding about the influence of altitude on the physicochemical and sensory quality of apple, and the influence of extrinsic information about type of and growing site on the consumer perception, this work could help apple producers and industry to valorize their products in a more effective way. As this work was carried out with a consumer test, further studies using a trained sensory panel would be valuable to understand better the effect of extrinsic information on the sensory perception of apples.

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AUTHOR CONTRIBUTIONS

C.M.C. and A.G. were responsible for conceptualization. C.M.C. and A.G. were responsible for methodology. C.M.C. and A.G. participated in investigation. C.M.C. and A.G. were involved in data curation. C.M.C. and A.G. were involved in writing and original draft preparation. C.M.C. was responsible for writing, reviewing, and editing. A.G. was involved in funding acquisition.

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