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Flavour and texture changes in apple cultivars during storage

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ABSTRACT

Storage induced sensory changes of Finnish apples were defined and quantified with descriptive analysis. Twelve cultivars were evaluated at 3–5 storage points during 8–17 weeks (+3 °C). The lexicon consisted of 15 attributes: two related to odour (*fruity*, *intensity*), five to texture (*hard*, *crispy*, *mealy*, *juicy*, *soggy*), five to flavour (*sour*, *sweet*, *astringent*, *intensity*, *diversity*), and three to deterioration (*mouldy odour*, *fermented odour/flavour*). Major changes were observed during the follow-up period, but differences in cultivar performance were large. Storage influenced mostly texture, especially juiciness and mealiness. Sourness diminished in several cultivars. Hierarchical cluster analysis on attribute intensities revealed four distinctive clusters (CL). Apples in CL1 were juicy, crispy and sour with high flavour intensity. In CL2 and CL3 apples were medium sour, but in the latter crispier, juicier and sweeter. Apples in CL4 were sweet and medium mealy with low sourness. During storage, most cultivars shifted clusters, especially to CL2 and CL4, indicating that storage time modifies their sensory profiles. Thus, not only the cultivar, but also the storage time shapes the sensory properties. Understanding that cultivars may belong to different clusters in the course of storage, and consequently appeal to different consumer segments, should be helpful for marketing.

1. Introduction

The apple (*Malus domestica* Borkh.) has been cultivated in Finland for hundreds of years (Meurman & Collan, 1943; Tahvonen, 2007), but most cultivars suffer from relatively short storage life and consequently, are available only during the apple season in August–November. Domestic apples are categorised as summer, autumn and winter apples, or early, mid and late season, respectively, based on their DD5 index (the cumulative base temperature over 5 °C during growth period) requirements (Tahvonen, 2007). However, the division between the categories is not strict and varies depending on the local traditions.

The maturity stage at harvest has a notable impact on the storability and sensory quality of apples (Kader, 2008; Kader & Barret, 2005). As a climacteric fruit, apples continue ripening after harvest. The synthesis rate of flavour components increases, as organic acids and starch are converted to sugars and other flavour components and used for respiration, causing the overall sourness to diminish (Defilippi, Dandekar, & Kader, 2004; Kader & Barret, 2005). These processes are believed to be regulated by ethylene prevalent in apples (Defilippi et al., 2004; Johnston, Hewett, & Hertog, 2002; Moya-Leon, Vergara, Bravo, Pereira, & Moggia, 2007). Emission of volatiles such as ethylene is highly cultivar-specific (Soukoulis et al., 2012). Ethylene may also induce apple softening (Johnston, Hewett, & Hertog, 2002). During storage, the crispy texture of a fresh apple gradually deteriorates and becomes soft, dry and mealy (Harker & Hallett, 1992; Johnston, Hewett, & Hertog, 2002). Consumers regard mealiness as a major defect in the perceived quality of apples (e.g. Andani, Jaeger, Wakeling, & MacFie, 2001; Jaeger, Andani, Wakeling, & MacFie, 1998).

The extent of softening and other textural changes varies greatly, depending on the cultivar, harvest date, storage conditions (Brummell, 2006; Costa et al., 2012; Galvez-Lopez, Laurens, Devaux, & Lahaye, 2012; Harker & Hallett, 1992) and even the apple size (Johnston, Hewett, Hertog, & Harker, 2002). Johnston, Hewett, Banks, Harker, and Hertog (2001) speculated that cultivars differ in their cell-wall composition, which would cause the differences in their postharvest behaviour. A major structural feature of apple is the parenchyma tissue, a rigid texture with turgor pressure keeping the tissue matrix extended and maintaining crispiness (Szczesniak, 1997). The integrity of the cellular connections has a great impact on crispiness (Brummell, 2006) and softness (Johnston, Hewett, & Hertog, 2002). Loss of water and turgor pressure are believed to be the major causes of fruit deterioration, bringing on losses in

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weight, appearance and texture (Johnston, Hewett, & Hertog, 2002; Kader & Barret, 2005). However, Harker, Amos, Echeverria, and Gunson (2006) discovered that perceived juiciness was not affected by the actual water content of the hard fleshed, juicy fruits such as apples. Neither could the changes in the perceived juiciness during ripening be predicted with standard instrumental methods. Harker et al. (2002) and Brookfield, Nicoll, Gunson, Harker, and Wohlers (2011) showed that in some cases, sensory differences were observed in apple texture even if not detected by instrumental analyses. Thus, sensory methods, providing a direct measure of human perception, are irreplaceable in studying storability and storage induced changes in apples.

Apart from traditional and new instrumental methods (Ballabio, Consonni, & Costa, 2012; Costa et al., 2012; Defilippi et al., 2004; Harker et al., 2002; Johnston, Hewett, Banks, et al., 2001), postharvest apples have been studied by sensory methods with varying aims and panel arrangements. For example, Brookfield et al. (2011) had three-member postharvest teams with long practical horticultural experience assessing two textural attributes, while others (Billy et al., 2008; Corollaro et al., 2013; Mehinagic, Royer, Symoneaux, Bertrand, & Jourjon, 2004; Varela, Salvador, & Fiszman, 2008) had 11–15 trained panellists and 5–17 attributes. Hedonic ratings and analytical sensory attributes are sometimes evaluated by the same panel (Echeverria, Fuentes, Graell, & Lopez, 2003; Echeverria et al., 2004; Hampson et al., 2000), a practise not encouraged by sensory specialists (Lawless & Heymann, 2010).

For assessing storage induced sensory changes, and then combining these results with instrumental data, both large untrained panels up to 30–40 members (Echeverria et al., 2003, 2004; Moya-Leon et al., 2007) or smaller trained panels (Aaby, Haffner, & Skrede, 2002; Billy et al., 2008; Galvez-Lopez et al., 2012; Mehinagic et al., 2004) are used. Storage effects have been studied with traditional descriptive analysis methods, having one (Aaby et al., 2002; Moya-Leon et al., 2007; Varela et al., 2008), two (Billy et al., 2008) or three (Andani et al., 2001; Jaeger et al., 1998; Mehinagic et al., 2004; Mehinagic, Royer, Symoneaux, & Jourjon, 2006) cultivars as sample materials. Apart from the very recent study by Corollaro et al. (2013), few extensive storability studies have been conducted with descriptive analysis and trained panel, using a broad range of cultivars as samples. Yet, it is generally admitted that cultivars differ greatly in their sensory properties, both at commercial maturity and during prolonged storage.

A research programme at Agrifood Research Finland (MTT) focuses on breeding new crosses best suited both to northern climate and to modern cultivation and postharvest techniques. A selection of promising crosses and traditional cultivars at commercial maturity was described by Seppä, Railio, Mononen, Tahvonen, and Tuorila (2012). As more information about storage life of the cultivars and storage induced changes is needed, the present study characterises sensory changes during storage in selected 12 cultivars to benefit future breeding and cultivation programmes and apple marketing.

2. Materials and methods

2.1. Cultivars

Twelve mid and late season cultivars were harvested in orchards at MTT fruit research station in Piikkiö and surrounding areas in South-western Finland during September–October 2010 (Table 1). Mid and late season cultivars were chosen as target products, as they have a slightly longer storage life than early season cultivars, and therefore have a higher commercial potential. Cultivars ‘Heta’, ‘Pekka’, ‘Tobias’ and ‘Konsta’ are crosses by MTT, already in production. Y9930 is a new cross by MTT, not in full scale production yet. The rest of the cultivars have their origins in other countries, such as Sweden or Canada (Tahvonen, 2007). Apart from MTT research station, ‘Eva-Lotta’ is cultivated only in Aland Islands, situated between Finland and Sweden.

The apples were kept in the cold storage of the orchards (+3 °C, RH 80–92%, normal atmosphere) and monitored for commercial maturity using horticultural methods such as appearance, starch iodine test and brix measurements (Seppä et al., 2012; Tahvonen, 2007). Due to the shortening days and frost, mid and late season cultivars have to be harvested before commercial maturity, and thus require ripening period in storage. Storage conditions were typical for Finnish apple production, as availability of controlled atmosphere storage is very limited. Before each evaluation, the apples were transported to the cold store (+4 °C, normal atmosphere) at the Department of Food and Environmental Sciences, University of Helsinki.

Each cultivar was evaluated for the first time when it had reached commercial maturity (evaluation point A) and then following the storage plan (Table 1). The last evaluation point was set at the estimated end of the storage life of the cultivar. In several cases, as seen from Table 1, the storage life was estimated to be longer than traditionally expected. No large scale storage life studies have previously been conducted on domestic cultivars. Decision of the evaluation points was based on the long-time expertise of orchard personnel. The points were coded with

Table 1
Evaluation schedule of the cultivars, with codes used in PCA graphs. DD5-indexes and storage life from Tahvonen (2007). Days after harvest to commercial maturity (evaluation point A), and days from A to subsequent points (B–E).

Cultivar	Code	DD5[a]	Storage life days[b]	Harvest date	Days to point A	Days from A to			
						B	C	D	E
Pekka	Pek	1230	28	3.9.	32	30	58		
Discovery	Dis	1235	42	12.9.	23	30	58		
Summerred	Sum	1260	56	14.9.	21	30	58		
Heta	Heta	1200	28–42	30.8.	18	24	48	76	
Tobias	Tob	1235	42–56	13.9.	31	22	43	67	
Red Atlas	Red	1250	28–42	14.9.	30	22	43	67	
Eva-Lotta	Eva	1260	56	20.9.	24	22	43	67	
Konsta	Kon	1264	28	12.9.	32	22	43	67	
Lobo	Lobo	1302	56	24.9.	28	27	48	80[c]	
Aroma	Aro	1338	42	8.10.	14	27	48	80[c]	
Y9330	Y93	1350	56–84	6.10.	16	27	48	80[c]	119[c]
Åkerö Hassel	Åke	1260	56	20.9.	32	27	48	80[c]	119[c]

[a] Requirement of cumulative base temperature over 5 °C during growth period.
[b] After having reached commercial maturity.
[c] Next year.