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A Novel System for Measuring Damaging Impacts on Table Olives

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The consumer today demands high quality products; fruit with defects or in poor condition generate dissatisfaction and a consequent reduction in consumption.
In recent years, interesting systems have been used (i. e. "artificial fruit") in order to identify the cause of damage during mechanical harvesting and/or post-harvest operations.
In this paper, the authors present a new system designed to measure the impacts received by table olives in the processing stages from harvesting to packaging.
The device is an instrumented sphere designed and implemented by the Agricultural Mechanics Section of the Department of Agricultural and Forest Sciences, University of Palermo, Italy. It contains a triaxial Micro Electro-Mechanical Systems (MEMS) sensor capable of acquiring acceleration from a few mg to 400 g (where g is the gravitational acceleration). It has a microcontroller with software developed for the specific application, a 16 bit A / D converter that allows a resolution of a few mg, a mini-USB port for connection to a master, which is connected to the PC via a common USB port. The master communicates with the sphere to download the data and to adjust parameters such as the data acquisition frequency, which can reach up to 1 kHz (50 Hz, 100 Hz, 400 Hz and 1 kHz).
Preliminary tests performed on the functionality of the acquisition system show that the information obtained by the instrumented sphere are useful for identifying the stresses the fruits are subjected to during harvesting and post-harvest.

1. Introduction

In recent years, interesting systems such as "artificial fruit" have been used to identify the cause of damage during mechanical harvesting and/or post-harvest operations. Bruising caused by post harvest treatments is a common problem in the long marketing chain of many fruits and vegetables (Sablani et al., 2006), as the consumer choice is strongly influenced by the presence of defects. Mechanical damage also accelerates physiological processes, which lead to senescence and spoilage (Moretti et al., 1998) as well as loss of nutritional value (Wilson et al., 1995).
The most commonly used systems, which mimic the physical properties and mechanical responses of fruits are instrumented devices containing accelerometers. They represent the response of fruit and vegetables during harvest and post-harvest handling. Arazuri et al. (2010) used an impact recorder device (IRD) sensor to assess several tomato harvesters evaluating the impacts during mechanical harvest with a wireless sensor, to determine the critical points at which damage occurs, and to assess the damage levels. Bajema and Hyde (1995) used an instrumented sphere (IS) to analyze the handling impact characteristics of five eastern Washington State summer sweet onion packing lines determining the onion bruise thresholds. Peach bruise thresholds using the instrumented sphere were also studied by Lin and Brusewitz (1994). An electronic beet to evaluate sugar beet damage at various forward speeds of a mechanical harvester was developed in Italy by Bentini et al. (2002) while Canneyt et al. (2003) used the Danish made PTR 200 instrumented sphere as a potato-shaped instrumented device; Ferreira et al. (2006) used the 70 mm diameter instrumented sphere by Techmark inc. to evaluate the critical points of citrus sorting lines that were identified at the receiving step and

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at the transfer of the fruit to the container for storage. The same device was used by Valentini et al. (2009) to evaluate persimmon quality on packing line for drop impacts. Also mango fruits were detected by firmness on a conveyor belt built for a packinghouse using an instrumented sphere as detector in Hahn (2004). Ragni and Berardinelli (2001) and Sober et al. (1990) studied the apples mechanical characteristics. The first evaluated the mechanical behaviour of apples of four cultivars, and their damage during sorting and packaging, while the second determined peak acceleration and velocity change of the fruit in commercial apple packing lines. Zapp et al.(1990) developed an 89-mm diameter self-contained, instrumented sphere to record its impacts while handled with like-sized commodities (apples, pears, peaches, oranges).
On the basis of the above, several systems are available today on the market to permit the capturing of information about the accelerations of the device which represents a given fruit. These systems are quite versatile and widely used for fruit in general.
In addition to this, there is the current trend of monitoring the damage suffered by a fruit during its processing with particular reference to post harvest treatments (Aiello et al., 2012a) to improve the product quality (Catania et al., 2013a) and control the production process (Catania et al., 2013b) and as well as the ambient parameters (Carrara et al., 2008).
The main limitation of the systems available on the market is the size and weight of the device which do not allow targeted use in the study of the stresses suffered by "small" fruits.
The aim of this study was to develop an innovative-instrumented sphere representing a table olive which is considered a “small fruit”, in order to study the stresses and shocks suffered by the fruit from harvest to processing.

2. Materials and Methods

2.1 Description of the system

The proposed system was developed at the Agricultural Mechanics Section of the Department of Agricultural and Forest Sciences, University of Palermo, Italy. A slave sensor node was realized and installed; this is a microelectronic system for conditioning the electrical signal emitted by the transducer. The sensor node is equipped with an analog to digital converter A / D, a microprocessor and a local memory; it digitizes the signal which can be transferred to the "master" ensuring the accuracy and reliability of the acquired data. The signal is verified with Error Correction Code (ECC) techniques included in the communication protocol.
The measuring system is made up of a sensor node, 20mm diameter, with a MEMS (Micro Electro-Mechanical Systems) sensor inside (a triaxial accelerometer) able to record acceleration from ±1 g to ± 400 g (where g is the gravitational acceleration) (Figures 1 and 2). The full scale can be modified choosing between ± 100, ± 200 or ± 400 g through a graphic interface. The device is equipped with an internal microcontroller with a crystal in which the software developed for the specific application is loaded. It manages and processes the data revealed by the MEMS sensor (Aiello et al., 2012b).

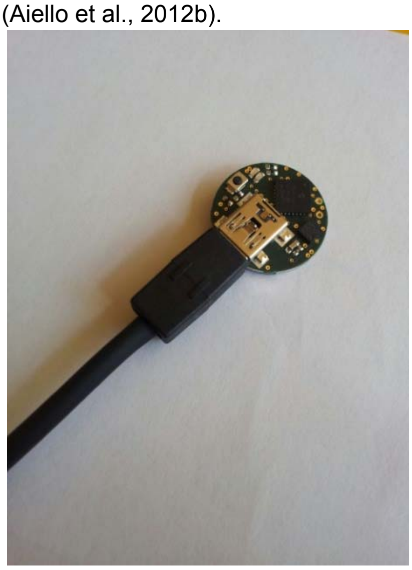

Figure 1: Sensor node with triaxial accelerometer

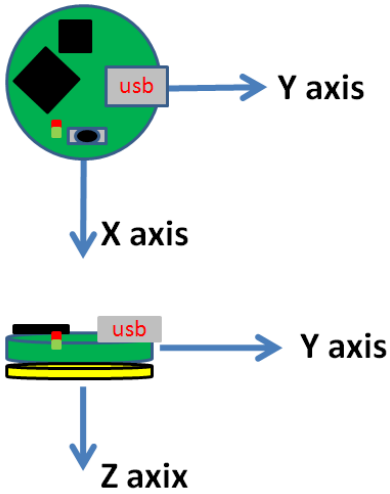

Figure 2: Device coordinate system

Figure 3: Sensor node placed in the middle of a foam sphere (35 mm diameter and 6 g weight) to represent a table olive Cv. Nocellara del Belice

The sensor node was placed in the middle of a foam sphere with a diameter of approximately 35 mm and 6 g weight (Figure 3), in order to represent a table olive Cv. Nocellara del Belice which is one of the most important varieties in Italy (Catania et al., 2014) whose characteristics are shown in Table 1.

Table 1: Olive fruit Cv. Nocellara del Belice characteristics

Character	Value[a]
Fruit longitudinal diameter [mm]	19.0 ± 0.6
Pit longitudinal diameter [mm]	10.9 ± 0.5
Mesocarp thickness [mm]	8.1 ± 0.9
Fruit mass [g]	5.5 ± 0.6
Pit mass [g]	0.9 ± 0.2
Mesocarp mass [g]	4.6 ± 0.5

[a] Numeric values are means ± standard error of thirty replicates

A 16 bit A / D converter allows a resolution of a few mg (for instance range ± 100 g -> 2 x 100 / 65,536 = 3,051 mg); a mini-USB port allows connection with a master which in turn is connected to the PC via the common USB port (Figure 4). The main components of the system are: a microcontroller (µC) a Ferroelectric RAM (FRAM), a Micro Electro-Mechanical System (MEMS) containing the triaxial accelerometer, a low dropout linear voltage regulator (LDO), a battery (BATT), two LED lights indicating that the device is working (LED1 and LED2) and a switch (SW).

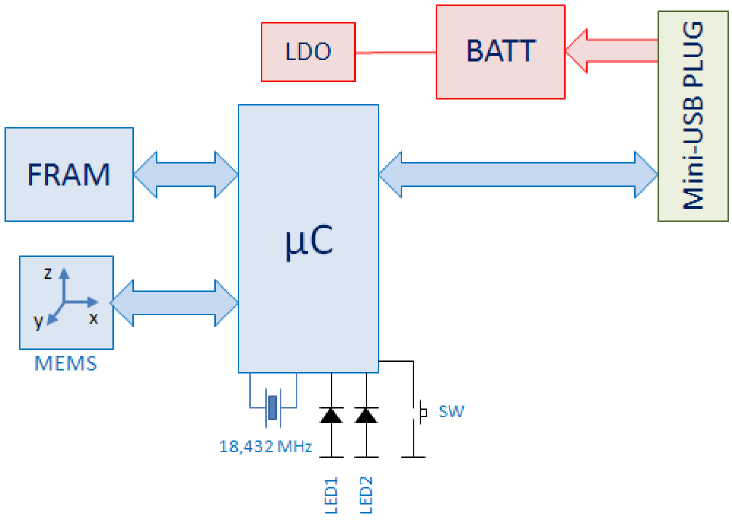

Figure 4: Block diagram of the device developed

The sampling is managed by the microcontroller and set via the software interface through the master to load and download commands and device data. The master communicates with the device to download the data and to change parameters such as data acquisition frequency which can reach up to 1 kHz (50 Hz, 100 Hz, 400 Hz and 1 kHz). A memory bank within the system can capture 20k samples (e. g. at 1 kHz for 20s), depending on the sampling frequency. The system can be configured depending on practical use, namely it can be activated to acquire data in different ways: time logger, after pressure switch and acceleration threshold exceeded. The microcontroller transfers the acquired data to an internal memory of appropriate size. The choice of the electronics of the system was conditioned by its size and weight. The device is equipped with a rechargeable lithium battery via pc, with a range of about 30 minutes in continuous acquisition, depending on the sample rate. The battery can be recharged by connecting the master to the computer and by placing the node in "charge" mode.

2.2 First laboratory tests

The first trials were carried out at the Laboratory of Agricultural Mechanics of the Department of Agricultural and Forest Sciences, University of Palermo, with the aim of testing the system.
After setting up the device, tests were performed to monitor the accelerations of the sphere during its drop from a known height, equal to 1.00 m, onto a hard surface. The tests lasted 6 s; the data acquisition frequency was 1 kHz.

3. Results

The results of the first laboratory tests performed with the novel instrumented sphere are shown in Figure 5 with the software screen. It shows acceleration vectors on X, Y and Z-axes [mG] as a function of time (milliseconds) throughout the laboratory test lasting 6s, during which the impact on a hard surface occurs.
Note that the impact on the hard surface is recorded 2,030 ms after starting. On the X-axis acceleration reaches 393,450 mG, on the Y-axis we have 388,086 mG and on the Z-axis 108,709 mG. Several rebounds and the relative peaks are recorded after the first impact.

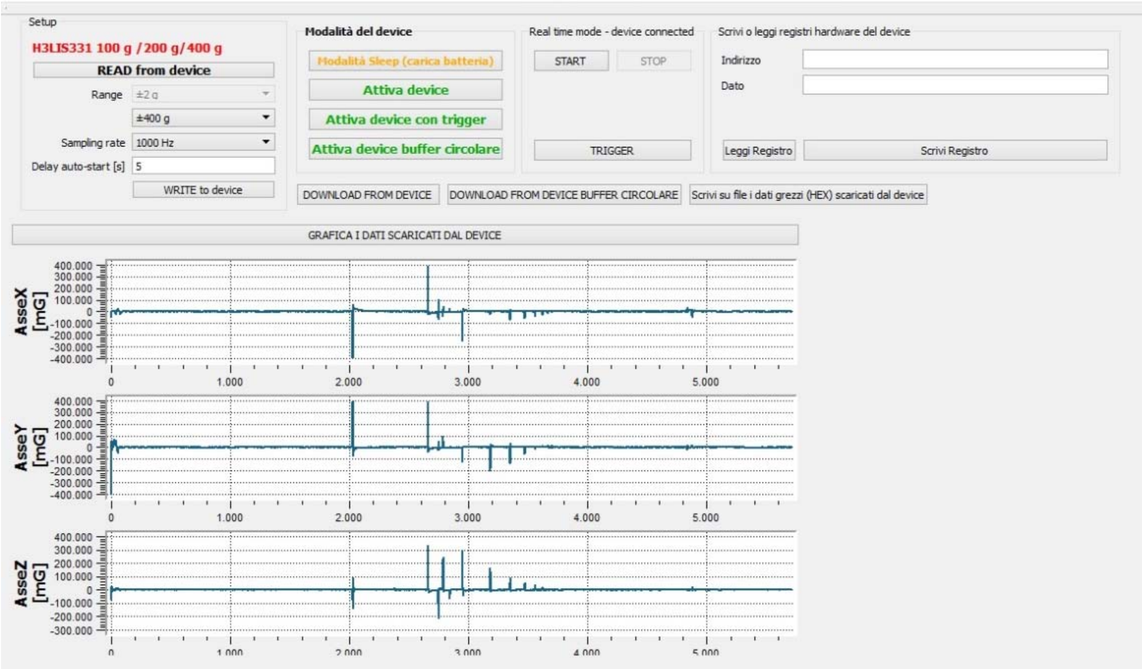

Figure 5: Acceleration vectors on X, Y and Z-axes [mG] as a function of time during the laboratory tests

4. Conclusions

The system developed is an instrumented sphere which represents a table olive Cv. Nocellara del Belice which is one of the most important varieties in Italy.
The aim of this study was to test a new device, designed by the authors, for studying the stresses and impacts experienced by the table olive fruit from harvest to processing.
The strength of the system lies in its small size and weight, compared to the most popular devices currently on the market. Its application opens the way to a variety of studies which may also relate to other types of fruit (especially small fruits) with the purpose of studying all the steps from harvest to processing.
In this way, it is possible to respect the integrity of the small fruits by limiting mechanical damage as much as possible, and therefore ensuring the quality of the product.

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