LWT - Food Science and Technology 75 (2017) 243–250

Contents lists available at ScienceDirect

LWT - Food Science and Technology

journal homepage: www.elsevier.com/locate/lwt

Evolution of cherries texture in brine: Impact of harvest conditions during long-time storage

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ARTICLE INFO

Article history:
Received 8 June 2016
Received in revised form
10 August 2016
Accepted 30 August 2016
Available online 31 August 2016

Keywords:
Prunus avium L.
Firmness
Candied cherries
Brine
Cytohistology
Cell wall

ABSTRACT

Texture is a primary quality attribute of brined sweet cherries (*Prunus avium* L.) and its preservation is a major objective for candying industry. In order to identify the harvest factors influencing textural changes during long period brine storage, different itineraries were applied: harvest at two different maturity stages, treatment or not with ethephon, manual or mechanical harvest, removal or not of peduncles. The cherries were immersed in brine and examined over a 12-months period for firmness, calcium and total soluble solids diffusion and cytohistological remodelling. Mechanical harvesting, harvest at late maturity stage and storage with peduncle decreased firmness while ethephon treatment had no effect. However, only presence or absence of peduncles influenced salt and total soluble solids diffusion, suggesting that peduncle removal promotes osmotic exchanges.

Brine storage led to a texture gain in the first two months in most cases compared to fresh cherries, as confirmed by a beneficial reshuffle at cytohistological level. This explains why it can allow storage of cherries for candying over the whole duration between two harvest seasons.

1. Introduction

Sweet cherries (*Prunus avium* L. cv. Napoléon) produced in Vaucluse (South France) are mainly intended for processing to glacé cherries, represented 10.000 tons of final product, with 70% destined for more than 60 countries. They must be harvested within a short time (3–4 weeks) and are then stored in brine for candying all along the year. The narrow window of harvesting prompted growers to adopt mechanical methods based on the use of ethephon (2-chloroethyl phosphonic acid) and harvesting at an earlier stage. The ethylene released by Ethephon induces a decrease of the pedicel-fruit retention force in sweet cherry (Smith & Whiting, 2007). This is mediated by its binding to receptor sites that initiates a signal transduction leading to acceleration of cell-wall degrading enzymes and cell death in the abscission zone (Estornell, Agusti, Merelo, Talon, and Tadeo (2013); Hall., Shakeel, & Schaller (2007)). In the case of cherries, approximately 80% fruits fall without peduncle. However, this harvesting method is not a rule and manually harvested cherries still represent 20% of total quantity delivered to industry (Ulrich Fleury, personal communication).

Between harvest and candying, cherry fruits are stored in brine containing sulfur dioxide and calcium salts. Acidity and sulphites protect fruit from microorganism proliferation due to SO_2 antiseptic effects (Dupuy, 1959; Julien, 1972). Calcium salts act on cherries firmness, as also noted to improve texture for pickled cucumbers (Hudson & Buescher, 1985). Sulfur dioxide and calcium are directly related to brined cherry quality. Improper use of these chemicals may result in cherries that are soft, poorly bleached, or spoiled due to fermentation (Payne, Beavers, Cain, & Station (1969)). Atkinson and Strachan (1962) pointed out other advantages of sulfur dioxide as a preservative. It is inexpensive and provides a quick method of handling large quantities of fruit. The

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http://dx.doi.org/10.1016/j.lwt.2016.08.059
0023-6438/

product may be placed in bulk containers for shipment, and the preservative is effective for a sufficient period of time to allow for storage and remanufacture. In addition, most of the sulfur dioxide can be removed easily and inexpensively before candying, so that this allergen is absent (Aptunion, internal analysis) in the glacé cherries. Moreover, storing for a long period without loss of fruit quality is one of industries objectives.

Firmness loss during fruit development is associated with cell-wall polysaccharide turnover (Brummell & Harpster, 2001). Cherry cell walls are modified in harvesting, whether after chemical ethephon treatment (Batisse, Coulomb, Coulomb, and Buret (1998)) or natural ripening-overripening mechanism (Batisse, Filslycaon, and Buret (1994)) leading to softness. Some of the genotypic variations in fruit firmness have been linked with differences in the patterns of cell-wall disassembly. For example, Cheol, Toivonen, Wiersma, and Kappel (2002) reported that soft varieties present lower total cell wall contents in fresh fruit. Taillan, Ambid, Pech, and Raynal (1992) demonstrated that pectic fractions were the main cell wall component modified during cherries storage in aluminium or calcium brines; fruits stored in calcium brine present a better firmness than in aluminium brine leading industry to continually improve brine formulation to increase the quality of stored fruits.

However, other factors have been reported to be important modulators for cherry post harvest behaviour. Richardson et al. (1998) reported that some harvest factors are susceptible to affect sweet cherries *P. avium* cv. Royal Ann texture, such as machine factors (pattern of tree shaking, duration of shakes, etc.), climatic conditions, crop loads, tree sizes or their spacing. Since this early work, no studies have attempted to evaluate the consequences of other harvest itineraries on the evolution of the quality of cherries in brine. Understanding the impact of the harvest conditions on cherry texture evolution during storage is of major importance for the industry. In the present study, evolution of firmness during brine storage was quantified according to the fruits maturity stage, the harvesting method, the ethephon application and the peduncle presence. Cytohistological investigations have been performed to follow the gross structural alterations during storage in brine.

2. Materials and methods

2.1. Plant material

Fruit of sweet cherry (*Prunus avium* L., cv. Napoléon) for industry were harvested in Provence (Lagnes 43° 53′ 39″ N and 5° 06′ 55″) in June 2013. Table 1 summarizes the different treatments and harvest conditions. Ethephon (PRM12, Bayer S.A.S, Lyon, France) was applied at 0.36 g L^{-1} on vigorous trees [conditions (1) and (2)], by high humidity and 20 °C (standard treatment). Untreated trees were also included in the study (conditions (3) and (4)). Cherries were picked at 10 “early” and 20 “late” days after treatment with ethephon corresponding to the beginning and end of the harvest. The fruits were harvested mechanically [condition (2)] or manually (1), (3) and (4) then immediately immersed in brine tanks (Type Aptunion, Apt, France) for storage with 50/50 ratio fruit/brine. Fruits (1) and (3) were stored in brine with their peduncle and fruits (2) and (4) without peduncle (Table 1).

Samples were taken at 0, 2, 5, 8, and 15 days and at 1, 2, 3, 4, 5, 6, 7, 8, 10 and 12 months in brine.

Table 1
: Summary of the different treatments and harvest conditions for the different sweet cherry samples. Ethephon was applied at 0.36 g l^{-1}; mechanical harvest stored in industrial container and manual harvest stored in bucket for practically. Each sample was picked at to maturity stage “early” and “late”.

Sample	1	2	3	4
Ethephon	+	+	−	−
Peduncle	+	−	+	−
Harvest method	Manual	Mechanical	Manual	Manual
Container (m^3)	0.025	3	0.025	0.025

2.2. Fruit texture characterization

For each treatment, 62 cherries (randomly chosen) were placed in holes, with the peduncle scar on top (Fig. 1). They were pitted with a texture analyser TA Plus (Ametek, Lloyd Instruments Ltd, Fareham, UK) using an 8 mm diameter probe moving at 20 mm s^{-1} for a course of 40 mm after first contact. The maximum load (Newton) during pitting, captured by a 250 N load cell, is our criterion to define the texture quality. It was chosen as the texture test as it is representative of the actual process, pitting being a critical point in the processing to glacé cherries, and presented a good correlation with a compression test such as routinely applied to other fruits, e.g. in Grotte, Duprat, Loonis, and Pietri (2001); Missang, Maingonnat, Renard, and Audergon (2011).

2.3. Physico-chemical characterizations

The total soluble solids (TSS) or Brix were measured in the brine with an ATAGO PR-1 Digital Refractometer (Atago Co., LTD, Tokyo, Japan). Indeed, brine TSS is complementary to fruit TSS due to the diffusion phenomenon that leads to an equilibrium state.

Calcium concentration in the brine was measured by Atomic absorption spectroscopy on a Varian AA 55 (Agilent technologies, Santa Clara, USA) equipped with an acetylene/nitrous oxide burner.

2.4. Microscopy

Cytohistological analyses were performed using tissue samples excised from median part of fruits going from exocarp to endocarp (Fig. 2). Immediately after excision all specimens were immersed in fixative solution consisting of 10% Acetic acid 10% Formalin and 80% Ethanol. To promote good penetration of the fixative product samples were subjected to vacuum for 20 min. After 48 h fixation at room temperature, the specimens were rinsed in distilled water and stored in 70% ethanol until required. They were then dehydrated in a graded ethanol series (80–100%) and embedded in methacrylate resin (Kit Technovit 7100, Heraeus-Kulzer GmbH,

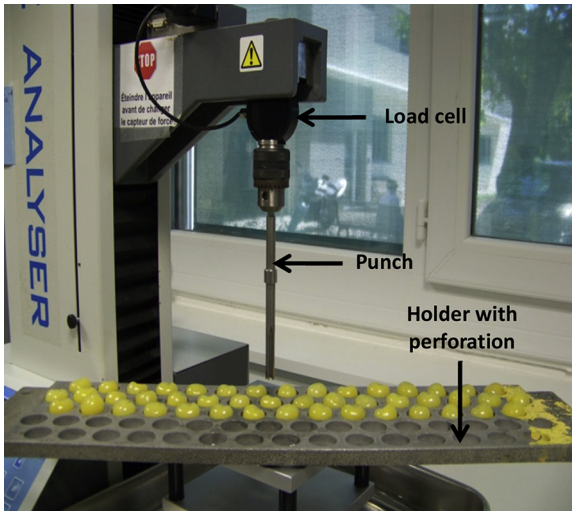

Fig. 1. Sweet cherry disposition and orientation for firmness measurements.