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METHOD FOR MEASURING FRUIT FAILURE CAUSED BY DIFFERENT MECHANICAL LOADS

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Abstract

There are different limit values of mechanical effects causing bruise or failure of fruits during the variety of processes: the allowable drop height (fruit harvesting), the static load of fruit column at storage bin, or maximal vibration acceleration while transporting. To reproduce each forces from manipulation, different measuring devices have to be employed. Using the DyMaTest instrument, we can analyze the failure mechanism of fruits producing various load-functions: constant, linear or cyclic waveforms. With a developed measuring method, we have the opportunity to determine the fruit's failure parameters, and compare the deformation graphs using different compressive loads.

Keywords

material testing, fruit processing, bruise investigation

1. Introduction

When mechanical injury remain undetected, the quality of the product decreases, and in some cases, this leads to the spoilage of the fruit, which can infect other crops in the storage bin. If the injured horticultural product can be recognized, we can remove it from the process. For this purpose, there are several effective image and thermal processing methods developed (e.g. discriminate bruised and non-bruised apples with visual and near-infrared spectroscopy [1] or detecting early-bruises using hyperspectral data and thermal imaging [2]). The damage often appears inside the fruit texture (e.g. enzyme browning inside apples and pears – [3] or hidden bruise on kiwi fruits [4]), the spectral investigation is also adaptable for this occurrence. These methods are able to spot the damaged fruits effectively, but if we want to reduce the losses, the mechanical injuries must be prevented. For this reason, the processing environment and the manipulating equipment must be designed properly (e.g. determine the optimal depth of hamper during transportation [5] or designing appropriate displacement components for tree-shaker systems [6]). Therefore, it is essential to reproduce the mechanical effects of manipulation in laboratory conditions.

Biological yield occurs, when the mechanical stress is step over the allowable limit value, and a tissue failure appears. This also means the destruction of fruit. The mechanical loads are very often come about repeatedly (e.g. during transport). Exposing the product to a periodic mechanical effect, the fruit texture is getting fatigued, and the biological yield point can be reached sooner. Loading the product with such an effect, the deformation is also periodic [7]. Besides the magnitude, the frequency of mechanical load also have a major role in emerging bruises.

Beyond the non-destructive examinations (e.g. vibration tests for determine stiffness factor [8, 9]), destructive techniques must be applied for study the failure mechanism of biological materials. Many measuring equipments developed to produce different mechanical loads. There are quasi-static compression devices like the Magness-Taylor hand-held penetrometer and the MGA-109 electronic penetrometer for off-laboratory field measurements, or the precision penetrometer for laboratory investigations [10]. To produce dynamic effects, impact tests can be executed, or we can use laboratory devices to create dynamic or cyclic force, loading the crop surface with a measuring pin. For our study, we using a computer-controlled compressive testing instrument called DyMaTest [11]. Applying this instrument, the effects of static, dynamic and periodic loads on fruits can be investigated.

2. Methods and materials

Most of the conventional material testing devices generating static load or low-rate deformation, the oscillatory instruments produce only periodic loads. Our instrument has all these abilities. Besides the linear load, DyMaTest can produce sinusoidal, saw-tooth and square signs in single or multiple sweep mode. Deformation can be measured with a laser sensor, the measurement data collected and displayed by a computer. The fruit sample placed into a sand bed during the examinations. The measuring circuit and the scheme of the measuring set-up are shown at Figure 1.

For most of our tested fruits or tubercular roots, approximately 10 N of compressive force needed during measurements. For rheological tests, the commonly used Ø 4 mm, 5 mm and 6 mm loading pins are available for the device. The technical specifications of DyMaTest instrument can be seen at Table 1.

With the PC measuring system, the force set-up and data acquisition can be executed in calibration and data handling (saving and loading) modes. The results of measurements can be seen immediately with the software's graphic chart (e.g. force-time, deformation-time and force-deformation functions), and the saved data can be exported and processed with other software.

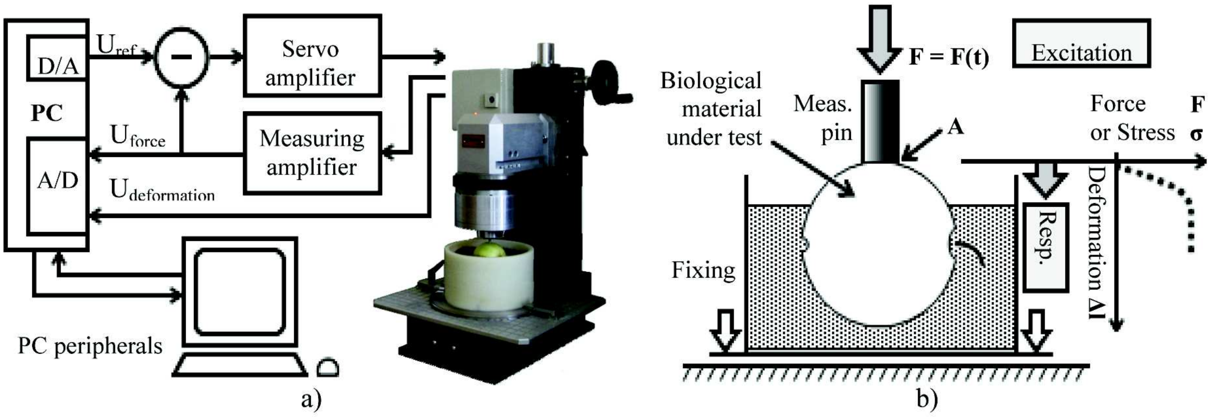

Figure 1. a) Measuring circuit, b) scheme of the measuring set-up [11]

Table 1. DyMaTest specifications

Max. compressive load	15 N
Force transducer	Low-mass special strain gage force transducer
Load	Single or periodic function
Force-time functions of the load	Constant load, linear up/down load, sinusoidal load, square-wave load
Deformation range	Max.10 mm

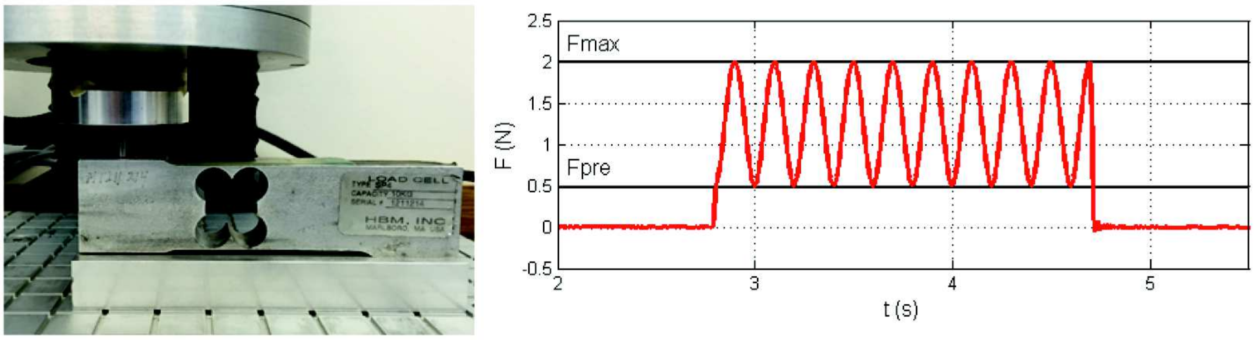

Figure 2. Adjusted periodic compressive load measured with HBM load cell

To provide the same contact circumstances on each examined fruit sample, there is an adjustable preload setting placed in the PC software's user interface. The periodic graph in Figure 2. is showing the relation between the compressive load (Fmax – set to 2 N) and the preload value (Fpre – set to 0,5 N), measured with a HBM SP4 type 100 N load cell.

3. Results and discussion

Our tests implemented in pears with different load functions, the results can be seen at Figure 3. The adjusted force-time functions marked with dashed line, the fruit texture's deformation indicated with solid line. Generally, we study the examined fruit's deformation-time function in our thesis.

Using a developed method, the "failure point" of the tested fruit (e.g. the graph endings placed the "bruise during test" column at Figure 3) can be defined. A deformation graph of an examined pear exposed to periodic load is shown at Figure 4. The periodic load has a constant amplitude, but the resulting deformation has a non-constant amplitude and time varying average. The enveloping or the average curves have a similar character to the creeping caused by a constant load, therefore, we can call this phenomenon to dynamic creeping [12].

Two different parts can be separated here. At the starting point of the second section (from point A - the phase of failure), the fruit texture is getting softened, and a fracture is beginning on the tissue. The end of the curve (point B) is showing, that the peel is teared through, and a permanent deformation occurring. The failure point can be defined between the two parts of the exponential regression curve (A), or at the breaking point of the peel (B - which is the ending of the deformation graph). The point between the two sections is more difficult to determine, because the failure probability has to be examined by studying the fruit spoilage process.

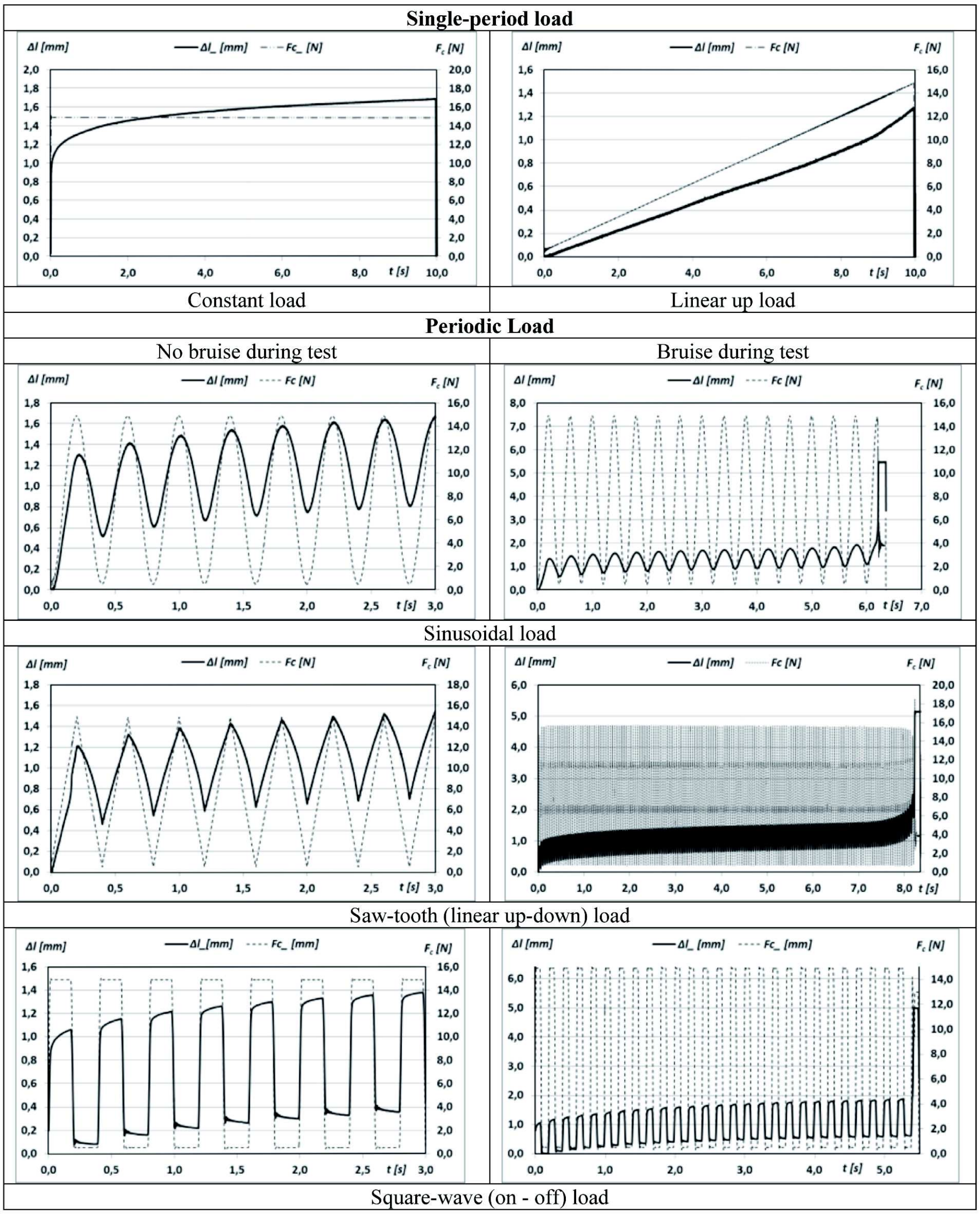

Figure 3. Deformation of pear texture measured with different compressive loads [11]

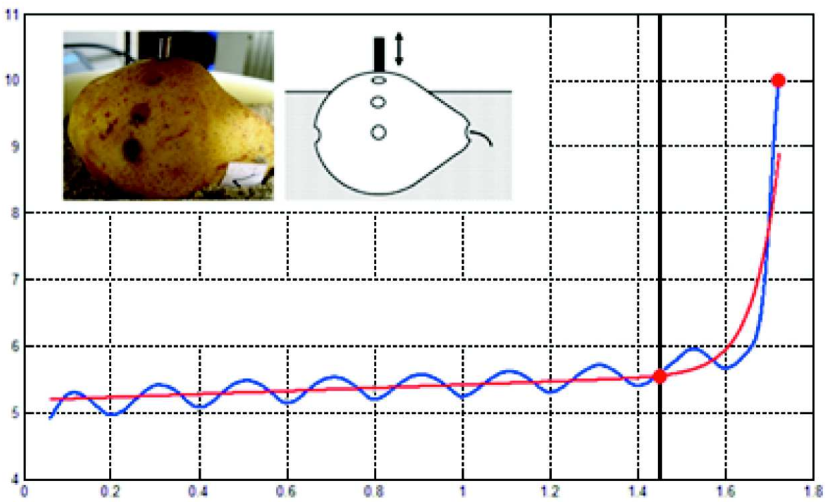

Figure 4. Dynamic creeping caused by periodic load

4. Conclusions

Beyond the static examinations, we are able to study the dynamic viscoelastic properties of fruit materials or plastics with our measuring system. Using cyclic mechanical loads, the fatigue phenomenon of biological materials can be investigated. With the resulted deformation functions, elements for a rheological model can be determined. We are also able to examine the damage susceptibility of specific fruits, influenced by different parameters of compressive load forces (e.g. frequency or wave-form). A more complex factor-analysis can be made, if we take in consideration other fruit properties, such as storage temperature, ripening status (related to moisture content) or spectral data. If we have a more accurate history of mechanical impacts effecting the crop (e.g. using a measuring fruit), we can reproduce the force values with generating stochastic loads.

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