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Acoustic resonance analysis for quality characterization of fruits and vegetables

Acoustic resonance analysis is a method which is successfully implemented in various industries for non-destructive quality assessment of different materials like roofing tiles or break discs in series production. The purpose of current investigations at Leibniz-Institute for Agricultural Engineering Potsdam-Bornim e.V. (ATB) in association with RTE Akustik + Prueftechnik GmbH is the adaption of this method for non-destructive quality determination of fresh fruits and vegetables.

Keywords
Acoustic resonance analysis, non-destructive, quality

Abstract
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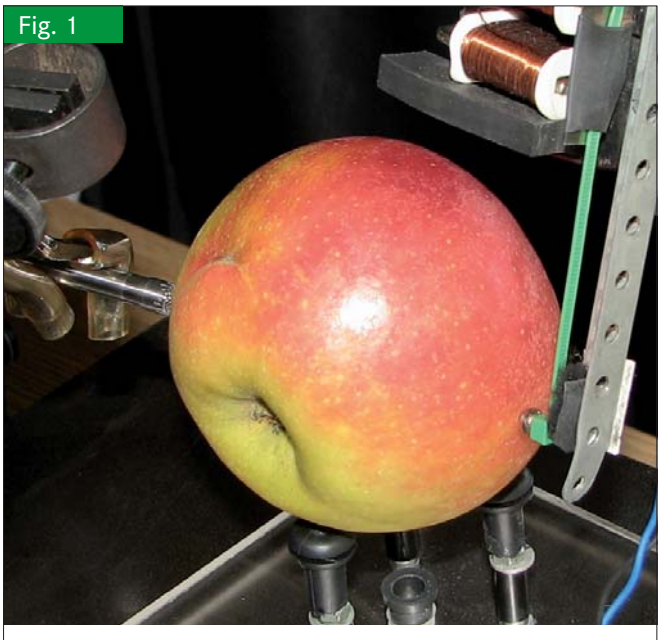
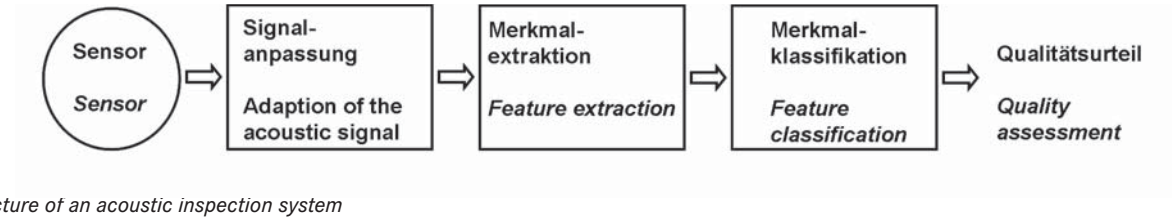
Since several years consumers increasingly demand for higher quality of fresh produce as a result of preferring a healthy and balanced nutrition. Growers endeavor to satisfy this requirement by using highly specialized sorting and grading machines. At this time the detection of external quality parameters like size, shape, color or surface state is feasible with high velocity and certainty. But the prevention of consumer disappointment because of poor inner quality gains in importance. Therefore physiological or mechanical damages during storage or conditioning processes have to be identified comprehensively and reliably. One of the most important quality attributes for quality characterization in fruit and vegetables

Fig. 1



Acoustic resonance analysis of an apple. Photo: ATB

Fig. 2



Structure of an acoustic inspection system

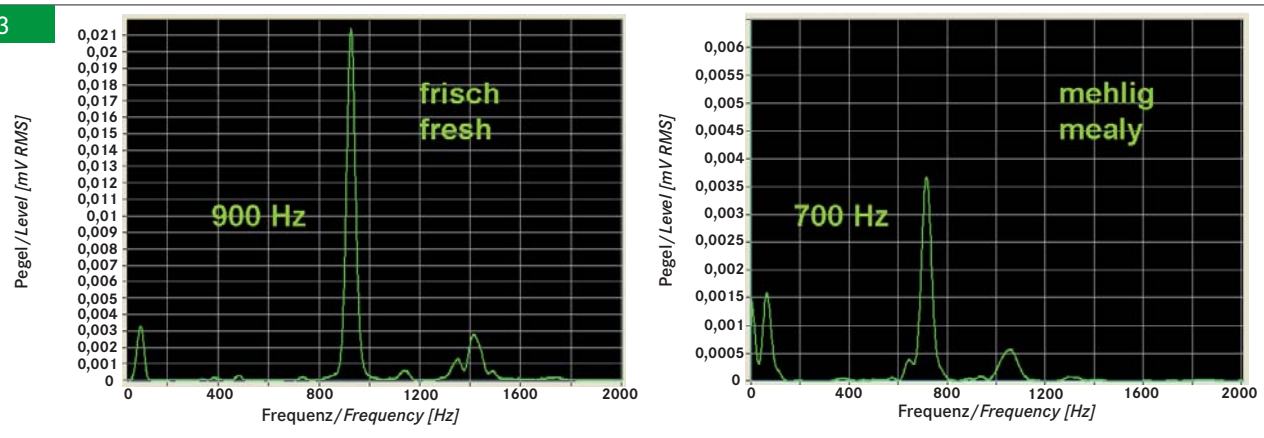
is texture. Comparing a firm and crisp apple with a soft and mealy one, the first one will be judged of higher value by consumer. Traditionally destructive methods are used to determine texture. The major disadvantage of these invasive methods is that it is not possible to examine a sufficient sample number resp. every single fruit. Existing non-destructive methods use sample surface elasticity but the results show only few correlation with Magness-Taylor (MT)-firmness measurements. The detection of internal tissue failure like mealiness in apples or woolliness in peaches is still an unsolved task. A promising approach could be the method of acoustic resonance analysis (**figure 1**). According to a physical effect a body will swing with its characteristic frequencies after a suitable excitation. Studies of almost spherical bodies indicate a close relationship between the first resonance frequency and the elastic properties of biological tissues which can be used to describe the stage of fruit development, the ripeness stage or the fruit firmness [1; 2; 3]. The aim of our investigation is the adaption of this method for internal quality characterization of fruit and vegetables.

The RTE Akustik + Prueftechnik GmbH has developed a method to detect defects in industrial products on the basis of acoustic resonance. Instead of analyzing roof tiles manually and subjectively they made it possible to classify them standardized and objectively. At the end of the manufacturing process the clay roofing tile passes the acoustic testing unit on a conveyor belt and gets classified automatically by comparing its characteristic frequency spectrum with spectra of known high-quality roofing tiles. **Figure 2** shows the typical functional structure of an acoustic inspection system [4]. The main difficulty for the successful implementation of this method into the current process was the raw material. Due to natural variations in the material composition the analysis of the characteristic response frequency spectrum was influenced and therefore more complicated [5].

The object of current investigations is the detection of inner quality defects or tissue changes by using mealy apples exemplary. Therefore defined stored samples were automatically and repeatable tapped with a clapper. The resulting mechanical vibrations (audio: ~ 20 Hz – 16 kHz, ultrasonic: > 16 kHz) of the sample can be detected with contacting or non-contacting sensors. Filter and amplifier convert them into suitable electrical signals. In the next step features were extracted and the basis for classification algorithms (specific acoustic parameter: finger prints) was calculated with the specially developed software SR20 AT (RTE, Pfinztal). Additionally, destructive and organoleptic investigations were performed simultaneously to determine if the apples were mealy or sound.

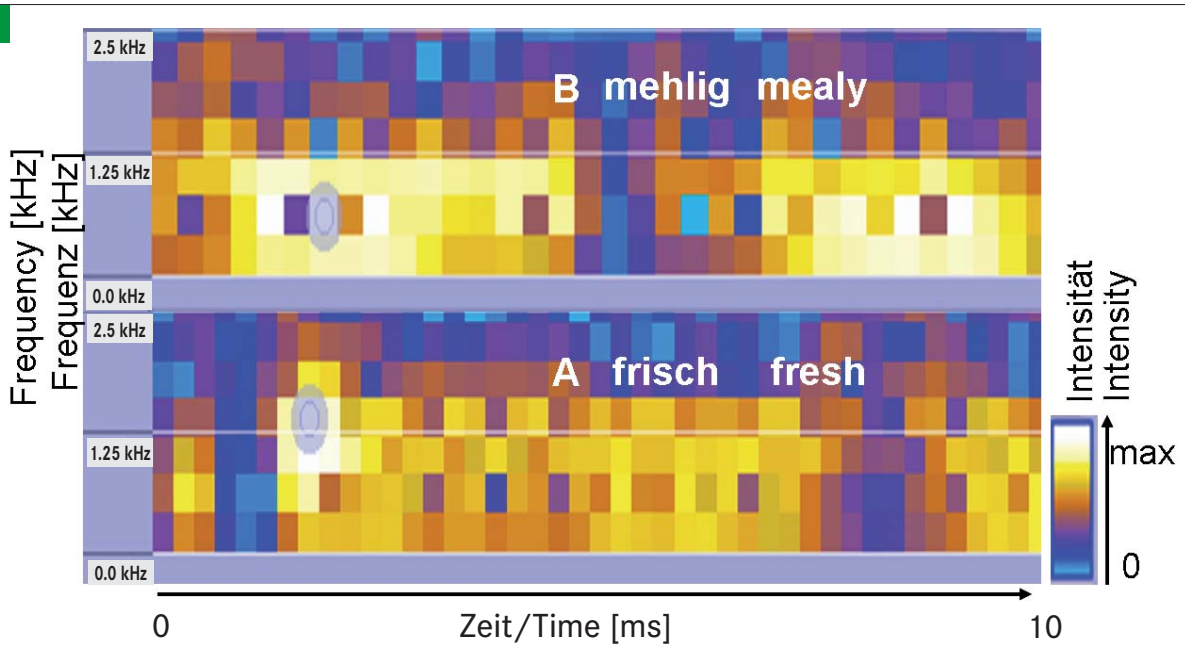
The precondition for a successful adaption of the roof tile characterization method for apple quality determination was the optimization of sensor technology on the spherical geometry of apples and the ambient measurement conditions. The excitation of the sample has to be realized without causing injury. Furthermore, to be able to distinguish between sound and mealy apples, textural specifics have to be of acoustic relevance. In Figure 3 and 4 the resonance behavior of an apple before and after storage period of four weeks at a temperature of 20 °C and a relative humidity of 95 % is shown. The shifts of single characteristic frequencies in the power spectrum (**figure 3**) as well as differences in the spectrogram (**figure 4**) indicate that the preconditions for an adaption of this method are given.

Fig. 3



Power spectra of an apple before (left) and after a storage period of four weeks (20 °C, RH 95 %)

Fig. 4



Spectrogram of an apple before (B) and after a storage period of four weeks (20 °C, RH 95 %)

Conclusions

The acoustic resonance analysis is a volume-oriented and qualitative method that compares the actual state with trained pattern. By using comprehensive algorithms the analysis of characteristic vibration behavior, the determination of single frequencies, and the changes of signal density with time are feasible. Physiological changes in tissue structure are detectable with the used device. Further investigations are necessary to classify products in current process.

Literature

Books are signed with ●

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