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Determining the optimum firmness for sweet cherries using Just-About-Right sensory methodology

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ABSTRACT

This study evaluated Just-About-Right (JAR) ratings of untrained panellists for whole sweet cherry (*Prunus avium* L.) crispness and flesh firmness. Cherries from 17 different cultivars and breeding selections representing a wide range of fruit firmness were harvested over the course of the cherry maturity season in 2011 and 2012. The firmness of each cherry (n = 183–500 per sample) was measured with the FirmTech 2 Fruit Firmness Tester, and the fruits were sorted into 19 firmness categories, of 0.20 N increments, ranging from 1.58 to 5.69 N. Untrained panellists (n = 48) assessed whole cherry crispness and flesh firmness using a 7-point JAR scale from '*much too soft*', through '*just about right*', to '*much too firm/crisp*'. Four to eight firmness categories were evaluated per session in a series of 10 sensory sessions. Linear regression was used to model the relationship between JAR ratings and analytical firmness values, for whole cherry crispness ($r^2_{2011-12} = 0.75$) and flesh firmness ($r^2_{2011-12} = 0.75$). Crispness and firmness were highly correlated in both years (R_{2011} = 0.99, R_{2012} = 0.99). Frequency distributions of JAR ratings identified the proportion of responses at each rating (1–7), within each firmness category. The "acceptable" firmness range was calculated to be 2.52–4.75 N from JAR flesh firmness scores of between 3 ('*slightly too soft*') and 5 ('*slightly too firm*'), respectively. Cherries with measured firmness values between 2.56 and 4.71 N were "acceptable" to 72.9–91.7% of panellists. The work established the relationship between sensory and analytical evaluations in order to develop guidelines for acceptable sweet cherry fruit firmness to use in research on cultural practices and the selection of new cultivars.

1. Introduction

Sweet cherry (*Prunus avium* L.) is an important commercial crop in over 40 countries (Webster and Looney, 1996), including the Pacific Northwestern USA and British Columbia (BC), Canada. According to Statistics Canada, BC sweet cherry exports rose from about C$500,000 annually for most of the 1990s to almost C$40 million in 2011.

Sweet cherries are a highly perishable commodity. Most of the crop is consumed fresh, and considerable effort goes into maximizing fruit quality and maintaining it during storage and transportation. Much prior work has been done to clarify what constitutes "quality" in sweet cherry at the consumer level, and which aspects of quality are the most important to consumers. Obvious visual clues to fruit condition include stem appearance, fruit glossiness, and freedom from defects, disease and injury. Assuming good condition, consumer research in diverse geographical regions has demonstrated that large fruit size (29–30 mm diameter), dark skin colour, and uniformity of skin colour among fruit are important drivers of overall liking or acceptability of appearance for dark sweet cherries (Cliff et al., 1996; Kappel et al., 1996; Crisosto et al., 2003; Turner et al., 2008). Among internal attributes, sensory sweetness, flavour intensity, flavour acceptability, the sum of sweetness and sourness, soluble solids concentration, and/or titratable acidity were found to be important (Guyer et al., 1993; Cliff et al., 1996; Dever et al., 1996; Kappel et al., 1996; Turner et al., 2008; Chauvin et al., 2009). Interestingly, no texture attributes were identified as being strongly associated with overall liking/acceptance in some of these studies (Cliff et al., 1996; Crisosto et al., 2003; Chauvin et al., 2009), but others made note that firmness was significantly ($p \leq 0.05$) correlated with overall acceptability (Guyer et al., 1993), or was an important contributor to overall liking in principle component analysis (Dever et al., 1996). Another sensory texture attribute, juiciness, was only identified as a preference driver by Dever et al. (1996). The absence of texture as a preference driver in some studies may have arisen if all samples presented for evaluation were of acceptable or good texture.

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Firmness is considered extremely important by industry. Fruit firmness and crispness are often associated with freshness in fruit (Fillion and Kilcast, 2002). Consumers are able to detect rather small differences in flesh firmness, particularly at the softer end of the continuum (Ross et al., 2009). Softness is estimated to be responsible for 60% of dockages in grade or price of sweet cherries (Younce and Davis, 1995). Great effort goes into providing product with high firmness and maintaining firmness throughout the cold chain. Farm-level factors affecting cherry firmness include maturity of the fruit at harvest, and horticultural manipulations. For example, gibberellic acid (GA) is used commercially in some production regions to increase cherry fruit firmness (Looney, 1996). Sensory firmness is usually higher in GA-treated fruit (Clayton et al., 2006) but some cultivars are unresponsive (Choi et al., 2004). Packers cool fruit as quickly as possible to ≤5 °C to reduce respiration rate and maintain firmness (Crisosto et al., 1993; Padilla-Zakour et al., 2007).

Genotypic differences in firmness among cultivars can be large. In a recent factorial experiment, cherry firmness was significantly affected by cultivar, storage time, and time "on the shelf" after storage, and all of these factors interacted significantly (Toivonen and Hampson, 2012), but cultivar accounted for the greatest proportion of the variance. Cultivars with softer fruit appear to have lower total cell wall contents and more water-soluble pectin upon ripening than cultivars with firm fruit (Choi et al., 2002). More recently, Salato et al. (2013) evaluated cell wall pectins and hemicelluloses in detail over four fruit developmental stages in two cultivars differing in firmness. Their results confirmed that the fruit of the soft cultivar was lower in total cell wall content, had more branching of tightly bound pectins in the cell wall, and higher content of neutral sugar-rich pectin side chains.

Crispness is another attribute that may contribute to consumers' liking of cherries. Crispness is associated with tissue fracture upon initial bite, and it encompasses a wide range of perceptions such as fracture characteristics, sounds, and density (Fillion and Kilcast, 2002). Fruit texture depends on epidermal and flesh strength, cell turgor, cell size and breaking pattern (rupture of cells with release of contents *vs*. cell–cell separation), cell wall structure and the amount of intercellular space (Brown and Bourne, 1988; Batisse et al., 1996; Mann et al., 2005). Batisse et al. (1996) found crisper 'Burlat' cherries to have more uniform cells and more intercellular spaces than softer 'Burlat' cherries. In addition, crisper cherries had higher degrees of polymerization of cell wall compounds. In short, both firmness and crispness have been studied and discussed (Brown and Bourne, 1988; Kappel et al., 1996; Fillion and Kilcast, 2002; Harker et al., 2002; Mann et al., 2005; Ross et al., 2009; Evans et al., 2010), but the relationship between these two attributes in cherry is not well understood.

Kappel et al. (1996) recognized the importance of fruit texture for screening germplasm in the Agriculture and Agri-Food Canada sweet cherry breeding program in Summerland, BC. They found a linear relationship between instrumental firmness, as measured by a handheld durometer, and consumer ratings of firmness acceptability on the Just-About-Right scale. Data were used to develop guidelines for screening new selections, as a supplement to in-field fruit tasting by the breeding team. Since 1997, the breeding program has been using the FirmTech (and later the FirmTech 2) Fruit Firmness Tester (BioWorks, Wamego, KS, USA). This instrument compresses the fruit across the cheeks and measures the force required to deform the fruit by 1 mm. The measurements taken by the FirmTech do not relate clearly to the measurements taken by the durometer. Mitcham et al. (1998) compared the Instron Universal Testing Machine to the FirmTech, three other devices, and the "finger squeeze" method for assessing flesh firmness of sweet cherry. Although the Instron performed best, the FirmTech was better than the other four methods for precision and accuracy. The FirmTech 2 is non-destructive, easy to operate, reasonably priced and relatively fast. It has come into common use in the cherry industry in North America, but its relationship to consumer preference has not been documented (Ross et al., 2009).

The objectives of this study were: (1) to correlate analytical determinations of cherry fruit firmness and JAR ratings of cherry texture (whole cherry crispness, flesh firmness), (2) to identify the "acceptable" range of cherry firmness, and (3) to explore the relationship between sensory ratings for flesh firmness and whole cherry crispness. Although the 7- or 9-point hedonic ("degree-of-liking") scale would have provided a value judgement regarding the acceptability of cherry firmness, it provides no information on the reason for liking/disliking. Likewise, paired preference tests were not suitable; pairwise assessments can result in a preference even where both samples are unacceptable. The JAR scale was selected as it is designed to find the optimum/most appropriate level of a specific attribute and is easy for untrained panellists to understand.

2. Materials and methods

2.1. Sampling and preparation of plant material

Cherries used in the study were grown in the research plots at the Pacific Agri-Food Research Centre (Summerland, BC, Canada), in accordance with commercial practices for the region (BC Ministry of Agriculture, 2010), except that GA was only applied to the cultivars as noted below. Fruit were hand-picked based on matching the external colour to the #5 to #6 colour chips (corresponding to commercial maturity) of the 7-category Centre Technique Interprofessionnel des Fruits et Légumes (CTIFL) colour chart (CTIFL, Paris, France) and evaluated as being sufficiently mature and appropriate for consumption by three sensory personnel based on fruit condition, skin colour, flavour and sweet/sour balance. The cultivars and selections used were chosen to represent as wide a range of firmness as possible, including a few samples that were intentionally harvested slightly under-ripe and very firm to obtain a range of firmness levels. Split, diseased, and damaged fruit were eliminated from the samples. Seventeen different dark sweet cherry cultivars or selections were harvested for the study (Table 1): eight cultivars without GA applied ('Sumnue' [Cristalina®], 13S-21-20, 'Summit', 'Van', 4W-11-42, 'Symphony', '13S2009' [Staccato®], '13S2101' [Sovereign®]); three cultivars treated with GA at 30 mg L^{-1} when the fruit were at straw colour ('SPC103' [Sentennial®], 'Sumste' [Samba®], 'Lapins'); and three cultivars both with and without GA ('Skeena', 'Sumtare' [Sweetheart®], 'Sandra Rose'). Two to four cultivars were harvested each week over the cherry ripening season for sensory evaluation during 5 wk in 2011 and 7 wk in 2012. Sensory data from different cultivars within the same firmness category (Table 1) were pooled together for data analysis. Fruit were harvested before 09:00 and immediately transported to the lab for processing. The number of fruit per sample was typically 275–500.

The firmness of each individual cherry was measured at 20 °C using the FirmTech 2 Fruit Firmness Tester (BioWorks, Wamego, KS, USA). Each fruit was measured twice and the second measurement was recorded since it is considered more consistent. The first measurement "seats" the fruit in the turntable depression, ensuring that the second measurement is taken with fruit sitting solidly on the turntable when the force is applied. The FirmTech 2 reports peak force during a 1 mm compression. The cherries were immediately segregated into 24 different firmness categories ranging from 1.0 to 6.1 N. At least 50 fruit were required for a sensory panel with 48 participants, and the lowest firmness category with ≥50 fruit was 1.58–1.76 N. The cherries were then washed by soaking and gently mixing in 5 L chlorinated wash water (30 mg L^{-1}) for 1 min