CHANGES IN DIAMETERS OF SWEET CHERRY FRUITS DURING RIPENING PROCESS

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Abstract

The aim of this study was to learn the process of cherry fruit ripening, using analysis of changes in fruit diameter, and attempt to learn the mechanism of water-induced cracking of cherry fruit. It was found that an increase of fruit volume as a result of water uptake through the fruit skin was not critical factor in fruit cracking. The investigations of the fruit ripening revealed irregularities of this process. Constant changes in fruit hydration manifesting themselves in its capacity changes influence the local water balance. It might affect the existing turgor pressure of the fruit. The role, this pressure play in fruit cracking mechanism is discussed.

Keywords: Fruit cracking, fruit ripening, micromorphometric variability, cherry

Olgunlaşma Süresince Kiraz Meyvelerinde Çap Değişimleri

Özet

Bu çalışmada, meyve çapındaki değişimlerin olgunlaşma üzerine etkisi ve sudan kaynaklanan meyve çatlama mekanizmasının belirlemesi amaçlanmıştır. Araştırma sonuçları, kabuk yüzeyinden su alımı yoluyla oluşan hacim artışının meyvede çatlamaya neden olan kritik bir faktör olmadığını göstermiş ve meyve olgunlaşması üzerindeki gözlemler, bu süreçte bazı düzensizliklerin olduğunu koymuştur. Meyve su içeriğindeki sabit değişimler, meyve içi lokal su dengesinde farklılıklar yaratmıştır. Bu durumun turgor basıncını etkileyebileceği düşünülmüş ve bu olayın çatlama mekanizması üzerine etkisi tartışılmıştır.

Anahtar Kelimeler: Kiraz, Olgunlaşma, Çatlama, Mikromorfometrik Değişkenlik

1. Introduction

Fruit cracking is an important factor reducing the profit in production of sweet cherries (Vittrup Christensen, 1996). It is suggested that fruit cracking is related to rapid changes in fruit volume; this relationship is particularly close during 3-4 weeks before fruit harvest. Intensive changes in fruit size can be induced by entering water into fruit flesh cells through surface skin layers (Vittrup Christensen, 1976). The driving force for the water diffusion might have been the difference between the osmotic potential of the water on the fruit surface and of the juice within the fruit (Sekse, 1998a). However, some authors claim that absorption of water by fruit tissue is not an essential factor having effect on sweet cherry fruit cracking. Yamamoto et al. (1993) and Yamamoto and Satoh (1994) showed that the presence of the interior turgor pressure caused by the water movement from the root system to the fruit, was responsible for the fruit cracking. In this model the driving force causing fruit cracking is the turgor pressure, while the role of surface water covering the fruit is limited to causing destruction of structures of the fruit surface, i.e. epidermal layers and the cuticle (Sekse, 1998a). Regardless of reason causing the fruit cracking it is assumed that changes in fruit size are critical factors determining this phenomenon.

In order to measure microchanges in fruit size, very accurate equipment is necessary. In this experiment we studied changes in sweet cherry fruit diameter by Pepista 3000 system which can record microchanges in organ size.

2. Materials and Methods

The experiment was carried out in the spring of 2000 in a greenhouse of the Research Institute of Pomology and Floriculture in Skierniewice, Poland on 2-year-old ‘Kordia’ sweet cherry trees/PHL-A planted in 50-L polypropylene containers filled with a soil. Soil material was taken from an apple orchard from sod surface. This soil had low status of organic matter (1.3%), $pH_{(1MKCl)}$ 5.8 and optimal concentrations of available phosphorus, potassium and magnesium. Contribution of the particles of sand, silt and clay in the soil were 70.1%, 15.3% and 14.6%, respectively. The trees were drip irrigated when water potential in the soil drop below – 0.03MPa. Since planting, the trees were not pruned. In the experiment the changes of the fruits' diameters were measured on fruit growing the central zone of canopy using the Pepista 3000 system (Copa-Informatique, France). Six series of the measurements were done. In each series, a few fruit growing on different trees were chosen. Part of the fruits was exposed to the direct influence of water through their immersion. Additionally, changes in the diameter of the lateral branches were measured. The sensors measuring the changes were integrated with the electronic module gathering and transforming the signals. After the transformation the data were presented in the form of graphs illustrating the changes of the diameters of the investigated fruits and branches as time function.

3. Results and Discussion

The charts show the changes in diameter in relation to the initial value (the moment of sensor installation). The variability is expressed in millimeters. The vertical, intermittent lines mark the subsequent days of measurements.

Constant change of the diameter of plant's organs characterizes their growth. In Figure 1 (Graphs B and C) a day's and night's changes of the diameters of two cherry fruits are presented. In the day's and night's cycle are periods during which the fruit shrank and then swelled. The most intensive growth of the fruit was observed during the night time and was more stable in comparison with the day time, during which the intensity of growth was much lower, even shrinkage was noticed. Fruits as well as other plant organs retain their sturdiness and shape being well hydrated. It is the result of water pressure (Szweykowska and Szweykowski, 1994). Firmness of the cells (turgor) can change which depends upon their physiological state and external conditions. The changes of turgor result in either swelling or shrinking of the cells which is followed by the changes in size of various plant organs (stems, branches, trunks, roots, fruits).

Sunlight right after sunrise stimulates opening of stomata which were shut during the night and the plant starts transpiration. Transpiration intensity is dependent upon light intensity, insufficiency of air humidity, and soil moisture. Temporary shrinkage of fruits and branches is also observed under conditions of water deficiency in soil or during intense transpiration caused by strong sunlight (Antoszewski, 1974; Klamkowki and Treder, 2000a).

In this experiment the largest shrinkage of the examined fruit was observed before the noon (9-11 a.m.) (Figure 1). According to Antoszewski (1974) shrinking of fruits during the day depends upon level of solar radiation and is connected with water translocation to leaves, after the opening of stomata. Water withdrawal from cherry fruits during the day time was suggested by Kozlowski (1968) while investigating the day's and night's changes of their sizes.

The changes shown in Figure 1 repeated periodically in the subsequent days (Figures 2 and 3) and they are typical of other fruits (Tukey, 1962; Antoszewski, 1974; Vanniere, 1992; Klamkowski and Treder, 2000b). The changes can also be observed on other plant organs like stems, trunks and roots. Figure 4 shows the changes of diameter of lateral branch of a cherry tree (against the background of the fruit growth curve) which took place during seven days. It can be understood that the stem growth, as in the case of fruits, is rather uneven and the changes in diameter are similar to those observed in the fruits but they are smaller. The total growth of stem is also smaller compared with that of fruits. The fruits change their size more dynamically and in broader range than organs which contain mechanical tissue. Such changes were also observed by Garnier and Berger (1986) in

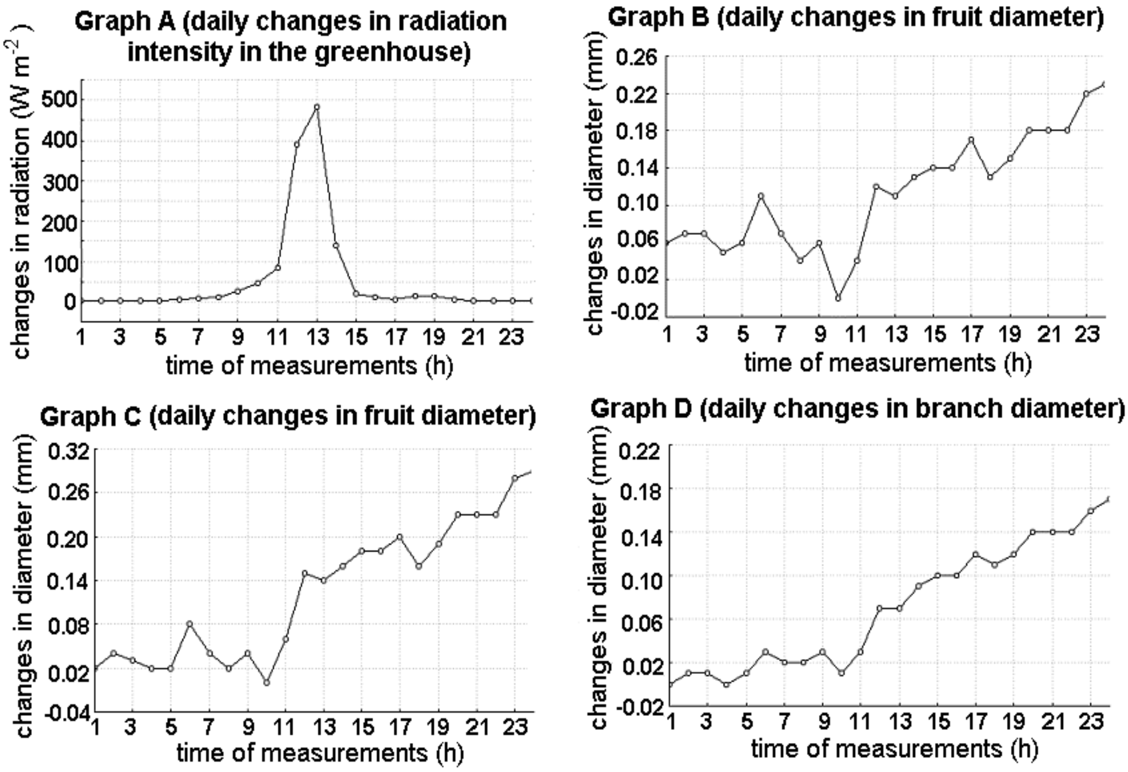

Figure1. Daily changes of solar radiation (A), diameter of fruit (B, C) and cherry branch (D).

peach trees, by Vanniere (1992) in stem of tangerine trees, by Michelakis (1997) in olive trees, and by Klamkowski and Treder (2000a) in apple trees. As it was in the case of fruits, the changes in the diameter of branches are related to level of solar radiation (Figure1, Graph D). This connection was also observed by Garnier and Berger (1986) in peach trees.

Analyzing intensity of solar radiation (Figure 1, Graph A) it is noticeable that the largest shrinkage of branches and cherry fruit took place before the maximum level of radiation. This phenomenon can be explained by a fact that after the sunrise, when transpiration increases, plant's organs start loosing their water accumulated in the tissues. As a result of this, a plant's organs start to shrink. When water is easily available, despite increasing solar radiation, loses caused by increasing transpiration can be supplied by water translocation. In his studies, Chaney (1981) observed that the transpiration stream flowing in the conducting units can be fed with the water stored in different parts of plant. Translocation of water, when it is easily available, can influence both a decrease and even suppression of water losses and restoration of original capacities by plant's organs and their further growth.

Figure 2 illustrates the differences in the rate of growth of sweet cherry fruits. The first fruit in the investigated time (7 days) increased its diameter about 1.2 mm, while the third fruit increased its diameter about 3.5 mm. According to Sekse (1998a), a rapid fruit expansion is related to high turgor pressure acting from inside the fruit, which in turn, is the main factor responsible for its cracking (Sekse 1995). We suggest that the differences in the rate of growth of the fruits shown in Figure 2 might be caused by their different water supplies. This is possible because some mechanisms located in the roots or in the tree may be responsible for that, e.g. differences in water absorbing capacity of the root zone or partly xylem discontinuity in the rootstock/scion grafting point, or mechanisms located in the fruit itself such as carbohydrate or nutritional element concentrations (Sekse 1998a).

Figure 3 presents the growth of a fruit in the course of 14 days. The curve is characteristic of not only of sweet cherry fruit; a similar one was observed by

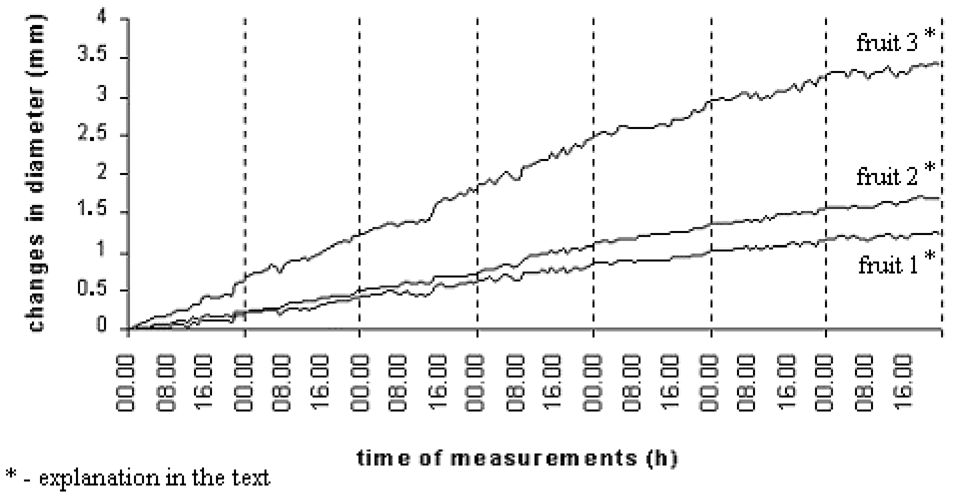

Figure 2. Changes in diameter of three different cherry fruits during ripening.

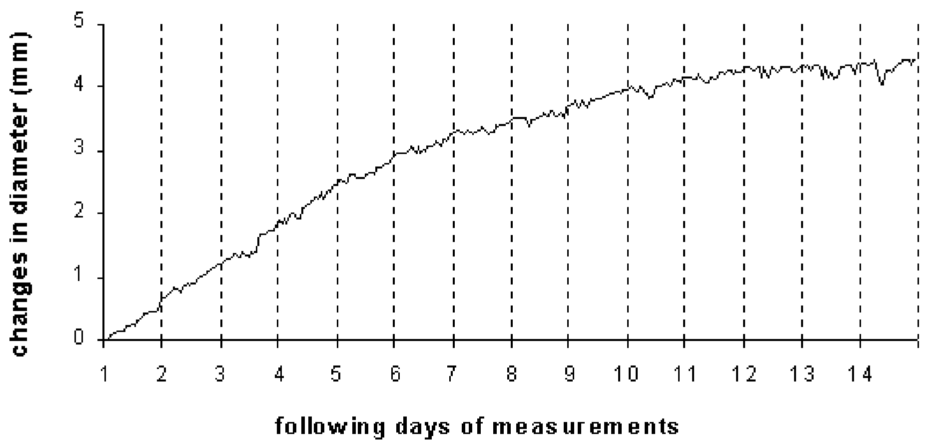

Figure 3. Changes in diameter of cherry fruit during its development.

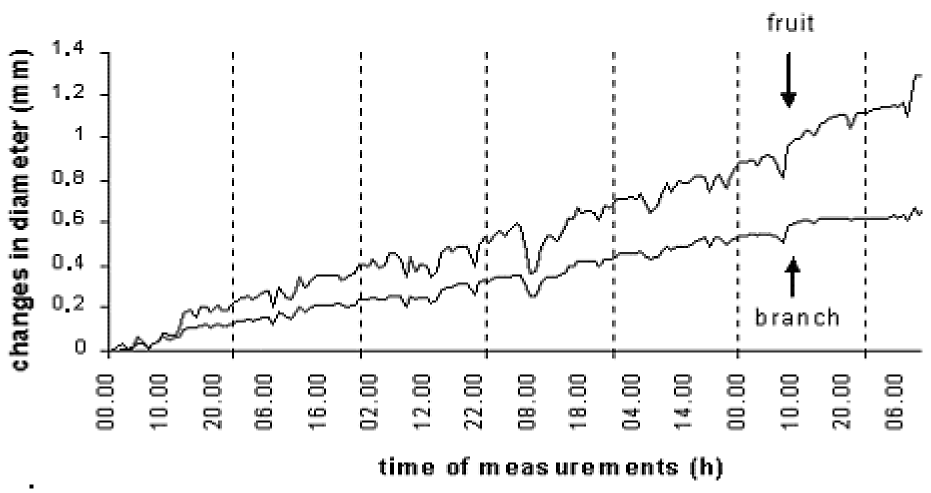

Figure 4. Differences in diameter changes of fruit and cherry branch.

Klamkowski and Treder (2000b) in strawberry fruit. The first stage of fruit development was an intense growth which lasted until the sixth day of measurements. During that time the diameter of the fruit increased about 3 mm. Next, the rate of growth slightly diminished, and since the eleventh day of measurements the total changes of the fruit diameter were hardly noticeable. Differences in the intensity of a day and night fruit diameter's change during various stages of its growth can be observed in this graph. In the final period of maturity when the fruit growth was minimal, the intensity of diurnal changes in its diametr increased (Figure 5). This dependence (lasting for about two weeks before harvest maturity) can be represented with a graph pictured in Figure 6. This phenomenon was not observed in strawberry fruit (Klamkowski and Treder 2000b). Increase of the intensity of the day's and night's changes in diameter in the final stage of maturity can be a moment in which the fruit becomes more susceptible to cracking. A larger irregularity of the process of water uptake by the fruit, can indirectly, according to Sekse (1998b), cause its cracking.

The fruit cuticle is a barrier to water and solute flow both into and out of the fruit. Water absorption through the surface of a fruit is a very important factor initiating the process of sweet cherry fruit cracking (Sekse 1995). Figure 7 presents the changes of the fruit's diameter after its immersion in water. A significant increase of the diameter (about

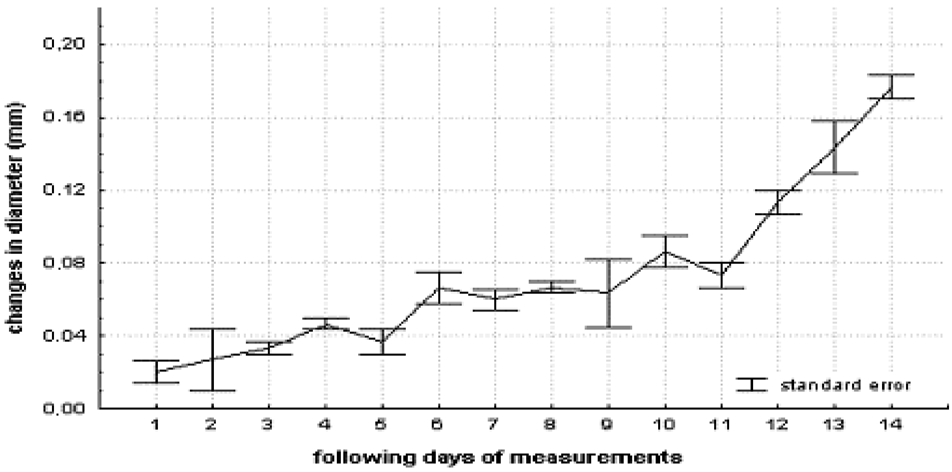

Figure 5. Average changes in fruit diameter in a period of two weeks before harvest

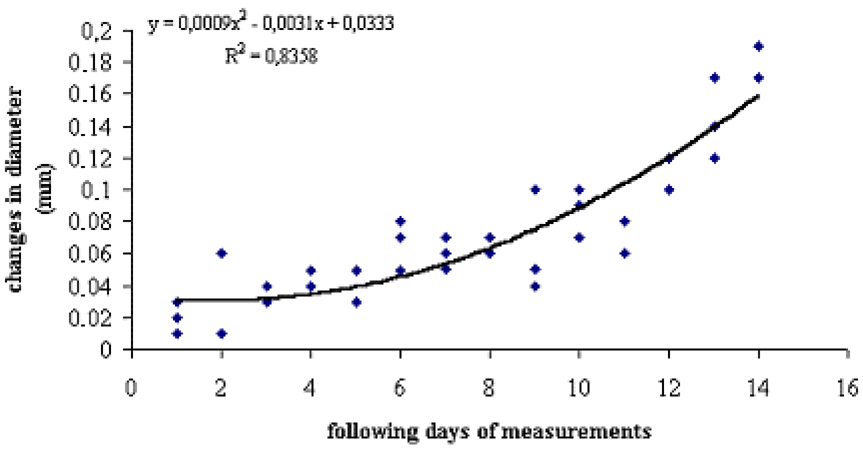

Figure 6. Relation between average changes in diameter and the stage of fruit development in the period of two weeks before harvest.

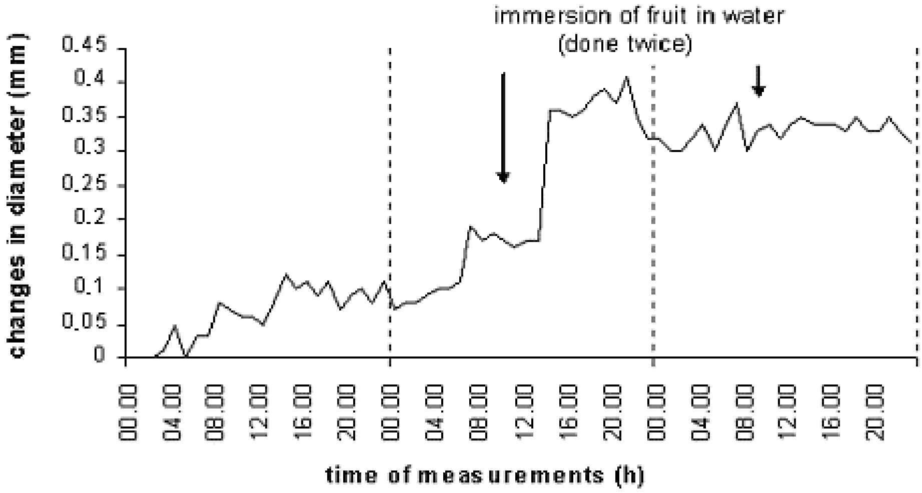

Figure 7. The effect of surface water on changes in fruit diameter.

0.2 mm) is observed right after the immersion of the fruit (2 p.m.). Water penetration through the skin of a fruit was also noted by Cline et al. (1995) and Belmans and Keulemans (1996). According to Sekse (1998a) water uptake through the surface of a fruit is far more rapid compared with that through the pedicel. Such a strong uptake of water by fruit may affect fruit cracking process; in some conditions it is enough to wet the surface of a fruit to trigger its cracking.

It is worth noticing that a fruit has some limited abilities to increase its capacity. The next day after its diameter got bigger, the fruit was immersed in water again, but no increase in fruit diameter was observed, only its typical daily changes (Figure 7).

In the above described experiment no fruit cracking was observed, although the fruit was in a direct contact with water. It confirms the thesis, which says that fruit swelling is not the main mechanism responsible for fruit cracking. The increase in fruit size caused by water uptake through the surface of the fruit was not sufficient to trigger fruit cracking.

4. Conclusions

A generally accepted theory took it for granted that sweet cherry fruit cracking was a direct result of water absorption through the surface of the fruit which in turn triggered its swelling and spontaneous cracking. Later experiments prove that this is a more complex process. As it has been shown in this experiment, water uptake through the surface of the skin does not have to cause fruit cracking, though the fruits can increase their capacity, which naturally diminishes the resistance of the surface layers. The investigations of the fruit ripening revealed its irregularities. Constant changes in fruit hydration manifesting themselves in its capacity changes influence the local water balance. It might influence the existing turgor pressure of the fruit. According to some authors this pressure is the main impulse triggering fruit cracking.

In further investigations it would be essential to focus on the methods of measuring the turgor pressure and define exact circumstances which cause the cracking. Some interesting conclusions could be obtained from microscopic observations of the surface of the fruit. It could be possible to watch the changes of the skin during swelling of the fruit which in turn could be the basis to work out new methods of controlling cuticle fracturing, ways to manipulate water penetration through the surface and to limit fruit cracking.

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