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# Identification of pre-harvest factors that affect fatty acid profiles of avocado fruit (*Persea americana* Mill) cv. 'Hass' at harvest

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ABSTRACT

'Hass' avocado is the most important avocado variety cultivated worldwide. In Chile alone, there are nearly 40,000 ha, distributed between the IV and VI regions, with production areas located close to both the coast and to the hills. Given the increasing competitiveness of fruit export markets, the quality of organoleptic attributes is a key issue in consumer acceptance. The quality of avocados is related to many attributes, especially oil content and firmness (among others), and these attributes are influenced by storage, growing and environmental conditions, as well as the stage of maturity/ripening.

This study measured the fatty acid profiles of avocado fruits during two seasons from 12 localities cultivated with the variety 'Hass.' Fifty additional variables were measured, including climate, nutrition, vegetative development, and agricultural management (called pre-harvest variables). The data obtained were analyzed with a partial mean squares multivariate regression (PLS). The analysis showed that the contents of oleic, palmitic, and palmitoleic acids were influenced by climatic and nutritional factors, with mean annual maximum temperature proving most important. In localities with lower temperatures, the 18-carbon fatty acid content increased, and the 16-carbon fatty acid content decreased. Moreover, the N and Mg contents in the mesocarp at harvest were related to the contents of palmitic and palmitoleic acids, and when the levels of N and Mg increased in the mesocarp, the 16-carbon fatty acid content decreased.

## 1. Introduction

Avocado (*Persea americana* Mill.) is a tropical-subtropical fruit that is highly appreciated worldwide. The main cultivar consumed is 'Hass,' which is produced by a large number of countries, with Mexico, Chile, USA, and Peru being the main producers. These countries have very different climatic conditions and management systems, which leads to great variation in the chemical composition of the commercialized fruit and in its postharvest duration.

Avocado fruit is unique in its nutritional value due to its high content of mostly unsaturated oils (Ozdemir and Topuz, 2004; Takenaga et al., 2008; Ariza et al., 2011; Donetti and Terry, 2014) that may reach approximately 79% of the fatty acids present in the mesocarp. Of these, 13.6% are polyunsaturated (Takenaga et al., 2008). The main fatty acids present in the mesocarp include monounsaturated oleic acid (50–60% fatty acid content), saturated palmitic acid (15–20%), unsaturated palmitoleic acid (6–10%), unsaturated linoleic acid (11–15%), and linolenic acid (near 1%).

A number of reports have indicated that the oil content and composition vary according to the location of the orchard (Landahl et al., 2009; Lu et al., 2009; Donetti and Terry, 2014), the variety (Ozdemir and Topuz, 2004; Takenaga et al., 2008), the number of days between flowering and harvest (Ozdemir and Topuz, 2004; Donetti and Terry, 2014), the dry matter contents (Requejo-Tapia et al., 1999), and even to the part of the fruit measured (Landahl et al., 2009). Additionally, Ozdemir and Topuz (2004) found that postharvest management affects the acid content, although the effect is small.

Donetti and Terry (2014) showed that Chilean avocados in the United Kingdom market arrive with oleic acid contents between 57% and 61% (those from Spain have 54–60% and those from Peru have 40–47%) and suggested that oleic acid content may serve as a marker of the place of origin of the fruit. Ratovohery et al. (1988) indicated that the fatty acid content of avocados depends on geography and climate. Similar results were reported in olive by Ranalli et al. (1999), who showed that the fatty acid composition depends on climate and soil factors. Requejo-Tapia et al. (1999) compared avocados grown in

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two areas, finding that the zone with the lower mean temperature had higher contents of monounsaturated fatty acid (oleic acid) and lower levels of saturated fatty acid (palmitic) than the zone with the higher mean temperature. Similarly, Canvin (1965) showed that oleic content increases with lower temperature in some seeded fruits. However, Requejo-Tapia et al. (1999) also indicated that temperature cannot be the only factor that determines the rate of lipid synthesis. To our knowledge, there are no studies that analyze by integrating different pre-harvest factors such as climate, soil and plantation management on the composition of fatty acids in fruit.

A strategy for differentiation in the world market is to sell healthy and efficacious products. This is only possible if the chemical characteristics of the product are well known. Thus, it is critical to understand the relationships between climate, soil, and management and the lipid composition of avocados to stimulate the development of these desirable fatty acids. The objectives of this study were to determine the pre-harvest factors that affect the bio-active fatty acids of avocado fruit var. ‘Hass’ in order to obtain homogeneous prime material for the industry and to add value to exported fresh fruit.

## 2. Materials and methods

### 2.1. Study locations

In central Chile, avocados are predominately grown in the valleys of the ‘El Maipo,’ ‘Aconcagua,’ ‘La Ligua,’ and ‘Petorca’ rivers. These rivers originate in the Andes mountain range and generally flow west to the Pacific Ocean. There are plantations in localities close to the sea (elevation 112 m) and others close to the mountains (elevation 1103 m); thus the climatic, topographic, and soil conditions of the plantations are widely variable. The mean annual maximum temperature may reach 23.3 °C in the highest zones and 18.6 °C near the coast (Table 1). We studied 12 localities growing ‘Hass’ avocados grafted on ‘Mexicola’ rootstock. Seven localities were in the ‘Aconcagua’ Valley, two were in the ‘El Maipo’ Valley, and two were in the ‘La Ligua’ and ‘Petorca’ valleys. These localities have different conditions of climate, topography, and soil and agricultural management, and thus account for different pre-harvest conditions on the fatty acid composition of the fruit at harvest. Table 1 indicates the climatic conditions of the areas in which the experimental sites are located.

### 2.2. Characterization of experimental sites and variables measured

Two homogeneous trees were used as a unit with three repetitions in each locality over two growing seasons (2012–2013 and 2013–2014). Each year in each repetition, the following were measured: a) nutrient content in leaves: N, P, K, Ca, Mg, Zn, Mn, B, and Cl; b) nutrient content of the mesocarp of harvested fruit: N, K, Ca, Mg; N/Ca, Ca/K, and K/Mg ratios; c) agro-climatic characteristics of each locality: annual solar radiation, relative humidity, reference evapotranspiration (Eto), mean annual temperature, absolute January maximum, absolute June minimum, maximum mean annual temperature, minimum mean annual temperature, and mean annual thermal amplitude; d) water applied to plants: total water applied, water applied in spring, and water applied in autumn and winter; e) vegetative tree development: trunk diameter and relative chlorophyll content in leaves (SPAD), index of leaf area, tree age, number of fruits per tree, number of sylleptic shoots, and days from 50% flowering to harvest; f) soil characteristics: percentage of sand, percentage of silt, percentage of clay and percentage of soil macropores; g) topographic characteristics: Universal Transverse Mercator (UTM) east, UTM north (UTMN), elevation, slope of plantation rows and orientation of plantation rows; h) agronomic management: level of tree pruning, application of growth regulators and level of tree ringing; and i) dry matter content of fruits at harvest.

Leaf analyses were performed in March and fruit analyses at harvest. To analyze leaf nutrients, samples of 60–80 fully mature and expanded leaves were obtained from each repetition from summer growth branches which had stopped development, thus we collected 3- to 4-month-old leaves at the end of autumn. For analyses of fruit nutrients, we sampled five fruits per repetition. Leaves and fruits were dried at 60 °C and ground. N content was analyzed using the Kjeldahl method; B by colorimetry; Ca, Mg, and Zn by atomic absorption spectrophotometry; and K by atomic emission spectrophotometry.

Temperature, relative humidity, wind velocity, Eto, and radiation were obtained from meteorological stations present in the orchards where the experimental sites were located. The amount of water applied was obtained from volumetric meters installed in the irrigation equipment and the amount of precipitation was obtained from the meteorological stations. The diameter of the tree trunks was measured with a caliper in March. The SPAD value was obtained from a mean of 50 leaves per repetition measured with a Minolta Model 502 plus instrument. The leaf area index was estimated from the photosynthetically active radiation (PAR) intercepted by the plant foliage at midday. The PAR measurements were measured once per year between August and September in a quadrant consisting of the trees of each repetition using a (Decagon model Sunfleck) ceptometer. The contents of sand, silt, clay, and calcium carbonate and the macroporosity were determined in each repetition in the first soil horizon. The sand, silt, and clay were measured by the method of Bouyoucos (1962) and calcium carbonate by the potentiometric titration method with acid. The macroporosity was calculated using the relationship proposed by Ball and Smith (1991). The topographic characteristics UTM, UTMN, elevation, slope, and row orientation were measured with a Garmin GPS model eTrex Vista HCx.

### 2.3. Fruit quality analyses

We sampled fruit from the three repetitions at the 12 localities when the fruit dry matter reached values close to 25.3 ± 1.5%. Oil was extracted from the fruit pulp, based on the methodology of Bligh and Dyer (1959), to obtain the fat or oil of the mesocarp by direct extraction with solvents under cold conditions. This process used 5 fruits per repetition (15 per locality) that were cut in half, peeled, and the pulp

**Table 1**
Climate characteristics of five experimental sites located in the low, middle, and high elevations.

| Zones | Altitude | UTME | RH | ETO | Temperature | | |
|---|---|---|---|---|---|---|---|
| | m.a.s.l | Km | % | | Average annual | Absolute maximum January | Average maximum annual |
| | | | | Mm year$^{-1}$ | °C | °C | °C |
| Low | 112 ± 5 | 283 ± 3 | 85 ± 0.0 | 796 ± 38 | 13.5 ± 0.6 | 25.7 ± 2.0 | 18.6 ± 0.7 |
| Lower middle | 161 ± 5 | 261 ± 3 | 85 ± 0.1 | 882 ± 2 | 12.8 ± 0.3 | 28.5 ± 1.8 | 20.7 ± 1.2 |
| Middle | 342 ± 5 | 308 ± 3 | 74 ± 3.1 | 1119 ± 25 | 14.8 ± 0.7 | 32.7 ± 0.1 | 23.2 ± 0.5 |
| High middle | 489 ± 5 | 322 ± 3 | 75 ± 0.0 | 1069 ± 9 | 15.6 ± 0.7 | 34.3 ± 0.3 | 24.4 ± 0.7 |
| High | 1103 ± 5 | 354 ± 3 | 55 ± 0.1 | 1931 ± 96 | 16.6 ± 0.7 | 35.1 ± 0.1 | 23.3 ± 0.7 |