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THE IMPULSE RESPONSE METHOD FOR MEASURING THE OVERALL FIRMNESS OF FRUIT

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Abstract

Dynamic resonance frequency based on dynamic frequency response of excited peach was determined by peach physical properties, such as, peach firmness, peach mass, and day of harvesting. Analysis showed that dominant frequency increased with peach firmness increasing, and dominant frequency decreased with increasing of the peach mass.

Abstrakt

Resonanční frekvence dynamické odezvy broskví při rázovém zatěžování byla hodnocena jako funkce pevnosti broskve, její hmotností a dobou sklizně. Výsledky ukázaly, že zmíněná frekvence roste s rostoucí pevností broskve a klesá s její hmotností.

1 INTRODUCTION

Firmness has been used as a criterion for sorting fresh fruits and vegetables for many years. The methods used include squeezing between the fingers or hands, pushing a thumb into the flesh, biting and chewing, and the penetrometer method, generally referred to as a Magness – Taylor (M–T) or Effe-gi test. Because of the destructive nature of these tests and an increasing emphasis on quality, non-destructive methods have been sought to quickly measure individual fruit for sorting by firmness to obtain a more uniform pack of consistent high-quality fruit and facilitate timely marketing investigated.

Some promising non-destructive methods for fruit quality evaluation are based on measurement of fruit response to forced vibration. For example, Affeldt and Abbott [1], Van Woensel, Verdonck, and De Baerdermaeker [2], and others found good correlation between the resonant frequencies derived from vibration tests and the mechanical properties of fruits. Armstrong, Zapp, and Brown [3] caused mechanical impulse by striking an apple with a ball of wax. Young's modulus, which was calculated from the dynamic response, had a good correlation with the measurement in compression tests of specimens taken from the same fruit. Poor correlation was

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found with the results of a standard M–T test. Chen and De Baerdemacker [4] tested apples and concluded that the acoustic impulse response method appeared to be more efficient and accurate than random vibration methods. This is the main reason why these methods are currently more and more studied. The specific objectives of the research presented in the given paper were to: (1) analyze the response time signals and frequency signals of peaches, (2) find the effect factors on dynamic resonance frequency, (3) establish relationship between the dominant frequency and the physical properties of peach, such as firmness.

2 RESULTS AND DISCUSSION

Peaches (*Red Heaven*) were hand-harvested from the experimental orchard in the Department of Horticulture, Mendel University, on July 2007. Fruit was transported immediately to the laboratory. Upon arrival, three measurements (mm) at right angles were taken per fruit, for size determination. Firmness was measured based on the resistance of the fruit flesh to deformation by the puncture probe. The Magness-Taylor technique measured the maximum force to pierce the peach to a puncturing depth. Typical dependence force – depth of the penetration is shown in the Fig.1

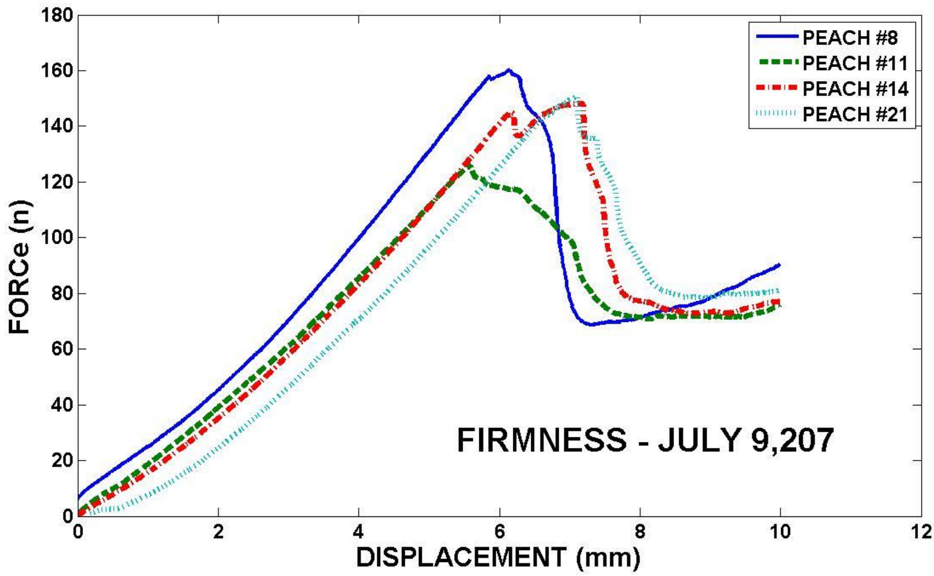

Fig.1 Example of the firmness measurement. The diameter of the penetrator was 11 mm

The maximum force, which is denoted as the firmness, depends on the date of the harvesting as shown in Fig. 2. Generally, the firmness decreases with the peach maturity.

The response has been measured using an experimental setup, which was developed and built to evaluate the resonance signal and analyze the frequency domain for peach fruit. The experimental setup consisted of a peach-bed, a mechanical impulse excitation device (a steel ball falling on the peach from a definite height), signal amplifiers, and a personal computer and software to control the experimental setup and to analyze its results. The peach response has been measured in terms of the surface displacement and/or surface velocity as well. The laser interferometer has been used. The signals were sampled at a rate of 200,000 samples per second for a period of 50 ms. The MATLAB computer program transformed the response from time to frequency domain (Fig. 3) by means of Fast Fourier Transform (FFT). A search algorithm was used to identify the dominant frequency (the peak frequency, where the response magnitude is the greatest) of the pear. A typical result is shown in Fig. 3.

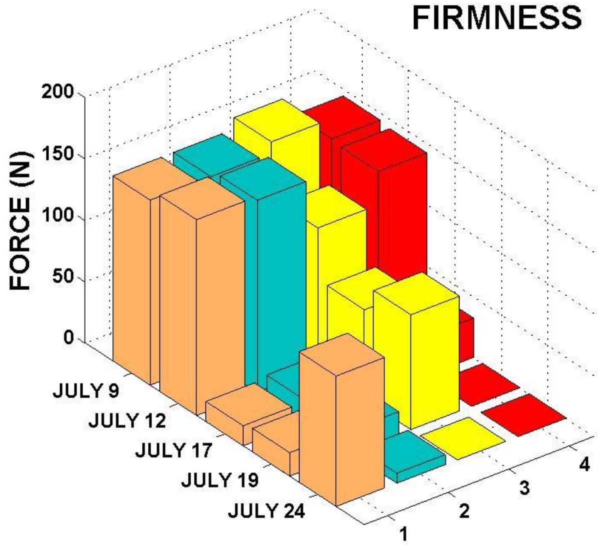

Fig.2. The firmness at the different days of the peach harvesting

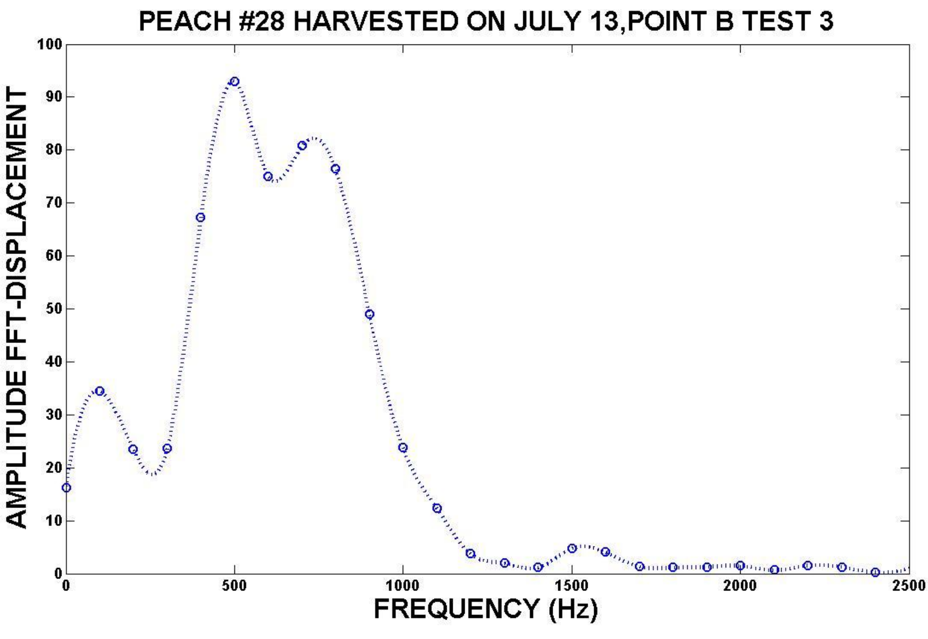

Fig.3. Example of the amplitude spectrum of the FFT displacement

The frequency at which the maximum of the amplitude has been observed has been denoted as a resonance frequency and/or dominant frequency, respectively. The detail analysis of the results shows that this dominant frequency decreases with peach maturity. It means this quantity behaves like the firmness. Impact orientation, detected orientation and impact velocity did not significantly affect dominant frequency.

3 CONCLUSIONS

The presented results suggest that the response of the peach to some dynamic excitation (steel ball impact) can be used for the peach maturity evaluation. Namely the frequency response seems be very promising. Dominant frequency increased with peach firmness increase, and dominant frequency decreased with increasing of peach mass. The better relationship was obtained between dominant frequency and peach firmness or peach mass, and stiffness coefficient regressed on Magness–Taylor firmness had a good relationship as well. The peach firmness could be considered as detectable by using the dynamic resonance frequency analysis.

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