Received: 30 June 2023 | Revised: 4 December 2023 | Accepted: 15 December 2023

DOI: 10.1111/1750-3841.16913

Journal of Food Science WILEY

ORIGINAL ARTICLE

Sensory and Consumer Sciences

Sensory profiling of pears from the Pacific Northwest: Consumers' perspective and descriptive analysis

Maria Laura Montero[1,2] | **Ann E. Colonna**[3] | **R. Karina Gallardo**[4] | **Carolyn F. Ross**[1]

[1]School of Food Science, Washington State University, Pullman, Washington, USA

[2]National Center for Food Science and Technology (CITA), University of Costa Rica, San José, Costa Rica

[3]Food Innovation Center, Oregon State University, Portland, Oregon, USA

[4]School of Economic Sciences, Puyallup Research and Extension Center, Washington State University, Puyallup, Washington, USA

Correspondence
Carolyn F. Ross, School of Food Science, Washington State University, Pullman, WA 99164, USA.
Email: cfross@wsu.edu

Funding information
USDA National Institute of Food and Agriculture; Washington Tree Fruit Research Commission-Fresh and Processed Pear Research Committee

Abstract: This study used data from consumer testing, descriptive analysis (DA), and preference mapping to determine the sensory characteristics of pear cultivars from two harvest seasons in the Pacific Northwest (PNW). A trained sensory panel ($n = 10$) used generic DA to evaluate multiple sensory modalities of 22 pear cultivars. Six pears from summer and six from winter season were evaluated by consumers ($n = 219$) to assess their liking of different attributes. Results of the DA showed the trained panel significantly discriminated the summer and winter pears on most of the sensory modalities. To identify the attributes driving consumer acceptability, external preference mapping was applied. Attributes such as *pear aroma*, *pear flavor*, *sweet*, *sour*, and *juicy* were the most contributory attributes to the liking of the summer pears. Conversely, *fermented aroma*, *stemmy–woody aroma*, *fermented flavor*, *stemmy–woody flavor*, and *grainy–gritty* attributes were associated with a reduction in consumer liking. Summer cultivars, "Bartlett," coded pear 573, and "Seckel" had the broadest preference, satisfying 60% to 80% of the consumers. Seventy-five percent of the consumers identified winter cultivars "Comice" and "Paragon" as the most appealing. Overall, cluster analysis showed that different pears appeal to different types of consumers; however, summer cultivars like "Bartlett" and "Seckel" and winter cultivars like "Comice" and "Paragon" would appeal to the greatest number of consumers in the PNW market.

KEYWORDS
acceptance, consumer, mapping, preference

Practical Application: Sensory attributes like *pear flavor*, *sweet*, and *juicy*, were important drivers of liking for pear consumers in the Pacific Northwest. These results should prove useful to pear growers and marketers to increase pear consumption in the United States.

1 | INTRODUCTION

Globally, pears (*Pyrus* spp.) are an important fruit tree crop (Lozano et al., 2023). In the United States, the Pacific Northwest (PNW) produces 78% of the annual US crops (Northwest Horticultural Council, 2021). Washington State and Oregon are in the top three pear-producing states, with most sold as fresh produce (Northwest Horticultural Council, 2021). Consumers' increasing expectations of fresh pears highlight the need for higher quality pears (Escribano et al., 2016).

Fruit quality is significantly influenced by sensory characteristics (Kappel et al., 1995). A study of "Conference" pears showed that high flavor/low firmness pears were most appreciated by consumers (Torregrosa et al., 2019). Consumers from China and Korea generally liked sweet, juicy, and crispy pears (Kim et al., 2019). Consumers in Australia were willing to pay a premium price for a new cultivar "ANP-0131" with an attractive color and shape (Turpin et al., 2016).

Size, color, and scarring play a role in initial pear purchases, but consumers are more likely to re-purchase based on flavor, aroma, taste, and texture (Gallardo et al., 2011). Consumers want sensory information on sweetness and flavor intensity on fresh fruit labels (Fernandez-Serrano et al., 2020). Research conducted with "Williams," and two Nashi cultivars found that a typical pear aroma and sweetness positively influenced consumers' liking (Taiti et al., 2017). A South African study showed that important sensory attributes included pear flavor, sweet taste, melting character, juiciness, and soft texture (Steyn et al., 2011).

Studies on pear cultivars from the PNW have identified sweetness, juiciness, and flavor as most important to consumers (Colonna et al., 2023; Gallardo et al., 2023; Turner et al., 2005). Consumer sensory evaluation of pears in Oregon and Northern California ($n = 2700$) showed that overall liking was driven by sweetness and flavor (Elkins et al., 2006). Researchers have also found that sweetness and texture are important sensory properties that influence the liking of cultivars, while gritty texture and lack of flavor are key attributes driving disliking of pears (Elkins et al., 2008). Gallardo et al. (2011) determined that the presence of preferred sensory characteristics increases the likelihood of re-purchase; consumers were willing to pay an extra 19–25 cents/kg for higher quality pears. In a willingness-to-pay study in the PNW, researchers found that higher liking ratings for size, sweetness, juiciness, firmness, and tartness led to higher bids for sliced fresh pears (Ikiz et al., 2018). These studies demonstrate that the sensory characteristics of pear cultivars and their influence on overall quality and consumer liking is an important component to commercial success.

Consumer preferences change rapidly as new pears enter the marketplace. Information regarding preferences and preferred sensory properties of pears can be used to select existing cultivars for more aggressive marketing, as well as provide priority traits for breeding targets in breeding programs (Colonna et al., 2023).

The current study employed consumer testing, descriptive analysis, and preference mapping to identify the desirable sensory characteristics of pear cultivars from the PNW to understand drivers of consumer interest and identify clusters of consumers based on preferences.

Pears from two different harvest seasons (summer and winter of 2021) were evaluated, respectively.

2 | MATERIALS AND METHODS

2.1 | Pears

Pears were provided by commercial producers and packers (US); Oregon State University (OSU) Mid-Columbia Agricultural Research and Extension Center; OSU Southern Oregon Research and Extension Center; Zupan's market (Portland, OR); the United States Department of Agriculture (USDA) Agricultural Research Service (ARS) National Clonal Germplasm Repository (Corvallis, OR); and the USDA ARS Appalachian Fruit Research Station. Most samples were harvested and transferred to a packing house in Wenatchee, WA for storage and conditioning. One day prior to the consumer testing, the pears were transported to the OSU Food Innovation Center (FIC) (Portland, OR), where they were stored at 20°C overnight. Prior to each consumer session, each pear served to consumers was pre-selected by pressure testing at the stem end (see: USA Pears "check the neck for ripeness®" at USA Pears, 2023b).

Twenty-two pear cultivars (10 summer/12 winter) underwent descriptive analysis and physicochemical measurements at two time points, October and December 2021, depending on the seasonality of each cultivar. Results of the descriptive analysis identified six pears per trial for consumer sensory evaluation at the OSU FIC. Each set of six pears represented a range of sensory attributes on offer within the United States (see Table 1); some cultivars with restricted proprietary ownership are coded. The "Gem" cultivar was served in a less ripened state given the qualities of being more *crunchy/firm* and less *soft/buttery* (Table S2). This cultivar is often described as having a *crisp*, *juicy texture*. The ARS's Appalachian Fruit Research Station (Kearneysville, WV) notes this pear can be served immediately after harvest without softening (Durham, 2015).

TABLE 1 Pear cultivars/code, source, month tested and inclusion in the consumer evaluations.

Pear cultivar name or code	Season	Testing date in 2021	Consumer trials
Bartlett	Summer	October	S
720	Summer	October	S
573	Summer	October	S
804	Summer	October	
391	Summer	October	
417	Summer	October	S
642	Summer	October	S
Seckel	Summer	October	S
Starkrimson	Summer	October	
Sylvania	Summer	October	
Abate Fetel	Winter	December	
Bosc	Winter	December	W
Comice	Winter	December	W
Concorde	Winter	December	W
Forelle	Winter	December	
Gem	Winter	December	W
D'Anjou	Winter	December	W
Packham's Triumph	Winter	December	
Paragon	Winter	December	W
Red Anjou	Winter	December	
OHUS-US783012-022	Winter	December	
US79453-007	Winter	December	

Abbreviations: S, cultivars from the summer season evaluated in consumer trials; W, cultivars from the winter season evaluated in consumer trials.

2.2 | Descriptive analysis

Ten panelists (80% female; 24–60 years old) with experience in descriptive analysis trained for 15 h (10 sessions × 1.5 h) over 22 days. The study was reviewed and approved by the Washington State University (WSU) Institutional Review Board (IRB) # *19063-001*. Informed consent was obtained from each subject prior to their participation in the study.

The panelists trained on: "Triumph de Vienne," "Dessertnaia," "Richard Peters," "Premices de Maria Lesueur," "Doyenne blanc," "Madame favre," "Mela di laconi," "General le clere," "Vavilov," "Bartlett," "Starkrimson," "D'Anjou," Asian species, and "Bosc."

During the first sessions, panelists were familiarized with the sensory characteristics, terms, and reference standards previously used for the sensory profiling of pears (Jaeger et al., 2003) until agreement was reached regarding the meaning, relevance, and the intensity of each attribute. The final list comprised 18 attributes (Table 2). The commercial products to establish the standards were purchased in a local supermarket in Pullman, WA (Table 2). Seasonal "Bartlett" pear served as a reference during both seasons. The intensities assigned for each attribute for "Bartlett" are shown in Table 2.

Intensity of each attribute was measured with a 15 cm unstructured continuous line scale with 1.5 cm anchors. The positions of reference standards, including "Bartlett" pear, were marked on each attribute line scale.

Six appearance attributes were evaluated on two sets of three whole pears: shape, russet coverage, blush coverage, skin appearance, skin color, and flesh appearance. The Chasset shape classification (Figure S1) was used (Bellini et al., 2007; Chasset, 1920; Martinelli et al., 2008).

Rate-all-that-apply (RATA) was used to evaluate color. Paint chip colors (Rodda Paint Company) were used to represent color intensities: red (1100, 1101, and 1103); yellow (0819, 0820, and 0821); green (0792, 0793, and 0781); and brown (0897, 0898, and 0900).

During training, the performance of each panelist was monitored. Replicates of some pear cultivars were evaluated to determine the panelists' performance. Sample slices were cut from different locations of the pear and then presented in 8 oz styrofoam containers (DART, 8SJ20) with plastic lids to ensure that for the replicated evaluations, each panelist received a slice from the same pear. Panelists' repeatability, consistency, and discrimination were determined with Sen PAQ v6 program (Qi Statistics, West Malling, UK).

Final evaluations followed training. Each pear cultivar from summer and winter seasons was tested in duplicate by each panelist in booths under white light and positive pressure control. Water and unsalted crackers served as palate cleansers. Questionnaires were designed and data were collected with Compusense® software (Compusense, Inc., Guelph, ON, Canada).

2.3 | Consumer sensory evaluation

Two sensory tests were conducted with consumers recruited from the Portland, Oregon Metro Area through the OSU FIC database. Consumers (≥18 years) were prescreened and recruited based on self-reported frequency of pear consumption. Most selected reported eating fresh pears at least once weekly (78%).

Consumers (n = 107) evaluated six summer cultivars in October 2021; a different set of consumers (n = 112) tested six winter cultivars in December 2021; 62% were female, 85% were white, 34% had a self-reported annual household income between $50,000 to $99,999 with 36% below $50,000 and 30% above $100,000 per year, 47% had a household size of two, while 30% lived alone, 82% did

TABLE 2 List of attributes, definitions, and references for the trained panel ($n = 10$) sensory profiling of pears from the Pacific Northwest.

Attribute	Definition	Reference	Intensity (along a 15-cm line scale)
AROMA (A)/FLAVOR (F)[a]			
Pear	The aromatics/taste of Bartlett pears	"Bartlett" pear Pears in heavy syrup (Signature Select Pear Slices Bartlett in Heavy Syrup, Signature Select, Pleasanton, CA, USA) 70 g of pears + 30 g of syrup in a 250 mL bottle	A:6/F:6 10
Vanilla	Aroma associated with vanilla	"Bartlett" pear 1 mL of pure vanilla extract (McCormick All natural pure vanilla extract [McCormick & Co., Inc., Hunt Valley, MD, USA]) in 100 mL of water	A:1/F:0 10
Floral	Aroma associated with flowers/honey	"Bartlett" pear 200 µL linalool (Sigma-Aldrich, St. Louis, MO, USA) in 400 mL of apple juice (Tree Top, 100% apple juice-from concentrate [Tree Top, Selah, WA, USA])	A:1.5/F:2 10
Fruity	Sweet aromatic, characteristic of ripe fruit	"Bartlett" pear Canned mix fruit (Del Monte peaches, pears and pineapple [Del Monte Foods, Walnut Creek, CA, USA]) 70 g of mix fruit + 30 g syrup	A:2/F:0 10
Apple	Aroma associated with fresh apple	"Bartlett" pear 100 g of freshly cut Fuji apple in a 250 mL bottle	A:0.5/F:1 10
Fermented	Aroma associated with fermented fruit	"Bartlett" pear Semi sweet hard cider (Seattle Cider Co., Seattle, WA, USA) (100 mL in a 250 mL bottle)	A:0/F:0 10
Grassy/green	Aroma associated with green wood stems; twiggy Aroma associated with unripe or "green" fruit that is similar to grass/leaves	"Bartlett" pear 100 µL of cis-2-hexen-1-ol (Sigma-Aldrich) diluted in 100 mL of Bartlett pears water (Del Monte, no sugar added, sliced pears [Del Monte])	A:5.5/F:3.5 11
Stemmy/woody	Aroma associated with fruit stalks/cores	"Bartlett" pear Broken stems in a 50 mL bottle	A:3/F:0 8
TASTE			
Sweet	Basic taste stimulated by sugar and high-potency sweeteners	2%(w/v) sucrose (pure cane sugar, granulated white [C&H, Domino Foods, Inc., Yonkers, NY, USA]) solution "Bartlett" pear 6%(w/v) sucrose (C&H) solution	3 5 12
Sour	Basic taste stimulated by acids	"Bartlett" pear 0.5 g malic acid (Brewcraft, Vancouver, WA, USA)/1 L water	5 6
Bitter	Basic taste stimulated by solutions or substances such as caffeine	"Bartlett" pear 0.35 g caffeine (Sigma-Aldrich)/1 L water	1 5

(Continues)

TABLE 2 (Continued)

Attribute	Definition	Reference	Intensity (along a 15-cm line scale)
MOUTHFEEL			
Astringency	The sensation associated with drying of the mouth	"Bartlett" pear	2.5
		0.5 g tannic acid (Sigma-Aldrich)/500 mL water	9
TEXTURE			
Crispy	The amount and pitch sound generated when the sample is first bitten with the front teeth	1 cm^3 banana (Del Monte)	0
		"Bartlett" pear	1
		1 cm^3 celery (Signature Farms trimmed celery stalks washed prepacked [Signature Farms, Pleasanton, CA, USA])	12
Crunchy	The amount of noise generated when chewing with the back teeth	1 cm^3 banana (Del Monte)	0
		"Bartlett" pear	1
		1 cm^3 carrot (Signature Farms baby-cut peeled carrots [Signature Farms])	14
Juicy	The amount of juice released by the sample during the first three chews	1 cm^3 banana (Del Monte)	0
		"Bartlett" pear	4.5
		Orange (one segment)	12
Firm	Force required to bite completely through the sample during the first bite/chew	1 cm^3 banana (Del Monte)	2
		"Bartlett" pear	3
		1 cm^3 carrot (Signature Farms baby-cut peeled carrots [Signature Farms])	12
Grainy/gritty	The presence of small hard particles in the flesh	"Bartlett" pear	1
		Apple sauce (unsweetened, O Organics [Albertsons Companies, Inc., Phoenix, AZ, USA]) (20 g)	4
		Cooked corn meal (O Organics, Albertsons Companies) (20 g)	14
Skin toughness	The amount of chewing required to cut through and breakdown the skin with the back teeth	"Bartlett" pear	2
		Granny smith apple with skin on	13

[a]The letter A, refers to aroma and F to flavor and were used to identify the intensities rates given to aroma and flavor attributes, respectively, for "Bartlett" pear. This pear was used as a reference.

not have children in the household, and 71% did most or almost all of the household grocery shopping with another 15% buying at least half the groceries for the household. The study was reviewed and approved by the OSU IRB -*IRB # 2021-1217*. Informed consent was obtained from each subject prior to their participation in the study.

Individual booths and white lighting were used for the consumers' evaluation. Questionnaire design and data collection were completed with Compusense® software (Compusense, Inc.). Before each session, pears were sliced with USA Pears slicers following a standardized methodology. Consumers received two slices of each pear and a whole pear for appearance evaluation to represent the size, shape, and color of each cultivar. The pears were identified with three-digit codes and were presented monadically according to a balanced design. Unsalted crackers and spring water were used as palate cleansers.

The consumers evaluated overall appearance, aroma, color of the skin, overall liking, pear flavor, sweetness, tartness/acidity, aftertaste, overall texture, firmness, juiciness, and crispness/crunchiness on a 9-point hedonic scale (1 = dislike extremely to 9 = like extremely); pear flavor, sweetness, tartness/acidity, firmness, crispness/crunchiness, juiciness, and skin texture were analyzed using 5-point just-about-right (JAR) scales; open-

ended questions were used to probe likes and dislikes and their favorite pear cultivar. Additionally, consumers were asked pear consumption-related habit questions such as the types of pears eaten in the last year (check-all-that-apply), pear purchase frequency (8-point scale where 1 = a few times a week or more to 8 = less than once a year), the importance of fresh pear characteristics such as size, shape, external color, ripeness, sweetness, juiciness, shelf life, and phytonutrient content when purchasing them (5-point scale where 1 = very unimportant to 5 = very important), and the main factors influencing overall food choices (ranking question where 1 = most important to 6 = least important) (Colonna et al., 2023).

2.4 | Physicochemical measurements of pears

Weight (g), firmness (kgf), and soluble solids (° Brix) were measured on the pear cultivars profiled by the trained panel ($n = 6$) and consumers ($n = 10–15$).

Pears were weighed on a digital scale (Pioneer, OHAUS, Parsippany, NJ, USA [trained panel] or EK-6100i, A&D Weighing, San Jose, CA, USA [consumer panel]).

Firmness of the pears profiled by the trained panel was measured with a GS-14 Fruit Texture Analyzer (GÜSS Instruments, Strand, South Africa) with an 8.0 mm probe set at 5.0 mm flesh penetration. The measurements were taken at three equidistant points around the equatorial region of each fruit after peel removal. For pears tested by consumers, two portions of the exocarp were removed from opposite sides of each fruit and staged on a MOHR Fruit Texture Analyzer (MOHR Test and Measurement LLC, Richland, WA, USA). Two measurements were conducted on each fruit.

The total soluble solids (TSS) for the pears profiled by the trained panel were measured with a handheld refractometer (Pocket Refractometer PAL-1, ATAGO, Japan). For the consumers study, a digital refractometer (Palette PR-101A, ATAGO USA, Inc., Bellevue, WA, USA) was used to measure TSS.

2.5 | Data analysis

XLSTAT 2022.4.1 (Addinsoft, New York, USA) software was used to run the different techniques for data analysis.

2.5.1 | Descriptive analysis

Trained panel data were analyzed with three-way analysis variance (ANOVA) at a 95% confidence level. The three main fixed effects were pear cultivar, panelist, and replicate. The interaction of the main effects pear cultivar*replicate was accounted for in the analysis (results are presented as Supporting Information). Tukey's Honestly Significant Difference (HSD) was used to compare means. Subsequently, principal component analysis (PCA) was applied to show the relationships between the attributes' scores that were significantly different ($p < 0.05$) and that characterized the sensory profile of the pear cultivars. The analysis was applied to the data collected for the pears from both the summer and the winter seasons.

2.5.2 | Consumer sensory evaluation

Consumers' ratings for the liking of each of the attributes were subjected to two-way ANOVA followed by Tukey's HSD. The two main effects analyzed were pear cultivar and panelist. The JAR data was separated into three groups; the bottom two categories (1 and 2) as "not enough," the middle category (3), as "just about right" and the top two categories (4 and 5), as "too much."

2.5.3 | Preference mapping

External preference mapping was conducted to evaluate the relationship between the consumers' overall liking of summer and winter pears and the sensory profiling obtained with the trained panel. First, PCA was run for each season data set from the trained panel to obtain the sensory map of the pears. Then agglomerative hierarchical clustering (AHC) was applied to generate clusters based on the consumers' overall liking of the pear cultivars. The scores of the different factors were obtained from the sensory map and the overall liking scores from the clusters.

External preference mapping techniques were applied to the first two principal components of the trained panel data to relate consumers' preferences to the pears' sensory map (Gámbaro et al., 2007; Oliver et al., 2018). Five and the four clusters were generated for the summer and winter pears, respectively.

To select the best model for the preference mapping, the *find the best model* approach was applied via PREFMAP (Oliver et al., 2018).

2.5.4 | Cluster characterization

Consumers in each cluster were characterized by demographic information (gender) and pear consumption-related habits. Responses to these questions were used to develop the characterization: *types of pears eaten in*

the last year (check-all-that-apply question); *what is your favorite pear cultivar and why* (open-ended question); *the importance of fresh pear characteristics such as size*, *shape*, *external color*, *ripeness*, *sweetness*, *juiciness*, *shelf life*, and *phytonutrient content when purchasing* them (5-point scale); and the *main factors influencing overall food choices* (ranking question). Based on consumers' responses, frequencies and averages were determined.

2.5.5 | Physicochemical measurements

Results are presented as means ± SD (Supporting Information). A one-way ANOVA with the main effect of pear cultivar was run to determine differences in these measurements among the pears tested on the summer and winter season, respectively. To determine mean separation, Tukey's HSD was applied.

3 | RESULTS AND DISCUSSION

3.1 | Descriptive analysis

The trained panel detected significant differences in the intensities of multiple attributes evaluated in the pears from the summer and the winter seasons.

3.1.1 | Appearance

Results of the appearance evaluations for the summer pears are presented in Table 3. Only the results from the pears that were also presented to the consumers are shown.

The Chasset classification (Bellini et al., 2007; Chasset, 1920; Martinelli et al., 2008) was used for the shape evaluation (Figure S1). For "Bartlett," 720, and "Seckel," the percentage of agreement/selection of a specific shape was 70% or higher. The shapes selected for each of these pears were *M*, for "Bartlett" and 720 and *J* for "Seckel." These three cultivars are European pears and 720 is a "Bartlett" cross. Therefore, it could be expected that the panelists were more familiarized with these cultivars and would be more consistent in the shape selection. "Bartlett" has been described as having a true pyriform or typical "pear shape" meaning a rounded bell on the bottom half of the fruit, and a smaller neck or stem end (USA Pears, 2023a). For red cultivars, 417 and 642, the panelists' agreement was more divided among multiple shapes. Potentially, these two cultivars might be less familiar to the panelists, as they are interspecific pear hybrids, and there might be more inherent variation among these cultivars.

There was high agreement among the panelists (90% or higher) when evaluating the skin appearance of the six cultivars. "Bartlett," 573 and 720 were described as *lumpy*. The 417, 642 and "Seckel" were described as *smooth*.

The color evaluation also presented good agreement among the panelists (90% or higher). "Bartlett" and 573 presented a high intensity, yellow color, and a low intensity green color. Previous characterizations of "Bartlett" also reported yellow color when ripening (USA Pears, 2023a). Pear 720 and "Seckel" were mostly described as having a medium intensity green color. Pear 417 was the only cultivar described as presenting a medium intensity, red color.

Russet coverage ranged from 2.8% (Seckel) to 10.5% (642). The blush percentage was the highest for 642 (65.7%) followed by "Seckel" (41.7%). This attribute may be important for commercial purposes; blush pears have gained popularity with consumers and may be priced up to three times higher than green/yellow pears (Human, 2013).

Results of the appearance evaluation for the winter pears are presented in Table 4. These cultivars were evaluated by consumers too.

Shape evaluation presented over 50% agreement by trained panelists for "Bosc," "Concorde," not ripened "Gem" and "D'Anjou." "Bosc" and "Concorde" were described with an *O* shape. For the rest of cultivars, the panelists did not identify a distinct shape to describe each. Hilton and Sugar (2015) reported the shape of "Paragon" as "Bartlett" -like, so it could have been expected to see similar results for these two cultivars. However, it is important to note that pear shapes vary considerably.

Russet coverage for the winter pears ranged from 2.4% to 6.4%. "Paragon" and "Comice" were the cultivars with the highest percentage of russet coverage. "Comice" was described as the cultivar with the highest blush coverage (36.1%).

Skin appearance was described by the panelists as *smooth* for "Bosc," "Concorde," and "D'Anjou" (90%–100% of agreement). "Comice," not ripened "Gem" and "Paragon" were most frequently described as *smooth*, but also *lumpy*.

For color evaluation, "Bosc" was the most different cultivar, as described with an intense, brown color. The other five cultivars were most frequently described as green or yellow, with intensities that ranged between low and medium. In the case of "Paragon" this cultivar has been described as having green skin and turning yellow with ripening (Hilton & Sugar, 2015).

3.1.2 | Aroma, flavor, taste, and texture

Figure 1 shows the sensory attributes that were significantly different ($p < 0.05$) for the summer pears. The PCA plot explained 65.4% of the variation among the summer pears, with 49.9% and 15.5% explained by PC1 and

TABLE 3 Frequency of selection and means of multiple appearance descriptors for the summer pear cultivars by the trained panel ($n = 10$).

Cultivar	Shape[a]	Percentage of russet coverage[b] (%)	Percentage of blush coverage[b] (%)	Skin appearance (smooth, lumpy, other)	Color
Bartlett	M (70%) L (30%)	4.1	10.0	Lumpy (90%)	Yellow-high (100%) Green-low (100%)
573	D (30%) M (30%) P (30%)	3.4	26.3	Lumpy (100%)	Yellow-high (70%) Green-low (80%)
720	M (90%)	6.7	24.5	Lumpy (100%)	Green-medium (90%) Yellow-low (80%)
417	C (40%) A (30%) E (30%)	4.7	20.0	Smooth (100%)	Red-medium (60%) Yellow-low (60%)
642	C (50%) E (30%) G (30%)	10.5	65.7	Smooth (90%)	Green-low (90%) Yellow-medium (50%)
Seckel	J (100%)	2.8	41.7	Smooth (100%)	Green-medium (90%)

[a]The letters for the shapes were obtained from Chasset classification (Bellini et al., 2007) (see Figure S1).
[b]The percentage values for russet and blush coverage represent the percentage of panelists who reported that attributes in the tested pears.

TABLE 4 Frequency of selection of multiple appearance descriptors for the winter pear cultivars by the trained panel ($n = 10$).

Cultivar	Shape[a]	Percentage of russet coverage[b] (%)	Percentage of blush coverage[b] (%)	Skin appearance (smooth, lumpy, other)	Color
Bosc	O (90%)[a]	2.4	0.2	Smooth (90%)	Brown-high (60%)
Comice	I (30%) J (30%)	6.4	36.1	Smooth (90%) Lumpy (50%)	Green-medium (90%) Yellow-medium (80%)
Concorde	O (60%) N (40%)	2.4	17.4	Smooth (100%)	Green-low (90%) Yellow-medium (70%) Yellow-high (70%)
Gem	C (60%)	1.6	14.9	Smooth (80%) Lumpy (60%)	Green-medium (60%) Yellow-low (50%)
D'Anjou	H (80%)	4.9	14.6	Smooth (100%)	Green-high (90%)
Paragon	H (50%) L (30%)	6.4	3.6	Smooth (80%) Lumpy (50%)	Green-low (80%) Yellow-medium (60%)

[a]The letters for the shapes were obtained from Chasset classification (Bellini et al., 2007) (see Figure S1).
[b]The percentage values for russet and blush coverage represent the percentage of panelists who reported that attributes in the tested pears.

PC2, respectively. PC1 was defined by the positively loaded attributes of *pear flavor*, *pear aroma*, *grassy/green aroma*, and *flavor*, *floral aroma* and *flavor*, and *sour* in contrast to the negatively loaded attributes of *fruity flavor*, *apple aroma*, *bitter taste*, *astringent*, *fermented aroma* and *flavor*, and some texture-related attributes such as *grainy–gritty*, *skin toughness*, *crispy*, *crunchy*, and *firm*. Pear cultivars including 573, "Sylvania" and "Bartlett" had higher associations with positively loaded attributes on PC1. "Bartlett" pear has been characterized as extremely aromatic, with a definitive "pear flavor" (USA Pears, 2023a). Sourness has been reported as a key sensory characteristic in fruits

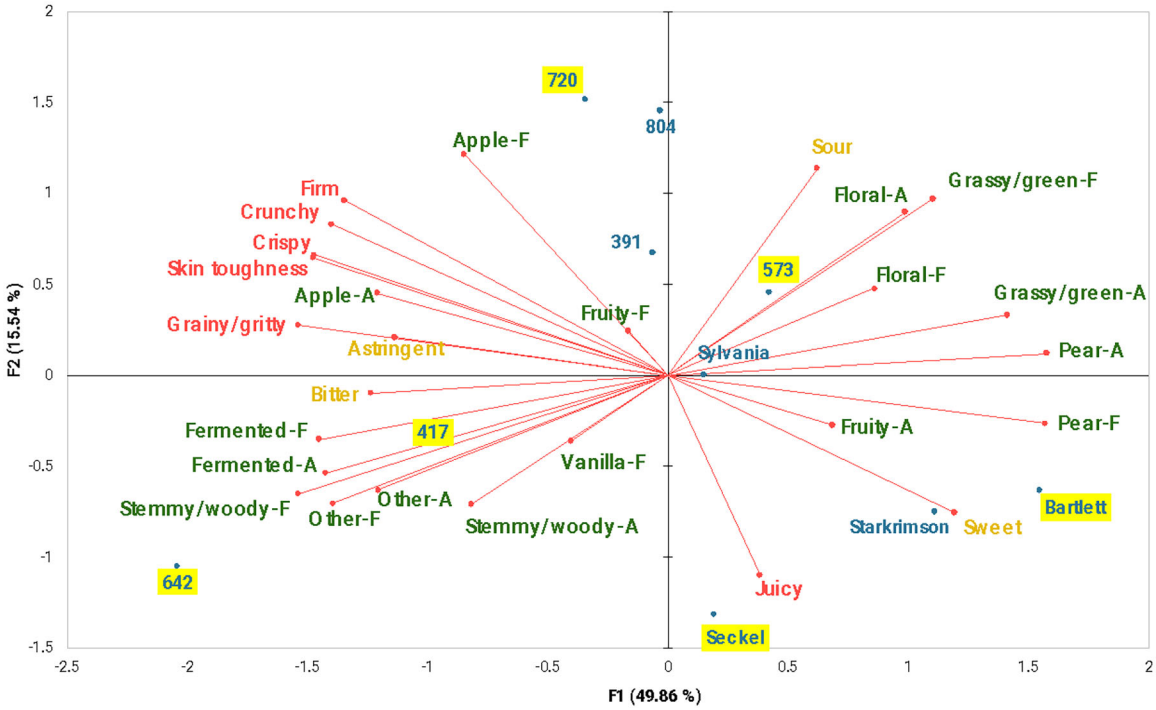

FIGURE 1 Principal component analysis of all significant attributes of the summer season pears as determined by the trained panel ($n = 10$). The aroma- and flavor-related attributes are presented in green. The aroma-related attributes are represented as -A and the flavor-related attributes are represented as -F. The basic taste attributes are presented in orange, and the texture-related attributes are presented in red. Pears cultivars highlighted in yellow were also evaluated by the consumers.

that can impact their acceptability and consumption by consumers (Lozano et al., 2023). Cultivars like 417 had a higher association with negatively loaded attributes on PC1 (*apple aroma*, *bitter taste*, *astringent*, and *grainy/gritty texture)*. Jaeger et al. (2003) reported an Asian pear species as described by a trained panel with the attributes of *fermented odor* and *flavor* and *grainy texture*. These findings align with one of the interspecific hybrid pear cultivars (417) in this study. PC2 was associated with the contrasting relationships of *apple flavor* and *fruity flavor* with *vanilla flavor*, *stemmy/woody aroma*, and *juicy*. Pear cultivars such as 720, 804, and 391 were mostly associated with the positively loaded attributes of *apple flavor* and *fruity flavor*. "Seckel" was associated with *juicy*.

Figure 2 shows the attributes that were significantly different ($p < 0.05$) for the winter pears. The PCA plot explained 69.6% of the variation among the winter pears, with 50.5% and 19.1% explained by PC1 and PC2, respectively. PC1 was defined by the positively loaded attributes *pear flavor* and *pear aroma*, *juicy*, *sweet*, f*ruity aroma* and *fruity flavor*, and *vanilla aroma* and *vanilla* flavor in contrast to the negatively loaded attributes of *grassy/green flavor*, *apple flavor*, *sour*, and *astringent*. Pear cultivars such as "Comice," "Paragon," "Packham's Triumph," and "Concorde" had higher associations with positively loaded attributes on PC1. In previous studies, "Paragon" has been described as *juicy*, *sweet*, and *buttery* (Courtney, 2022). Jaeger et al. (2003) reported that "Comice" and "Packham" were described as having a *sweet* and *pear aroma*.

The other cultivars like "D'Anjou" and "Gem" (not ripened) had higher associations with negatively loaded attributes (*grassy/green flavor*, *apple flavor*, *sour*, and *astringent)*. Jaeger et al. (2003) also reported descriptors such as *grassy/green flavor* for less than ripe pear cultivars. In our study, we chose to serve the "Gem" not ripened so it may be expected that this cultivar was described with *grassy/green flavor* and *astringent* mouthfeel. PC2 was associated with the contrasting relationship of *grassy/green aroma* with *bitter*, *stemmy/woody flavor*, and *other flavor*. "Packham's Triumph" was associated with the positively loaded attribute of *grassy/green aroma*. A previous study reported the attributes of *grassy/green aroma*, *flavor*, and *bitter taste* when evaluating the effect of ripeness level in "Packham's Triumph" (Jaeger et al., 2003). "Forelle," "Abate Fetel," and "Bosc" were associated with the negatively loaded attributes including *stemmy/woody*, *bitter taste*.

Based on the PCA results, six pear cultivars from each season were selected to be evaluated by consumers. The selected cultivars are highlighted in Figures 1 and 2.

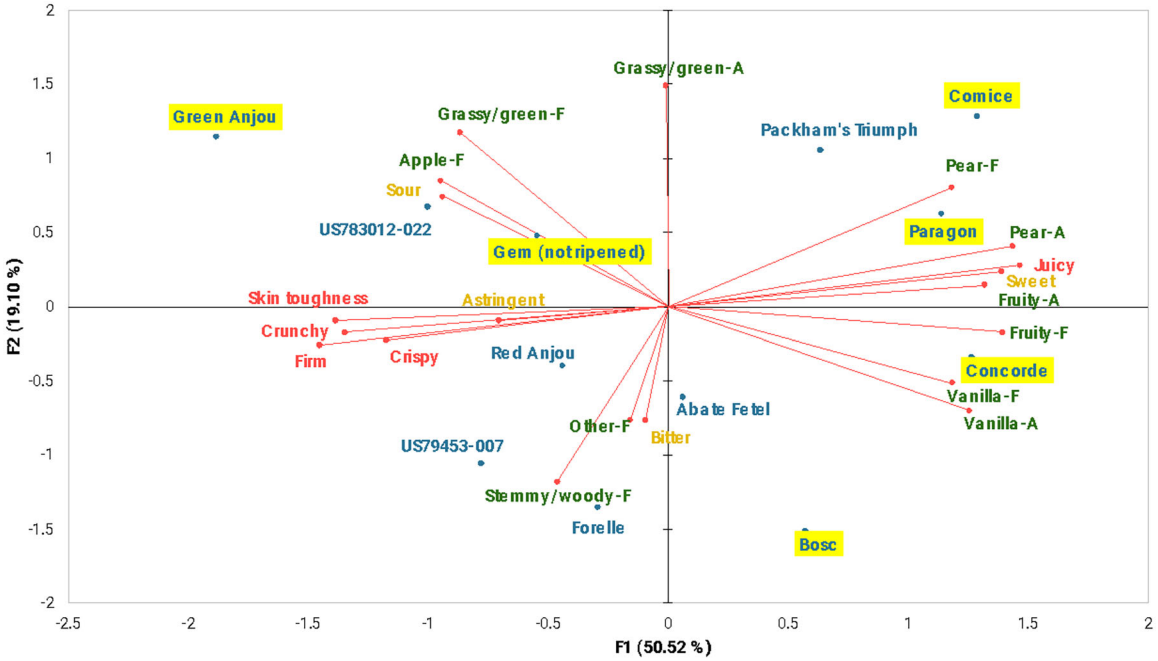

FIGURE 2 Principal component analysis of all significant attributes of the winter season pears as determined by the trained panel ($n = 10$). The aroma- and flavor-related attributes are presented in green. The aroma-related attributes are represented as -A and the flavor-related attributes are represented as -F. The basic taste attributes are presented in orange, and the texture-related attributes are presented in red. Pears cultivars highlighted in yellow were also evaluated by the consumers.

3.2 | Consumer sensory evaluation

3.2.1 | Summer pears

"Bartlett," 573, and "Seckel" were liked significantly more ($p < 0.0001$) than pears 642, 417, and 720 in overall liking. Pear flavor is important to overall liking (Steyn et al., 2011) and the "Bartlett" and "Seckel" cultivars were rated by most consumers as JAR for pear flavor (Table 6). Sweetness is another key attribute to the overall liking of pears (Taiti et al., 2017) and when considering sweetness preferences, "Bartlett" and "Seckel" cultivars exemplified the sweetness these consumers preferred in a pear (Table 5). The "Bartlett" cultivar was rated by 80% of consumers as JAR in sweetness, while pears 642, 720, and 417 were all rated by fewer than 50% of the consumers tested as JAR.

Juiciness is considered to be a key attribute in consumer liking of pears (Turner et al., 2005). "Bartlett" was liked significantly ($p < 0.0001$) more for juiciness compared to the other summer pears tested (Table 6). Few consumers rated any of the pears as having too much pear flavor, sweetness, or juiciness as these were highly desirable attributes and were qualities linked to cultivars with the highest overall liking such as the "Bartlett" and "Seckel" (Tables 5 and 6). These results are similar to a study of South African consumers ($n = 200$) who stated their most preferred pear attributes were juicy (19%), sweet (18.5%), not mealy (15%), and soft (14%) (Steyn et al., 2011).

Pears that do not exhibit the attributes of sweetness and flavor are generally not well liked (Elkins et al., 2006). Pear 417, which was described by many consumers in open-ended comments as *bland* or *lacking flavor*, was rated by 90% of consumers as having too little pear flavor, and not sweet or tart enough (Table 6). Pear 417 was rated significantly ($p < 0.0001$) lower in overall liking than the highest rated pears ("Bartlett," 573, and "Seckel"), despite that it had the highest mean score in overall appearance liking and skin color liking (Table 5). The pears with the lowest overall liking scores (720, 642, and 417) had the fewest number of consumers rating JAR for pear flavor and sweetness and most consumers rated the pears as too firm, too crisp/crunchy, and too dry/mealy (Table 6).

3.2.2 | Winter pears

For overall liking, "Paragon," "D'Anjou," and "Concorde" presented significantly ($p < 0.0001$) higher mean scores than the not fully ripened "Gem" and "Bosc" (Table 5). The same pears that were rated highest in overall liking also were rated highest in pear flavor liking, specifically "Paragon," "Comice," "D'Anjou," and "Concorde" (Table 5). These four pears were liked significantly ($p < 0.0001$) more in pear flavor than the "Bosc" and not ripened "Gem" (Table 5). The "Paragon" was rated by 73% of consumers as JAR in pear flavor (Table 7). The liking

TABLE 5 Consumer liking by cultivar for 12 sensory attributes on a 9-point hedonic scale where 1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely.

Sensory attributes	Overall liking	Appearance	Color of skin	Aroma	Pear flavor	Sweetness	Tartness/acidity	Overall texture	Firmness	Juiciness	Crispiness/ crunchiness	Aftertaste
Summer pears ($n = 107$)												
Bartlett	7.3 a	7.3 a	7.1 ab	6.9 a	7.6 a	7.6 a	6.6 a	6.9 a	6.4 a	7.8 a	6.0 a	6.9 a
573	6.8 a	7.3 a	7.3 ab	7.0 a	6.8 b	6.8 b	6.3 a	6.5 ab	6.7 a	6.1 b	6.3 a	6.3 a
Seckel	6.8 a	6.3 b	6.5 c	5.1 c	7.0 ab	6.9 ab	5.9 ab	6.3 ab	6.6 a	6.7 b	6.0 a	6.4 a
642	5.5 b	6.1 b	6.8 bc	5.2 c	5.1 c	5.7 c	5.3 bc	5.9 b	6.2 a	6.7 b	6.4 a	5.3 b
417	5.3 b	7.5 a	7.7 a	6.7 a	4.8 c	4.9 d	4.7 c	5.8 b	6.1 a	6.2 b	6.2 a	5.0 b
720	5.1 b	6.9 a	7.1 ab	6.0 b	5.2 c	4.9 d	5.3 bc	4.6 c	4.7 b	4.1 c	4.9 b	5.1 b
p-value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Winter pears ($n = 112$)												
Paragon	7.5 a	6.6 bc	6.7 c	6.5 ab	7.5 a	7.3 a	6.5 a	7.1 a	7.0 a	7.6 a	6.4 ab	6.7 a
Anjou	7.0 a	7.2 ab	7.1 bc	6.1 ab	7.0 a	6.9 a	6.3 a	6.9 ab	7.0 ab	7.4 a	6.3 abc	6.8 a
Concorde	7.0 a	7.3 a	7.2 bc	6.7 a	7.0 a	6.9 a	6.1 a	7.3 a	7.2 a	7.6 a	6.9 a	6.5 a
Comice	6.8 ab	7.1 ab	7.5 ab	6.7 a	7.1 a	6.9 a	6.2 a	6.3 bc	6.2 c	7.2 a	5.7 c	6.2 ab
Gem nr	6.2 bc	7.7 a	7.9 a	6.0 bc	5.9 b	6.0 b	6.1 a	6.2 bc	6.3 bc	6.1 b	6.5 ab	6.3 a
Bosc	5.9 c	6.2 c	6.0 d	5.5 c	5.9 b	5.7 b	5.3 b	6.1 c	6.5 abc	6.5 b	6.0 bc	5.5 b
p-value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Note: The values reported are means. Different letters within a column (a, b, and c) indicate that the tested variable mean value was different among the pear cultivars ($p < 0.05$) as determined by using Tukey's HSD.
Abbreviation: nr, not ripe.

TABLE 6 Percentages of responses for the just-about-right questions (collapsed) for the summer pear varietal ($n = 107$).

		Percentage of responses (%)					
Variable	Level	**Bartlett**	**573**	**720**	**417**	**642**	**Seckel**
Pear flavor	Not enough	19	48	69	90	75	33
	JAR	76	49	28	9	24	64
	Too much	6	4	3	1	1	4
Sweetness	Not enough	11	39	64	73	42	20
	JAR	80	55	33	24	48	73
	Too much	8	6	3	3	10	7
Tartness	Not enough	27	23	13	52	39	39
	JAR	66	64	50	40	50	59
	Too much	7	12	37	7	10	2
Firmness	Too soft	45	18	1	1	1	28
	JAR	53	60	23	52	51	65
	Too firm	2	22	76	47	48	7
Crunchiness	Too soft/buttery	43	30	4	0	0	36
	JAR	54	52	32	57	58	58
	Too crisp/crunchy	3	18	64	43	42	7
Juiciness	Too dry/mealy	6	60	87	33	31	29
	JAR	86	40	13	63	65	68
	Too juicy	8	0	0	5	4	3
Skin texture	Too thin	12	4	1	0	4	2
	JAR	78	86	73	69	64	63
	Too thick/tough	10	10	26	31	33	36

responses for sweetness also showed preferences for the same four cultivars, "Paragon," "D'Anjou," "Concorde," and "Comice" (Table 5). These cultivars were rated by a majority of consumers as JAR in sweetness, while the "Bosc" and not ripened "Gem" were rated by >50% of consumers as not sweet enough (Table 7). "Bosc" was rated with a ($p < 0.0001$) lower mean score in tartness/acidity liking than the other five winter pear cultivars.

Soft and juicy texture in pears has been found to be an important driver of liking (Colonna et al., 2023). For texture liking, the "Concorde" and "Paragon" were scored significantly ($p < 0.0001$) higher than the other cultivars tested except the "D' Anjou." The "Paragon," "Concorde," "D'Anjou," and "Comice" were all well liked in juiciness (Table 5); over 80% of consumers rated these four cultivars as JAR in juiciness (Table 7).

3.3 | Preference mapping

3.3.1 | Summer pears

Five clusters were identified based on the consumers' ($n = 107$) liking of the summer cultivars, with 71.8% of the variance within consumers accounted for (Figure 3). Eighty percent of the consumers were satisfied or liked "Bartlett" and "Seckel" the most. "Bartlett" is one of the major cultivars grown in North America (Westwood, 1993), so this result is unsurprising given that consumers are likely to be very familiarized with this cultivar and have a particular preference for it.

Consumer clustering was mainly determined by the most liked pear cultivar. Consumers in Cluster 1 ($n = 33$, 73% women) liked "Seckel" the most, which was characterized for its *juicy* texture. Their second cultivar most liked was "Bartlett," followed by 417. "Bartlett" was liked for its familiarity, *good flavor*, *sweetness*, *juiciness*, and *mix of crunchy* and *smooth* texture. Consumers in Cluster 1 were characterized as having consumed mostly "Bartlett" pears in the last year. These consumers preferred *juicy*, *pear flavor*, and *sweet* attributes in their pears. The main factors influencing their food choices were *taste* and *flavor appeal*, *health and nutrition*, and *price*. Asian pears were the second most consumed pears by consumers in Cluster 1. Asian pears were liked for their texture, *juiciness*, and *sweetness*. Blattný (2003) reported that Asian pears are distinctive for their flesh texture. Cluster 1 preference for 417 may be related to their liking for Asian pears.

Clusters 2 ($n = 29$, 69% women) and 4 ($n = 27$, 63% women) liked "Bartlett" the most. "Bartlett" was charac-

TABLE 7 Percentages of responses for the just-about-right questions (collapsed) for the winter pear varietal ($n = 112$).

		Percentage of responses (%)					
Variable	**Level**	**Anjou**	**Bosc**	**Comice**	**Concorde**	**Gem**	**Paragon**
	Not enough	39	65	27	36	73	18
Pear flavor	JAR	58	33	63	61	27	73
	Too much	4	2	10	3	0	9
	Not enough	23	52	23	24	51	11
Sweetness	JAR	72	42	62	66	48	69
	Too much	5	5	14	10	1	20
	Not enough	31	48	21	45	23	32
Tartness	JAR	65	45	64	52	65	62
	Too much	5	7	15	3	13	6
	Too soft	32	23	50	23	0	36
Firmness	JAR	68	64	49	75	54	63
	Too firm	0	13	2	3	46	1
	Too soft/buttery	36	30	51	24	0	43
Crunchiness	JAR	62	58	47	72	56	55
	Too crisp/crunchy	2	13	2	4	44	2
	Too dry/mealy	11	26	6	5	44	11
Juiciness	JAR	84	70	82	88	54	82
	Too juicy	5	4	12	7	2	7
	Too thin	4	9	8	9	1	12
Skin texture	JAR	72	60	44	66	77	79
	Too thick/tough	24	31	48	25	22	9

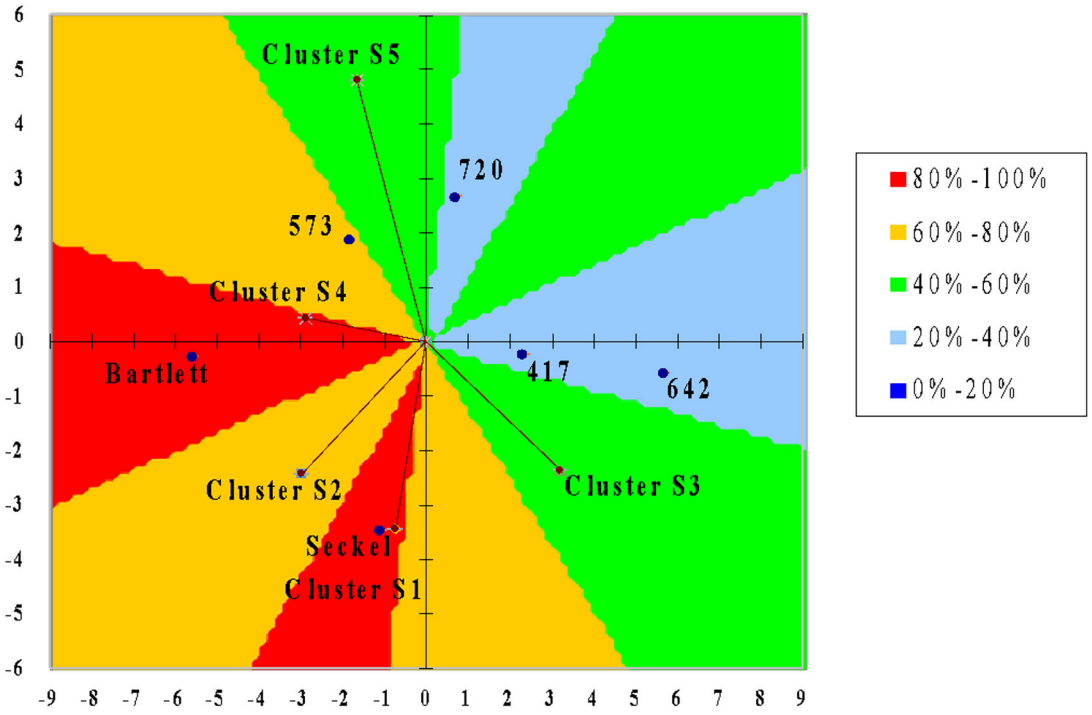

FIGURE 3 Preference map of sensory profiling data for six summer pear cultivars explaining 71.8% of the total variance overlaid by consumer ($n = 107$) liking data via a Vector model. Percentages represent regions whereby the given percentage of consumers have a preference above the mean.

terized by its *pear aroma*, *grassy/green aroma*, *pear flavor*, *sweet* taste, and *juicy* texture. "Bartlett" was their most consumed pear in the last year, liking its flavor (e.g., *sweetness*) and texture attributes (e.g., *soft*, *juicy*, *crispness*, *creaminess);* consumers also found it *predictable* (e.g., constant flavor). These consumers rated *flavor*, *juiciness*, *sweetness*, and *freshness* as the most important factors when purchasing fresh pears. Previous studies have reported that the most common reasons for liking pears are *sweetness* and *juiciness*, while *firm*, *gritty* textures and lack of flavor were disliked (Escribano et al., 2016). Therefore, it can be expected that the pear which most exhibited these qualities, "Bartlett," was the most liked by the consumers of the two largest identified clusters.

Consumers in Cluster 3 ($n = 8$, 100% women) presented the highest preference for the red cultivars 642 and 417 and the lowest liking for "Bartlett." Eighty percent of these consumers consumed Asian pears in the last year and selected this type of pear as their favorite because of the *texture* (e.g., *crunchy*, *crispness*), *juiciness* and *flavor* (e.g., *apple flavor*). They expressed c*rispness*, *flavor*, *freshness*, and *juiciness* are the most important characteristics in pears. The Asian type pears, which were liked by 20% of the consumers overall, were characterized by attributes such as *stemmy/woody aroma*, *fermented aroma*, *stemmy/woody flavor*, *fermented flavor*, *bitter taste*, *astringent*, and *grainy/gritty texture*. The clear preference for the consumption of Asian pears could explain why they liked 642 and 417 pears the most. This finding suggests there is a niche group that prefers a crisper/juicier type Asian pear. Lwin and Le (2020) reported that pear growers and consumer interest for Asian pears is increasing. When consumed at the appropriate ripeness level, Asian pears have a pleasant firmness, crispness, and juiciness similar to apples but with a different and distinctive texture (Blattný, 2003).

Consumers in Cluster 5 formed a small cluster ($n = 10$, 50% women). In the last year, they mostly consumed "Bosc," followed by "Bartlett." Their criteria for buying fresh pears were, *freshness*, *flavor*, and *juiciness*. Their food choices/eating patterns were mainly influenced by *taste and flavor appeal*, *health and nutrition*, and *price*. This cluster presented a profile of consumers open and willing to explore new cultivars as 30% of these consumers expressed having *no particular favorite* or *having tried some of the newer cultivars*. This may explain why pear 573, profiled as having *floral aroma*, *green/grassy flavor*, *floral flavor*, and *sour taste* was the most liked cultivar for consumers in Cluster 5.

3.3.2 | Winter pears

Four clusters were identified based on the consumers' ($n = 112$) liking of the six winter pear cultivars. The 81.4% of the variance within consumer preferences was accounted for (Figure 4).

"Comice" and "Paragon" were the winter cultivars most liked by the consumers (75%). Both cultivars were described as having *pear aroma*, *fruity aroma*, *pear flavor*, *fruity flavor*, *sweet taste*, and *juicy texture*. Consumers in Cluster 2 ($n = 12$), Cluster 3 ($n = 45$), and Cluster 4 ($n = 25$) expressed the highest preference for "Comice" and the lowest for "Bosc" (Clusters 2 and 3) and "D'Anjou" (Cluster 4).

Overall, 50% of the consumers were satisfied with "D'Anjou," not ripened "Gem," and "Concorde." "D'Anjou" was profiled as having *grassy/green flavor*, *apple flavor*, *sour taste*, and *astringent*. "Gem" (not ripened) was mostly characterized with texture-related attributes such as *crispy*, *crunchy*, *skin toughness*, and *firm*. "Concorde" was profiled as having a *vanilla aroma*, *vanilla flavor*, and *bitter taste*.

Consumers in Cluster 1 ($n = 29$, 41% women) liked "Bosc" the most which satisfied the liking/preference of 25% of the total consumers. "Bosc" was mainly described as having a *stemmy/woody flavor*. In other studies, ripe "Bosc" has been described as less *juicy*, and more *firm* than "Comice" (Jaeger et al., 2003). Consumers in Cluster 1 liked "Comice" the least. This group presented a differentiated preference compared to the consumers in the other three identified clusters. When asked about the pear cultivars consumed in the past year, 79% of consumers in Cluster 1 indicated "Bosc" (79%) as their most consumed cultivar, followed by "Bartlett" (76%) and Asian pears (65%).

However, when asked about their favorite pear cultivar, the responses varied. Twenty-one percent mentioned "D'Anjou" (e.g., *appearance*, *texture of skin and interior*, *balance of sweetness to tartness*, and *familiarity*); 17% "Comice" (e.g., *flavor*, *texture*, and *sweetness*); 14% "Bartlett" (e.g., *availability*, *consistent*, *texture*, *juiciness*, and *sweetness*); and 10% "Bosc" (e.g., f*lavor*, *texture*, *crispness*, and *tartness*). When asked about their criteria for purchasing fresh pears, consumers rated *flavor* as *somewhat important* to *very important* and *crispness*, *firmness*, and *juiciness* between *neutral* and *somewhat important*.

For Cluster 2 consumers ($n = 12$, 58% women), "Comice" was the most liked and "D'Anjou" was the second most liked cultivar. Consumers described "D'Anjou" with attributes such as *apple flavor*, *grassy/green flavor*, *sour taste*, and *crispy texture*. Their most frequently consumed pears in the last year were "Bartlett" (100%), "Bosc" (75%), and "Comice" (67%). "Bartlett" was their favorite (42%) followed by Asian pears (25%). They described "Bartlett" as *budget friendly*, *available*, *familiar*, *juicy*, and having *strong pear flavor*. Asian pear was another favorite because of its texture (e.g., *firm*, *crispness*), *juiciness*, and *flavor*. The most important characteristics of fresh pears

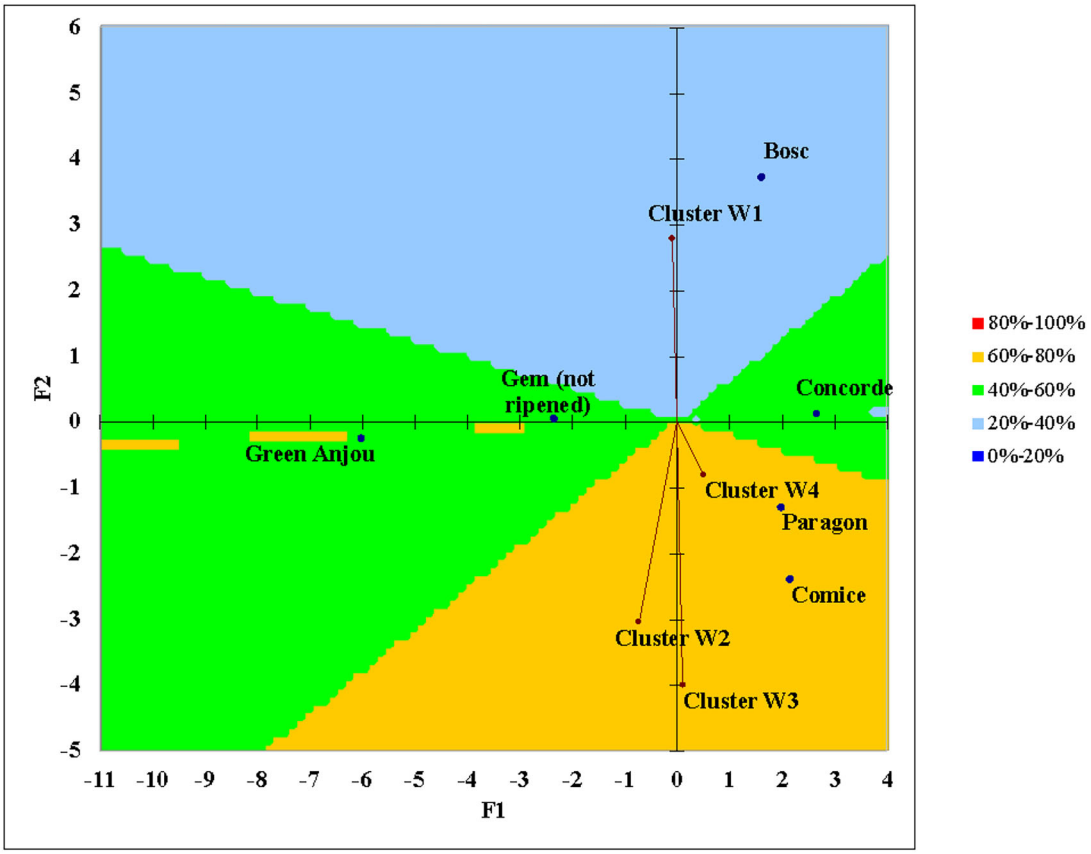

FIGURE 4 Preference map of sensory profiling data for six winter pear cultivars explaining 81.4% of the total variance overlaid by consumer ($n = 112$) liking data via a Vector model. Percentages represent regions whereby the given percentage of consumers have a preference above the mean.

were *flavor*, *freshness*, and *pears free of defects*. These consumers' food choices/eating patterns were mostly described by *taste and flavor appeal*, *health and nutrition*, and *price*, as was also observed for consumers in Clusters 3 and 4.

For consumers in Cluster 3 (n = 45, 62% women), the preferred pear was "Comice," followed by "Paragon" and "D'Anjou"(Figure 4). "Comice" and "Paragon" were mostly described by *pear aroma*, *pear flavor*, and *sweet taste*, similar to previous work (Vaysse et al., 2005). In this cluster, the pear cultivars most commonly consumed in the last year were "Bartlett" (89%) and "D'Anjou" (71%), followed by "Red Anjou" (62%), Asian pears (62%) and "Comice" (51%). When asked about their favorite pear cultivar, 24% mentioned "Bartlett" because of its *good pear flavor*, *good texture*, *familiarity*, *soft/ buttery texture*, *sweetness*, *juiciness*, and *firmness* and 16% mentioned "Red Anjou" as their favorite pear. The characteristics most desired in fresh pears were *juiciness*, *freshness*, and *flavor*.

Cluster 4 ($n = 25$, 56% women) gathered consumers who also had the highest preference for "Comice." As in Cluster 3, "Paragon" was also the second most liked cultivar followed by "Concorde." Their most frequently consumed pears in the last year were "Bartlett" (96%), "D'Anjou" (68%), "Bosc" (68%), and Asian Pear (68%). "Comice" was consumed by 36% of the consumers in this cluster and "Concorde" by 24%. The favorite pear for these consumers was "Bartlett" (44%) because of its *size*, *color*, *taste overall*, *perfect pear flavor*, *right amount of sweetness*, and *juiciness*. When purchasing fresh pear *flavor*, *juiciness*, and *sweetness* were the most important characteristics for these consumers.

3.4 | Physicochemical measurements of the pears

The physicochemical measurements of summer and winter season pears profiled by the trained panel and consumers are presented as Supporting Information (Tables 1 and 2).

Weight ranged from 125.4–310.9 g for summer cultivars (Table 1) and 160.4–262.4 g for winter cultivars (Table 2). All European-style pears from both summer and winter seasons were at optimal firmness for consumption, except for pears 720 (5–6 kgf) and Bosc (7.0 kgf). Firmness usually

ranges from 6 to 7 kgf for European pears when harvested and 2 to 3 kgf or less when ready for consumption (DeEll & Slingerland, 2012). The TSS ranged from 12.3 to 16.3 °Brix for summer cultivars (Table 1) and 10.2 to 20.5 °Brix for winter cultivars (Table 2).

3.5 | Study limitations

This study presented results of consumer and trained panel profiling of a large number of pears. However, it must be noted that pears have a natural variation in their physicochemical composition that is challenging to account for. These differences (e.g., firmness, TSS), which are mostly associated with their ripeness level, may have impacted the perception of the sensory attributes evaluated both by the trained panel and the consumers. These potential differences were mitigated by testing samples in duplicate by the trained panel and by over 100 consumers, with this testing occurring within a day.

4 | CONCLUSIONS

The aim of this study was to identify the sensory characteristics of summer and winter pears considered desirable by consumers in the PNW region. After profiling 23 pear cultivars with a trained panel, significant differences were found in the appearance, aroma, flavor, taste, and texture profile. The consumer study showed that frequent pear consumers are most interested in pears that are high in *pear flavor*, *sweetness*, *juiciness*, and have a *soft/juicy texture*. Pears that were less well liked were rated as not having enough *pear flavor*, *sweetness*, or *juiciness*, and as being too *firm* and too *crispy/crunchy*. Also, consumer niche groups of pear consumers were identified. These niche groups prefer the Asian style crispier, juicy cultivars that are less well known and less commonly consumed than more common cultivars like "Bartlett" (Taiti et al., 2017).

Overall, the main contributions of this study suggest the pear industry should seek to deliver pears with the attributes desired by consumers, which include sweetness, juiciness, and a softer texture. These attributes have been shown by previous researchers (Colonna et al., 2023; Elkins et al., 2006, 2008; Gallardo et al., 2023; Steyn et al., 2011; Taiti et al., 2017; Torregrosa et al., 2019; Turner et al., 2005) to be highly desirable to pear consumers. However, the pear industry should also consider introducing pears with other sensory attributes as the present results suggested that there is consumer interest.

AUTHOR CONTRIBUTIONS

Maria Laura Montero: Methodology; investigation; formal analysis; writing—original draft; writing—review and editing. **Ann E. Colonna**: Conceptualization; investigation; resources; formal analysis; writing—original draft; supervision; methodology; funding acquisition; project administration. **R. Karina Gallardo**: Conceptualization; methodology; investigation; formal analysis; resources; supervision; funding acquisition; project administration; writing—review and editing. **Carolyn F. Ross**: Conceptualization; methodology; investigation; resources; formal analysis; writing—original draft; project administration; funding acquisition; writing—review and editing.

ACKNOWLEDGMENTS

Funding was provided by the Washington Tree Fruit Research Commission- Fresh and Processed Pear Research Committee under the grant title: Identification of pears' desirable sensory profile for consumers in the Pacific Northwest (PNW) (WSU ORSO # 141583). This work was also supported by the USDA National Institute of Food and Agriculture, Hatch Project (Accession #1016366). The authors would like to thank different persons and institutions for their contribution to this research: the Fresh and Processed Pear Research Committee, trained panelists, Beata Vixie at the WSU Sensory Science Center, consumers, the sensory team at OSU FIC, Kelsey Galimba and Mackenzie DeNew of the OSU Mid-Columbia Agricultural Research and Extension Center for the physicochemical measurements of pears for the consumer research, Elizabeth Siler from the English Department at WSU for the editing and proofreading of the paper, Kate Evans and Stefano Musacchi from WSU Wenatchee Tree Fruit Research and Extension Center, and Tory Schmidt at the Washington Tree Fruit Research Commission. Special thanks to the following institutions who provided guidance on the cultivars tested and the fruit used in this research: Brandt's Fruit Trees, Duckwall Fruit, Mt. Adam's Fruit, OSU Mid-Columbia Agricultural Research and Extension Center, OSU Southern Oregon Research and Extension Center, Pear Bureau Northwest, Prey's Fruit Barn, Stemilt Growers, USDA ARS Appalachian Fruit Research Station, and USDA ARS National Clonal Germplasm Repository.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon request.

ORCID

Maria Laura Montero https://orcid.org/0000-0003-4318-9045
R. Karina Gallardo https://orcid.org/0000-0002-6609-4711
Carolyn F. Ross https://orcid.org/0000-0002-5319-1950

REFERENCES

Bellini, E., Giordani, E., Giannelli, G., & Picardi, E. (2007). *Le specie legnose da frutto. Liste dei caratteri descrittivi. The fruit woody species. Descriptor list*. Agenzia Regionale per lo Sviluppo e l'Innovazione nel settore Agricolo-forestale (ARSIA).

Blattný, C. (2003). Pears. In L. Trugo & P. M. Finglas (Eds.), *Encyclopedia of food sciences and nutrition* (2nd ed., pp. 4428–4433). Academic Press.

Chasset, L. (1920). The determination of pears. *Journal of Pomology and Horticultural Science*, *2*(1), 11–15. https://doi.org/10.1080/03683621.1920.11513233

Colonna, A., Gutierrez, J., Montero, M., Gallardo, R., & Ross, C. (2023). An investigation of consumer pear knowledge, consumer preferences and desirable sensory traits to increase pear consumption. *Acta Horticulturae*, In press.

Courtney, R. (2022). *Pearest of them all: Seven pear cultivars tie for favorite in consumer trial*. https://www.goodfruit.com/pearest-of-them-all/

DeEll, J., & Slingerland, K. (2012). Recommendation for harvest and storage of pears. *Ontario Ministry of Agriculture, Food and Rural Affairs*, https://omafra.gov.on.ca/english/crops/facts/12-041.htm

Durham, S. (2015). A new 'Gem' of a pear released by ARS Cooperators. *Agricultural Research Service*, https://www.ars.usda.gov/news-events/news/research-news/2015/a-new-gem-of-a-pear-released-by-ars-cooperators

Elkins, R., Castagnoli, S., Colonna, A., Tuner, J., Seavert, C., Mitcham, E., Biasi, W., & Bell, R. (2008). Evaluation of potential alternative European pear cultivars for U.S. west coast growers. *Acta Horticulturae*, *800*, 483.

Elkins, R., Turner, J., Castagnoli, S., Seavert, C., Mitcham, E., Biasi, W., & Colonna, A. (2006). (96) Sensory evaluation of alternative pear cultivars for the U.S. West Coast. *Hortscience*, *41*(4), 1029–1029. https://doi.org/10.21273/HORTSCI.41.4.1029D

Escribano, S., Lopez, A., Siversten, H., Biasi, W., Macnish, A., & Mitcham, E. (2016). Impact of 1-methylcyclopropene treatment on the sensory quality of 'Bartlett' pear fruit. *Postharvest Biology and Technology*, *11*, 305–313.

Fernandez-Serrano, P., Tarancon, P., & Besada, C. (2020). Consumer information needs and sensory label design for fresh fruit packaging. An exploratory study in Spain. *Foods*, *10*(1), 72. https://doi.org/10.3390/foods10010072

Gallardo, R., Kupferman, E., Beaudry, R., Blankenship, S., Mitcham, E., & Watkins, C. (2011). Market quality of Pacific Northwest pears. *Journal of Food Distribution Research*, *42*(1), 89–99.

Gallardo, R., Ma, X., Colonna, A., Montero, M. L., & Ross, C. (2023). Consumers' preferences for novel and traditional pear cultivars: Evidence from sensory evaluation and willingness to pay elicitation. *Hortscience*, *58*(12), 1474–1483. https://doi.org/10.21273/HORTSCI17317-23

Gámbaro, A., Ares, G., Giménez, A., & Pahor, S. (2007). Preference mapping of color of Uruguayan honeys. *Journal of Sensory Studies*, *22*, 507–519. https://doi.org/10.1111/j.1745-459X.2007.00125.x

Hilton, R., & Sugar, D. (2015). 'Paragon' and 'Bestever', two 'Comice' hybrid pear cultivars developed in Southern Oregon. *Acta Horticulturae*, *1094*, 149–151. https://doi.org/10.17660/ActaHortic.2015.1094.17

Human, J. P. (2013). Breeding blush pears (*Pyrus communis* L.) in South Africa. *Acta Horticulturae*, *976*, 383–388. https://doi.org/10.17660/ActaHortic.2013.976.52

Ikiz, D., Gallardo, R., Dhingra, A., & Hewitt, S. (2018). Assessing consumers' preferences and willingness to pay for novel sliced packed fresh pears: A latent class approach. *Agribusiness*, *34*(2), 321–337. https://doi.org/10.1002/agr.21532

Jaeger, S., Lund, C., Lau, K., & Harker, F. (2003). In search of the "Ideal" pear (*pyrus spp.*): Results of a multidisciplinary exploration. *Journal of Food Science*, *68*, 1108–1117. https://doi.org/10.1111/j.1365-2621.2003.tb08296.x

Kappel, F., Fisher-Fleming, R., & Hogue, E. J. (1995). Ideal pear sensory attributes and fruit characteristics. *Hortscience*, *30*(5), 988–993. https://doi.org/10.21273/HORTSCI.30.5.988

Kim, Y., Cho, M., & Chung, S. (2019). Understanding the drivers of liking for fresh pears: A cross-cultural investigation of Chinese and Korean panels and consumers. *Journal of the Science of Food and Agriculture*, *99*(11), 5092–5101. https://doi.org/10.1002/jsfa.9753

Lozano, L., Iglesias, I., Puy, J., & Echeverria, G. (2023). Performance of an expert sensory panel and instrumental measures for assessing eating fruit quality attributes in a pear breeding programme. *Foods*, *12*(7), 1426. https://doi.org/10.3390/foods12071426

Lwin, H. P., & Lee, J. (2020). Fruit quality and major metabolites in cold-stored 'Wonhwang' Asian pears are differentially affected by fruit size. *Journal of the Science of Food and Agriculture*, *100*, 5117–5125. https://doi.org/10.1002/jsfa.10422

Martinelli, F., Busconi, M., Camangi, F., Fogher, C., Stefani, A., & Sebastiani, L. (2008). Ancient Pomoideae (*Malus domestica* Borkh. and *Pyrus communis* L.) cultivars in "Appenino Toscano" (Tuscany, Italy): Molecular (SSR) and morphological characterization. *Caryologia*, *61*(3), 320–331. https://doi.org/10.1080/00087114.2008.10589643

Northwest Horticultural Council. (2021). *Pacific Northwest pears. Pear fact sheet*. Northwest Horticultural Council. https://nwhort.org/industry-facts/pear-fact-sheet/

Oliver, P., Cicerale, S., Pang, E., & Keast, R. (2018). Identifying key flavors in strawberries driving liking via internal and external preference mapping. *Journal of Food Science*, *83*, 1073–1083. https://doi.org/10.1111/1750-3841.14109

Steyn, W. J., Manning, N., Muller, M., & Human, J. P. (2011). Physical, sensory and consumer analysis of eating quality and appearance of pear genotypes among South African consumers. *Acta Horticulturae*, *909*, 579–586. https://doi.org/10.17660/ActaHortic.2011.909.69

Taiti, C., Marone, E., Lanza, M., Azzarello, E., Masi, E., Pandolfi, C., Giordani, E., & Mancuso, S. (2017). Nashi or Williams pear fruits? Use of volatile organic compounds, physicochemical parameters, and sensory evaluation to understand the consumer's preference. *European Food Research & Technology*, *243*(11), 1917–1931. https://doi.org/10.1007/s00217-017-2898-y

Torregrosa, E., Illa, J., & Giné-Bordonaba, J. (2019). Ripening behaviour and consumer acceptance of "Conference" pears dur-

ing shelf life after long term DCA-storage. *Postharvest Biology and Technology*, *155*, 94–101. https://doi.org/10.1016/j.postharvbio.2019.05.014

Turner, J., Bai, J., Marin, A., & Colonna, A. (2005). Consumer sensory evaluation of pear cultivars in the Pacific Northwest, USA. *Acta Horticulturae*, *671*, 355–360. https://doi.org/10.17660/ActaHortic.2005.671.50

Turpin, S., Jones, L., Norton, J., Probst, R., Konings, J., & Langford, G. (2016). Perfect pears for the next generation of consumers. *Acta Horticulturae*, *1120*, 507–514. https://doi.org/10.17660/ActaHortic.2016.1120.77

USA Pears. (2023a). *Pear varieties: Bartlett*. https://usapears.org/bartlett/

USA Pears. (2023b). *Ripening and handling*. https://usapears.org/pear-ripening-and-handling/

Vaysse, P., Reynier, P., Roche, L., & Lavialle, O. (2005). Sensory evaluation of new pear cultivars. *ISHS Acta Horticulturae*, *671*, 341–347. https://doi.org/10.17660/ActaHortic.2005.671.48

Westwood, M. N. (1993). *Temperate-zone pomology: Physiology and culture* (3rd ed.). Timber Press.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Montero, M. L., Colonna, A. E., Gallardo, R. K., & Ross, C. F. (2024). Sensory profiling of pears from the Pacific Northwest: Consumers' perspective and descriptive analysis. *Journal of Food Science*, 1–18. https://doi.org/10.1111/1750-3841.16913